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S. Thorneloe provided technical direction for this research. In addition, she was responsible for obtaining samples, communication, and report writing.

ABSTRACT

This report evaluates changes in composition and constituent release by leaching that may occur to fly ash and other coal combustion residues (CCRs) in response to changes in air pollution control technology at coal-fired power plants. The addition of flue-gas desulfurization (FGD) systems, selective catalytic reduction, and activated carbon injection to capture mercury and other pollutants will shift mercury and other pollutants from the stack gas to fly ash, FGD gypsum, and other air pollution control residues. The objective is to understand the fate of mercury and other constituents of potential concern (COPC) in air pollution control residues and support EPA's broader goal of ensuring that emissions being controlled in the flue gas at power plants are not later being released to other environmental media.

This report includes data on 73 CCRs [34 fly ashes, 20 flue gas desulfurization (FGD) gypsum, 7 "other" FGD residues (e.g., scrubbers without oxidation or with inhibited oxidation), and 8 blended CCRs "as managed" (e.g., scrubber sludge mixed with fly ash and lime prior to disposal)]. Each of the CCRs sampled has been analyzed for a range of physical properties, total elemental content, and leaching characteristics for mercury, aluminum, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, lead, molybdenum, selenium and thallium.

The leach testing methods that were used in this research consider the impact on leaching of management conditions. These methods are intended to address concerns raised by the National Academy of Science and the EPA's Science Advisory Board with the use of single-point pH tests. Because of the range of field conditions that CCRs are managed during disposal or use as secondary (or alternative) materials, it is important to understand the leaching behavior of materials over the range of plausible field conditions that can include acid mine drainage and co-disposal of fly ash and other CCRs with pyrites or high-sulfur coal rejects. The methods have also been developed into draft protocols for inclusion in EPA's waste testing guidance document, SW-846, which would make them available for more routine use. (http://www.epa.gov/osw/hazard/testmethods/sw846/index.htm)

The major conclusions from this research include:

- There is great variability in both the range of total constituent concentration values and in leaching values (orders of magnitude). In comparing there results to health indicator values such as the maximum concentration limit or toxicity characteristic, there are multiple COPCs of potential concern.
- Distinctive patterns in leaching behavior have been identified over a range of pH values that would plausibly be encountered for CCR management.
- Total constituent content is not a good indicator of leaching which has been found to be a function of the characteristics of the material (pH) and field conditions in which the material is managed.
- The maximum eluate concentration from leaching test results varies over a wide range in pH and is different for different CCR types and elements. This indicates that there is not a single pH for which testing is likely to provide confidence in release estimates over a wide range of disposal and beneficial use options, emphasizing the benefit of multi-pH testing. Furthermore, for CCRs, the rate of constituent release to the environment is affected by leaching conditions (in some cases dramatically so), and that leaching

evaluation under a single set of conditions will, in many cases, lead to inaccurate conclusions about expected leaching in the field.

The intended use for the data in this report is to support future risk and environmental assessments of the CCRs studied. A follow-up report is planned which will use these data in conducting a probabilistic assessment of mercury and other COPCs release rates based on the range of plausible management scenarios for these materials in either disposal or beneficial use situations. The data summarized in this report will also be made available electronically through a leaching assessment tool (LeachXS Lite®) that can be used to develop source-term inputs needed for using groundwater transport and fate models. The leaching assessment tool will also provide means for data management in viewing data resulting from the of the improved leaching test methods.

GLOSSARY OF TERMS

ACI	Activated Carbon Injection
Al	Aluminum
AL	Action Level
APC	Air Pollution Control
APPCD	Air Pollution Prevention and Control Division
As	Arsenic
ASTM	American Society for Testing and Materials
B	Boron
Ba	Barium
BDL	Below Detection Limit
BET	Brunauer, Emmett and Teller (method for estimating surface area)
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
Cd	Cadmium
CCRs	Coal Combustion Residues
CCV	Continuing Calibration Verification
Co	Cobalt
COPCs	Constituents of Potential Concern
Cr	Chromium
CV	Coefficient of Variation
CVAA	Cold Vapor Atomic Adsorption
DIC	Dissolved Inorganic Carbon
DOC	Dissolved Organic Carbon
DOE	United States Department of Energy
DI	Deionized (i.e., deionized water)
DRC	Dynamic Reaction Chamber
dw	dry weight basis
DWEL	Drinking Water Equivalent Level
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic Precipitator

GLOSSARY OF TERMS - CONTINUED

ESP-CS	Cold-side Electrostatic Precipitator
ESP-HS	Hot-side Electrostatic Precipitator
FF	Fabric Filter (baghouse)
FGD	Flue Gas Desulfurization
FID	Flame Ionization Detector
FO	Forced Oxidation
FSS	Fixated Scrubber Sludge
FSSL	Fixated Scrubber Sludge with Lime
Gyp-U	Unwashed Gypsum
Gyp-W	Washed Gypsum
Hg	Mercury
HHV	Higher Heating Value
Ho	Holmium
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ICV	Initial Calibration Verification
In	Indium
IO	Inhibited Oxidation
IOx	Inhibited Oxidation (this abbreviation used in some figures to improve clarity)
LF	Landfill
LOI	Loss On Ignition
LS	Liquid-to-Solid Ratio (LS ratio)
M	Molar
Max	Maximum
MCL	Maximum Contaminant Level (for drinking water)
MDL	Method Detection Limit
Mg Lime	Magnesium Enriched Lime (often also referred to as “mag-lime”)
Min	Minimum
ML	Minimum Level of Quantification
Mo	Molybdenum

GLOSSARY OF TERMS - CONTINUED

NETL	National Energy Technology Laboratory (DOE)
NIOSH	National Institute of Occupational Safety and Health
NO	Natural Oxidation
NO_x	Nitrogen Oxides
NSPS	New Source Performance Standards
OC/EC	Organic Carbon/Elemental Carbon
ORD	Office of Research and Development (EPA)
OSWER	Office of Solid Waste and Emergency Response (EPA)
PAC	Powdered Activated Carbon
Pb	Lead
PJFF	Pulse-Jet Fabric Filter
PM	Particulate Matter
PRB	Sub-bituminous coal mined in Wyoming’s Powder River Basin
PS	Particulate Scrubber
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RFA	Reference Fly Ash
SAB	EPA Science Advisory Board
SCA	Specific Collection Area
Sb	Antimony
ScS	Scrubber Sludge
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SDA	Spray Dryer Absorber
Se	Selenium
SI	Surface Impoundment
SO_2	Sulfur Dioxide
SOFA	Separated Overfire Air
SPLP	Synthetic Precipitation Leaching Procedure
SRM	Standard Reference Material
S/S	Stabilization/Solidification

GLOSSARY OF TERMS - CONTINUED

SWDA	Solid Waste Disposal Act
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
Tl	Thallium
XAFS	X-Ray Absorption Fine Structure
XRF	X-Ray Fluorescence

EXECUTIVE SUMMARY

This report is the third in a series to evaluate changes in composition and constituent release by leaching that may occur to fly ash and other coal combustion residues (CCRs) in response to changes in air pollution control technology at coal-fired power plants. The addition of flue-gas desulfurization (FGD) systems, selective catalytic reduction, and activated carbon injection to capture mercury and other pollutants will shift mercury and other pollutants from the stack gas to fly ash, FGD gypsum, and other air pollution control residues. The Air Pollution Prevention and Control Division (APPCD) of EPA's Office of Research and Development (ORD) is conducting research to evaluate potential leaching and other cross media transfers of mercury and other constituents of potential concern (COPCs) resulting from the management of CCRs resulting from wider use of state-of-the art air pollution control technology. This research was cited as a priority in EPA's Mercury Roadmap[1] to ensure that one environmental problem is not being traded for another. The objective is to understand the fate of mercury and other COPCs in air pollution control residues and support EPA's broader goal of ensuring that emissions being controlled in the flue gas at power plants are not later being released to other environmental media.

Approximately 40% of the 126 million tons of CCRs produced in the U.S. as of 2006 were utilized in agricultural, commercial, and engineering applications. The remainder (i.e., 75 million tons) was managed in either landfills or impoundments. The physical and chemical characteristics of CCRs make them potentially suitable as replacements for materials used in a wide range of products including cement, concrete, road base, and wallboard. Use of CCRs as an alternative to virgin materials helps conserve natural resources and energy, as well as decrease the amount of CCRs being land disposed.

In developing data to characterize the leaching potential of COPCs from the range of likely CCRs resulting from use of state-of-the-art air pollution control technology, improved leaching test methods have been used[2]. The principle advantage of these methods is that they consider the impact on leaching of management conditions. These methods address concerns raised by National Academy of Science and EPA's Science Advisory Board with the use of single-point pH tests. Because of the range of field conditions that CCRs are managed during disposal or use as secondary (or alternative) materials, it is important to understand the leaching behavior of materials over the range of plausible field conditions that can include acid mine drainage and co-disposal of fly ash and other CCRs with pyrites or high-sulfur coal rejects[3, 4]. The methods have

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[1] EPA (2006). EPA's Roadmap for Mercury, EPA-HQ-OPPT-2005-0013. U.S. Environmental Protection Agency, http://www.epa.gov/mercury/pdfs/FINAL-Mercury-Roadmap-6-29.pdf (accessed August 21, 2009).

[2] Improved leaching test methods described in (Kosson et al., 2002) have been developed as draft SW-846 protocols. These methods consider the effect of varying environmental conditions on waste constituent leaching.

[3] National Academy of Sciences (2006). Managing Coal Combustion Residues in Mines, Washington, D.C.

[4] Sanchez, F.; Keeney, R.; Kosson, D., and Delapp, R. Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control, EPA-600/R-06/008, Feb. 2006; http://www.epa.gov/ORD/NRMRL/pubs/600r06008/600r06008.pdf.

also been developed into draft protocols for inclusion in EPA's waste testing guidance document, SW-846, which would make them available for more routine use. (http://www.epa.gov/osw/hazard/testmethods/sw846/index.htm).

The selected testing approach was chosen for use because it evaluates leaching over a range of values for two key variables [pH and liquid-to-solid ratio (LS)] that both vary in the environment and affect the rate of constituent release from waste. The range of values used in the laboratory testing encompasses the range of values expected to be found in the environment for these parameters. Because the effect of these variables on leaching is evaluated in the laboratory, prediction of leaching from the waste in the field is expected to be done with much greater reliability.

The categories into which samples have been grouped are fly ash, flue gas desulfurization (FGD) gypsum, "other" FGD residues (such as from spray drier absorbers), blended CCRs "as managed" (mixtures of fly ash and scrubber residues with and without added lime or mixture of fly ash and gypsum), and wastewater filter cake. In the first report from this research[5], results of leaching from fly ash were reported for mercury, arsenic, and selenium. Report 2 provided leaching results for an expanded list of materials and COPCs to include mercury, aluminum, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, lead, molybdenum, selenium and thallium[6]. In the current report (Report 3), analyses of eluates from CCR samples presented in Report 1 have been included for the expanded list of COPCs. Report 3 also includes the data previously reported in Report 2, and leach test results for an additional 38 CCRs. A total of 73 samples were evaluated, and all results are presented in the current report to facilitate comparisons (Table ES-1).

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[5] Sanchez, F.; Keeney, R.; Kosson, D., and Delapp, R. Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control, EPA-600/R-06/008, Feb. 2006; http://www.epa.gov/ORD/NRMRL/pubs/600r06008/600r06008.pdf.

[6] Sanchez, F.; Kosson, D.; Keeney, R.; Delapp, R.; Turner, L.; Kariher, P.; Thorneloe, S. Characterization of Coal Combustion Residues from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control; EPA-600/R-08/077, July 2008; http://www.epa.gov/nrmrl/pubs/600r08077/600r08077.pdf.

Table ES-1. Identification of CCRs evaluated and included in this Report.

Samples Evaluated	Report 1*	Report 2**	Additional Samples Collected	Total in Report 3
Fly Ash	12	5	17	34
FGD Gypsum	-	6	14	20
"Other" FGD Residues	-	5	2	7
Blended CCRs "as managed"	-	7	1	8
Wastewater Treatment Filter Cake	-		4	4

* Sanchez, F.; Keeney, R.; Kosson, D., and Delapp, R. Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control, EPA-600/R-06/008, Feb. 2006; http://www.epa.gov/ORD/NRMRL/pubs/600r06008/600r06008.pdf.

**Sanchez, F.; Kosson, D.; Keeney, R.; Delapp, R.; Turner, L.; Kariher, P.; Thorneloe, S. Characterization of Coal Combustion Residues from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control; EPA-600/R-08/077, July 2008; http://www.epa.gov/nrmrl/pubs/600r08077/600r08077.pdf.

Each of the CCRs sampled has been analyzed for a range of physical properties, total elemental content, and leaching characteristics. Laboratory leach data are compared to field observations from industry and EPA data from sampling of impoundments and landfills. The laboratory leach results are also compared to reference indicators to provide context for the data including:

- The toxicity characteristic (TC), which is a threshold for hazardous waste determinations;
- The maximum concentration limit (MCL), which is used for protecting drinking water; and,
- The drinking water equivalent level (DWEL), which is used to be protective for non carcinogenic endpoints of toxicity over a lifetime of exposure[7].

These comparisons to reference indicators do not consider dilution and attenuation factors (collectively referred to in this report as attenuation factors) that arise as a consequence of disposal or beneficial use designs and transport from the point of release to the potential receptor. Minimum attenuation factors needed to reduce maximum leach concentrations (based on laboratory test results) to less than MCL or DWEL values are provided to illustrate the importance of consideration of attenuation factors during evaluation of management options.

The intended use for the data in this report is to support future risk and environmental assessments of the CCRs. A follow-up report is planned which will use these data in conducting a probabilistic assessment of mercury and other COPCs release rates based on the range of plausible management scenarios for these materials in either disposal or beneficial use situations.

The data summarized in this report will be made available electronically through a leaching assessment tool that can be used to develop source-term inputs needed for using groundwater

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[7] DWEL was developed for chemicals that have a significant carcinogenic potential and provides risk managers with evaluation on non-cancer endpoints, but infers that carcinogenicity should be considered the toxic effect of greatest concern (http://www.epa.gov/safewater/pubs/gloss2.html#D).

transport and fate models[8]. The leaching assessment tool will provide easier access to the leach data for a range of CCRs and potential field conditions. The tool can be used to develop more detailed leach data as input to more refined assessments of CCRs and support environmental decision-making that will ensure protection of human health and the environment.

Summary of Conclusions

In Table ES-2 and Table ES-3, the total metals content of the fly ash and FGD gypsum samples evaluated is provided along with the leach test results. Reference indicators (i.e., TC, MCL, and DWEL) are also provided to provide some context in understanding the leach results. It is critical to bear in mind that the leach test results represent a distribution of potential constituent release concentrations from the material as disposed or used on the land. The data presented do not include any attempt to estimate the amount of constituent that may reach an aquifer or drinking water well. Leachate leaving a landfill is invariably diluted in ground water to some degree when it reaches the water table, or constituent concentrations are attenuated by sorption and other chemical reactions in groundwater and sediment. Also, groundwater pH may be different from the pH at the site of contaminant release, and so the solubility and mobility of leached contaminants may change when they reach groundwater. None of these dilution or attenuation processes is incorporated into the leaching values presented. Thus, comparisons with regulatory health values, particularly drinking water values, must be done with caution. Groundwater transport and fate modeling would be needed to generate an assessment of the likely risk that may result from the CCRs represented by these data.

In reviewing the data and keeping these caveats in mind, conclusions to date from the research include:

1. Review of the fly ash and FGD gypsum (Table ES-2 and Table ES-3) show a range of total constituent concentration values, but a much broader range (by orders of magnitude) of leaching values, in nearly all cases. This much greater range of leaching values only partially illustrates what more detailed review of the data shows: that for CCRs, the rate of constituent release to the environment is affected by leaching conditions (in some cases dramatically so), and that leaching evaluation under a single set of conditions may, to the degree that single point leach tests fail to consider actual management conditions, lead to inaccurate conclusions about expected leaching in the field.
2. Comparison of the ranges of totals values and leachate data from the complete data set supports earlier conclusions[9, 10, 11] that the rate of constituent leaching cannot be reliably estimated based on total constituent concentration.

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[8] The leaching assessment tool, LeachXS Lite®, will be available for inclusion in the CCR docket (December 2009).

[9] Senior, C; Thorneloe, S.; Khan, B.; Goss, D. Fate of Mercury Collected from Air Pollution Control Devices; Environmental Management, July 2009, 15-21.

[10] U.S. EPA, Characterization of Mercury-Enriched Coal Combustion Residuals from Electric Utilities Using Enhanced Sorbents for Mercury Control, EPA-600/R-06/008, Feb. 2006; http://www.epa.gov/ORD/NRMRL/pubs/600r06008/600r06008.pdf.

3. The maximum eluate concentration from leaching test results varies over a wide range in pH and is different for different CCR types and elements. This indicates that there is not a single pH for which testing is likely to provide confidence in release estimates over a wide range of disposal and beneficial use options, emphasizing the benefit of multi-pH testing.
4. From the more complete data in this report, distinctive patterns in leaching behavior have been identified over the range of pH values that would plausibly be encountered for CCR disposal, depending on the type of material sampled and the element. This reinforces the above conclusions based on the summary data.
5. Summary data in Table ES-2 on the leach results from evaluation of 34 fly ash samples across the plausible management pH domain of 5.4 to 12.4, indicates leaching concentration ranges over several orders of magnitude as a function of pH and ash source:
    - the leach results at the upper end of the concentration ranges exceeded the TC values for As, Ba, Cd, Cr, and Se.
    - the leach results at the upper end of the concentration ranges exceeded the MCL or DWEL for Sb, As, Ba, B, Cd, Cr, Pb, Mo, Se, and Tl.
6. Summary data in Table ES-3 on the leach results from evaluation of 20 FGD gypsum samples across the plausible management pH domain of 5.4 to 12.4, indicates leaching concentration ranges over several orders of magnitude as a function of pH and FGD gypsum source:
    - the leach results at the upper end of the concentration ranges exceeded the TC values for Cd and Se.
    - the leach results at the upper end of the concentration ranges exceeded the MCL or DWEL for Sb, As, B, Cd, Cr, Mo, Se, and Tl.
7. The variability in total content and the leaching of constituents within a material type (e.g., fly ash, gypsum) is such that, while leaching of many samples exceeds one or more of the available reference indicators, many of the other samples within the material type may be lower than the available regulatory or reference indicators. Additional or more refined assessment of the dataset may allow some distinctions regarding release potential to be made among particular sources of some CCRs, which may be particularly useful in evaluating CCRs in reuse applications.

Work is underway to develop a fourth report that presents such additional analysis of the leaching data to provide more insight into constituent release potential for a wider range of scenarios, including beneficial use applications. This will include calculating potential release

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[11] U.S. EPA, Characterization of Coal Combustion Residuals from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control; EPA-600/R-08/077, July 2008; http://www.epa.gov/nrmrl/pubs/600r08077/600r08077.pdf.

rates over a specified time for a range of management scenarios including use in engineering and commercial applications using probabilistic assessment modeling[12].

In interpreting the results provided in this report, please note that the CCRs analyzed in this report are not considered to be a representative sample of all CCRs produced in the U.S. For many of the observations, only a few data points were available. It is hoped that through broader use of the improved leach test methods (as used in this report), that additional data from CCR characterization will become available. That will help better define trends associated with changes in air pollution control at coal-fired power plants.

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[12] Sanchez, F. and D. S. Kosson, 2005. Probabilistic approach for estimating the release of contaminants under field management scenarios. *Waste Management* 25(5), 643-472 (2005).

Table ES-2. Leach results for 5.4 ≤ pH ≤ 12.4 and at "own pH[13]" from evaluation of thirty-four fly ashes.

	Hg	Sb	As	Ba	B	Cd	Cr	Co	Pb	Mo	Se	TI
Total in Material (mg/kg)	0.01 – 1.5	3 – 14	17 – 510	590 – 7,000	NA	0.3 – 1.8	66 – 210	16 – 66	24 – 120	6.9 – 77	1.1 – 210	0.72 – 13
Leach results (µg/L)	<0.01 – 0.50	<0.3 – 11,000	0.32 – 18,000	50 – 670,000	210 – 270,000	<0.1 – 320	<0.3 – 7,300	<0.3 – 500	<0.2 – 35	<0.5 – 130,000	5.7 – 29,000	<0.3 – 790
TC (µg/L)	200	-	5,000	100,000	-	1,000	5,000	-	5,000	-	1,000	-
MCL (µg/L)	2	6	10	2,000	7,000 DWEL	5	100	-	15	200 DWEL	50	2

Note: The shade is used to indicate where there could be a potential concern for a metal when comparing the leach results to the MCL, DWEL, or TC. Note that MCL and DWEL values represent well concentrations; leachate dilution and attenuation processes that would occur in groundwater before leachate reaches a well are not accounted for, and so MCL and DWEL values are compared to leaching concentrations here to provide context for the test results and initial screening.

Table ES-3. Leach results for 5.4 ≤ pH ≤ 12.4 and at "own pH" from evaluation of twenty FGD gypsums.

	Hg	Sb	As	Ba	B	Cd	Cr	Co	Pb	Mo	Se	TI
Total in Material (mg/kg)	0.01 – 3.1	0.14 – 8.2	0.95 – 10	2.4 – 67	NA	0.11 – 0.61	1.2 – 20	0.77 – 4.4	0.51 – 12	1.1 – 12	2.3 – 46	0.24 – 2.3
Leach results (µg/L)	<0.01– 0.66	<0.3 – 330	0.32 – 1,200	30 – 560	12 – 270,000	<0.2 – 370	<0.3 – 240	<0.2 – 1,100	<0.2 – 12	0.36 – 1,900	3.6 – 16,000	<0.3 – 1,100
TC (µg/L)	200	-	5,000	100,000	-	1,000	5,000	-	5,000	-	1,000	-
MCL (µg/L)	2	6	10	2,000	7,000 DWEL	5	100	-	15	200 DWEL	50	2

Note: The shade is used to indicate where there could be a potential concern for a metal when comparing the leach results to the MCL, DWEL, or TC. Note that MCL and DWEL values represent well concentrations; leachate dilution and attenuation processes that would occur in groundwater before leachate reaches a well are not accounted for, and so MCL and DWEL values are compared to leaching concentrations here to provide context for the test results and initial screening.

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[13] "Own pH" is defined as the end-point (equilibrium) eluate pH when a CCR is extracted with DI water at liquid to solid ratio of 10 mL/g, and is measured as part of leach testing as a function of pH.

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1. INTRODUCTION

More wide-spread implementation of multi-pollutant controls is occurring at U.S. coal-fired power plants. Although much research has occurred to characterize high-volume coal combustion residues [i.e., fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) solids] extending back to the 1970s, previous research has not considered the wide range of field conditions that occur for coal combustion residues (CCRs) during land disposal and use in agricultural, commercial, and engineering applications. The objective of this research is to characterize the changes in total composition and constituent release potential occurring to CCRs resulting from wider use of multi-pollutant controls at U.S. coal-fired power plants. This characterization includes detailed analysis of the fly ash and other air pollution control residues in relationship to differences in air pollution control configurations and coal rank. The characterization also includes evaluating the leaching potential of constituents of potential concern (COPCs) across the range of plausible management conditions that CCRs are likely to encounter during land disposal or use in agricultural, commercial, and engineering applications. This research was cited as a priority in EPA's Mercury Roadmap (EPA, 2006b) to evaluate the potential for any cross-media transfers from the management of CCRs resulting from more stringent air pollution control at coal fired power plants. This report is part of a series of reports helping to document the findings of this research to provide more credible, up-to-date data on CCRs to identify any potential cross-media transfers.

The focus of this report is to present an evaluation of air pollution control residues that may result from the use of SO_2 scrubbers and other air pollution control technologies being used to control multiple pollutants at coal-fired power plants. The pathway of concern addressed in this report is the potential for transfer of pollutants to water resources or other environmental systems (e.g., soils, sediments). The residues studied for this report were fly ashes, unwashed and washed flue gas desulfurization (FGD) gypsum, scrubber sludge, blended CCR residues "as managed" (mixtures of fly ash and scrubber residues with and without added lime or mixture of fly ash and gypsum), and wastewater filter cake generated from power plants with a range of air pollution control configurations.

In particular, this report focuses on the potential for leaching of mercury and other COPCs during land disposal or beneficial use of the CCRs is the focus of this report. This research is part of an on-going effort by EPA to use an integrated, comprehensive approach to account for the fate of mercury and other metals in coal throughout the life-cycle stages of CCR management (Sanchez et al., 2006; Thorneloe et al., 2009; Thorneloe et al., 2008). Related research and assessment on environmental fate of constituents during CCR management includes conducting thermal stability studies, leach testing, and probabilistic assessment modeling to determine the fate of mercury and other metals that are in coal combustion residues resulting from implementation of multi-pollutant control technology (EPA, 2002; Kilgroe et al., 2001).

CCRs include bottom ash, boiler slag, fly ash, scrubber residues and other miscellaneous solids generated during the combustion of coal. Air pollution control can concentrate or partition metals to fly ash and scrubber residues. The boiler slag and bottom ash are not of interest in this study because air emission controls are not expected to change their composition. Use of multi-pollutant controls minimizes air emissions of mercury and other metals by the transfer of the metals to the fly ash and other CCRs. This research will help determine the fate of mercury and other COPCs from the management of CCRs through either disposal or reuse. Fly ash may include unburned carbonaceous materials and inorganic materials in coal that do not burn, such as oxides of silicon, aluminum, iron, and calcium. Fly ash is light enough to be entrained in the flue gas stream and captured in the air pollution control equipment.

The type and characteristics of FGD scrubber residue produced is primarily a function of (i) the scrubber sorbent used (i.e., limestone, lime, magnesium enriched lime referred to as Mg lime, or alkaline fly ash), (ii) the extent of oxidation during scrubbing (i.e., forced oxidation, natural oxidation, or inhibited oxidation), (iii) post-scrubber processing, including possibly dewatering or thickening, drying, water rinsing, or blending with other materials, and (iv) coal rank combusted. The presence and leaching characteristics of the COPCs in air pollution control residues is a consequence of the coal combusted, process sequence employed, process conditions, process additives and use or disposal scenario.

Figure 1 illustrates the processes used in the production of materials that were sampled for this study, sample nomenclature, and the typical management pathways for each material. FGD gypsum is defined here as the by-product of the SO_2 wet scrubbing process when the scrubber residue is subjected to forced oxidation. In forced oxidation systems, nearly all of the by-product is calcium sulfate dihydrate ($CaSO_4•H_2O$). The resulting wet gypsum is partially dewatered and then either disposed in a landfill (unwashed gypsum; Gyp-U) or water rinsed (in some cases) and dried to produce washed gypsum (washed gypsum; Gyp-W) that then potentially can be used in wallboard manufacturing or agricultural applications. Scrubber sludge (ScS) is the by-product of the SO_2 wet scrubbing process resulting from neutralization of acid gases at facilities that use either inhibited oxidation or natural oxidation of scrubber residue. In inhibited oxidation systems, nearly all of the by-product is calcium sulfite hemihydrates ($CaSO_3•½H_2O$). In natural oxidation systems, the by-product is a mixture of $CaSO_3•½H_2O$ and $CaSO_4•H_2O$. Scrubber sludge typically will be either partially dewatered in a thickener and then disposed in a surface impoundment, or after thickening, further dewatered and mixed with fly ash to form blended CCRs “as managed[14].” In most cases, additional lime is also blended with the scrubber sludge and fly ash. The blend of fly ash and scrubber sludge is typically between 0.5 to 1.5 parts fly ash to 1 part scrubber sludge on a dry weight basis, with 0 or 2-4% additional lime added. Blended CCRs typically are either disposed in a landfill or supplied to a beneficial use (e.g., fill in mining applications). Facilities that have spray dryer absorbers (SDA) collect fly ash and FGD residues simultaneously as a sample residue stream.

This report evaluates the characteristics of fly ash, FGD gypsum, SDA, scrubber sludge, and blended CCRs “as managed” from thirty one (31) coal combustion facilities. In addition filter cake from waste water treatment was evaluated from four facilities.

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[14] As managed is defined as how the material is managed by the coal-fired power plant either through disposal or reuse.

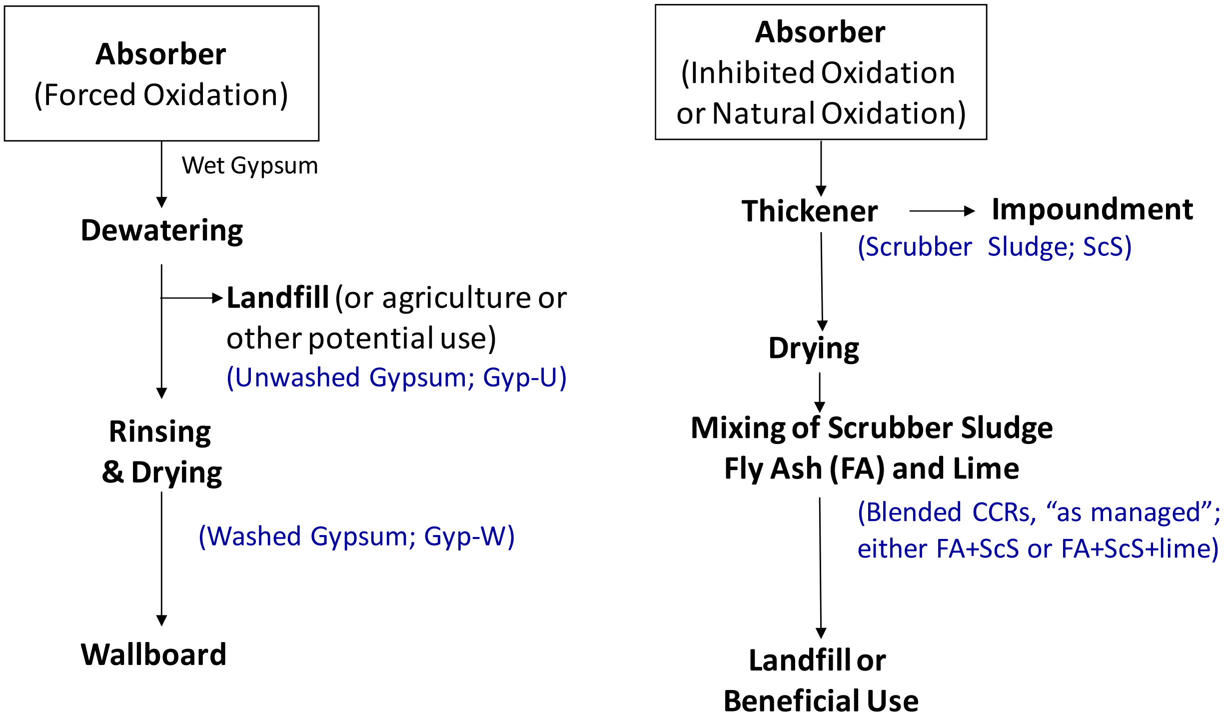

Figure 1. Flow diagram describing processing and nomenclature of FGD scrubber residues and samples included in this study.

When coal is burned in an electric utility boiler, the resulting high combustion temperatures vaporize the Hg in the coal to form gaseous elemental mercury (Hg^0). Subsequent cooling of the combustion gases and interaction of the gaseous Hg^0 with other combustion products may result in a portion of the Hg being converted to gaseous oxidized forms of mercury (Hg^{2+}) and particle-bound mercury (Hg_p). The specific chemical form–known as the speciation-as a strong impact on the capture of mercury and other metals by boiler air pollution control (APC) equipment (EPA, 2001).

Mercury and other elements partition between the combustion gas, fly ash and scrubber residues. Depending upon the gas conditioning, presence or absence of post-combustion NO_x control and other air pollution control technology in use, there may be changes occurring to the fly ash that can affect the stability and mobility of mercury and other metals in the CCRs. Similarly, NO_x control and SO_2 scrubber technology may affect the content, stability and mobility of mercury and other metals in scrubber residues.

The specific objectives of the research reported here are to:

1. Conduct analysis on range of air pollution control residues (i.e., fly ash, FGD residues and other CCRs) resulting from differences in coal rank and air pollution control configurations;
2. Evaluate the potential for leaching to groundwater of mercury and other COPCs (i.e., aluminum, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, lead, molybdenum, selenium, and thallium) removed from the flue gas of coal-fired power plants using multi-pollutant controls to reduce air pollution; and

3. Provide the foundation for assessing the impact of enhanced mercury and multi-pollutant control technology on leaching of mercury and other COPCs from CCR management including storage, beneficial use, and disposal.

This is the third of a series of reports that addresses the potential for cross-media transfer of COPCs from CCRs. The first report focused on the use of sorbent injection (activated carbon and brominated activated carbon) for enhanced mercury control (Sanchez et al., 2006). The second report focused on facilities that use wet scrubbers for multi-pollutant control and includes results for 23 CCRs (fly ash, gypsum, scrubber sludge, fixated scrubber sludge) sampled from eight facilities (Sanchez et al., 2008). This report focuses on CCRs from coal-fired power plants that use air pollution control technologies, other than those evaluated in the first two reports, necessary to span the range of anticipated coal-types and air pollution control technology configurations. A subsequent report will address:

- Assessment of leaching of COPCs under additional management scenarios, including impoundments and beneficial use on the land (report 4); and,
- Broader correlation of CCR leaching characteristics to coal rank, combustion facility characteristics and geochemical speciation within CCRs supported by information and analysis on additional trace elements and primary constituents (report 4).

Sampled CCRs were subjected to multiple leaching conditions according to the designated leaching assessment approach, which is designed to examine leaching potential over a range of pH and LS ratios. Leaching conditions included batch equilibrium[15] extractions at acidic, neutral and alkaline conditions at an LS of 10 mL/g, and LS from 0.5 to 10 mL/g using distilled water as the leachant. In this report, the results of this testing are being used to evaluate the likely range of leaching characteristics during land disposal (i.e., landfill or surface impoundment) scenarios. Results of the laboratory leaching tests carried out in this study were compared to the range of observed constituent concentrations in field leachates reported in a U.S. EPA database (EPA, 2007b) and an Electric Power Research Institute (EPRI) database (EPRI, 2006). The testing results presented here will be used for evaluating disposal and beneficial use scenarios in a subsequent report.

The extensive nature of the results reported here necessitates detailed data presentation with only a broad assessment overview. Future reports will provide more detailed data evaluation and application of the data to evaluation of specific CCR management scenarios.

As part of this research program, a quality assurance/quality control (QA/QC) plan consistent with EPA requirements was developed for the leaching assessment approach (see Section 2.4). The QA/QC methodology included initial verification of acceptable mercury retention during laboratory testing through evaluation of a mass balance around testing procedures (Sanchez et al., 2006). Modifications to the QA/QC program to reduce the experimental and analytical burden while maintaining confidence in the resulting data, based on program results to date, are presented in Report 2 (Sanchez et al., 2008); further modifications are identified in this report.

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[15] In the context of leaching tests, the term “equilibrium” is used to indicate that the test method result is a reasonable approximation of chemical equilibrium conditions even though thermodynamic equilibrium may not be approached for all constituents.

Laboratory testing for leaching assessment was carried out at the EPA National Risk Management Research Laboratory (Research Triangle Park, North Carolina).

1.1. REGULATORY CONTEXT

1.1.1. Waste Management

The management of coal combustion residues is subject to the Resource Conservation and Recovery Act (RCRA) which is the federal law regulating both solid and hazardous wastes. Hazardous waste regulations are developed under Subtitle C of RCRA whereas other solid and non-hazardous wastes fall under RCRA Subtitle D. Subtitle C wastes are federally regulated while Subtitle D wastes are regulated primarily at the state level. The original version of RCRA did not specify whether CCRs were Subtitle C or D wastes. In 1980, the Solid Waste Disposal Act (SWDA) amendments to RCRA conditionally excluded CCRs from Subtitle C regulation pending completion of a study of CCR hazards. Since that time, CCRs have been regulated at the state level under Subtitle D.

The SWDA amendments to RCRA required EPA to prepare a Report to Congress identifying CCR hazards and recommending a regulatory approach for CCRs. In this report (EPA, 1988) and the subsequent regulatory determination, EPA recommended that CCRs generated by electric utilities continue to be regulated under RCRA Subtitle D (See 58 FR 42466, August 9, 1993).

Other residues generated at coal-fired electric utilities were not included in this 1993 decision. EPA conducted a follow-up study specifically aimed at low-volume, co-managed wastes[16] and issued another Report to Congress (EPA, 1999) with a similar recommendation. In April 2000, EPA issued a regulatory determination retaining the existing exemption from hazardous waste regulation for these wastes, although national regulation under RCRA Subtitle D were considered to be warranted (see 65 FR 32214, May 22, 2000). Concern also was expressed over the use of CCRs as backfill for mine reclamation operations, and it was determined that this practice should also be regulated under a federal Subtitle D rule. No regulation of other beneficial uses of CCRs was considered necessary at that time. Currently, the agency is in the process of developing these regulations (http://www.epa.gov/osw/nonhaz/industrial/special/index.htm). The results presented in this report, and subsequent reports, will help provide the information needed to identify the release potential of mercury and other metals that have been removed from stack gases into air pollution control residues, over a range of plausible management options. These data will help identify those conditions that will either reduce or enhance releases to the land so that the effects of different management conditions can be factored into any controls developed under the regulations.

1.1.2. Air Pollution Control

Coal-fired power plants are the largest remaining source of anthropogenic mercury emissions in the country. Power plants are also a major source of nitrogen and sulfur oxides, particulate matter, and carbon dioxide. New environmental regulations in the U.S. will result in lower mercury air emissions, but potentially more mercury in CCRs. The Clean Air Mercury Rule (CAMR) would have required the electric utility sector to remove at least 70% of the mercury

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[16] Co-managed wastes are low-volume wastes that are co-managed with the high-volume CCRs.

released from power plant stack emissions by 2018. However, CAMR was vacated by the United States Court of Appeals for the District of Columbia Circuit in 2008. EPA is currently developing regulations under Section 112 of the Clean Air Act to reduce hazardous air pollutants (including mercury) from coal-fired power plants. Twenty states have implemented their own mercury regulations already, according to the National Association of Clean Air Agencies (Senior et al., 2009). Other EPA regulations[17] will necessitate the addition of new air pollution control devices for NO_x and SO_2 at some power plants. This can also affect the fate of mercury and other COPCs.

1.2. CONFIGURATIONS OF U.S. COAL FIRED POWER PLANTS AND MULTI-POLLUTANT CONTROL TECHNOLOGIES

In the U.S., there are approximately 1,100 units at approximately 500 coal-fired electricity generating facilities. These facilities represent a range of coal ranks, boiler types, and air pollution control technologies. The combined capacity of U.S. coal-fired power plants as of 2007 is 315 GW with a projection to 360 GW by 2030 (DOE-EIA, 2009). The coal rank burned and facility design characteristics affect the effectiveness of multi-pollutant control technologies that are or could be used at these plants. The U.S. coal-fired power plants typically burn one of three types of fuel: (1) bituminous coal (also referred to as “high rank” coal), (2) sub-bituminous coal, and (3) and lignite (sub-bituminous coal and lignite are referred to as “low rank” coals). Some of the characteristics of interest related to the possible environmental impacts of burning these different coal ranks are given in Table 1 (EPA, 2005).

Table 1. General characteristics of coals burned in U. S. power plants (EPA, 2005).

	Mercury		**Chlorine**		**Sulfur**		**Ash**		**HHV**[a]	
	ppm (dry)		**ppm (dry)**		**% (dry)**		**% (dry)**		**BTU/lb (dry)**	
Coal	**Range**	**Avg**	**Range**	**Avg**	**Range**	**Avg**	**Range**	**Avg**	**Range**	**Avg**
Bituminous	0.036 - 0.279	0.113	48 – 2,730	1,033	0.55 - 4.10	1.69	5.4 - 27.3	11.1	8,650–14,000	13,200
Sub-bituminous	0.025 - 0.136	0.071	51 – 1,143	158	0.22 - 1.16	0.50	4.7 - 26.7	8.0	8,610–13,200	12,000
Lignite	0.080 - 0.127	0.107	133 - 233	188	0.8 - 1.42	1.30	12.2 - 24.6	19.4	9,490–10,700	10,000

[a] Higher Heating Value.

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[17] On March 10, 2005, EPA announced the Clean Air Interstate Rule (CAIR) (FR 25612, May 2005) which is expected to increase the use of wet scrubbers and selective catalytic reduction (SCR) units to help reduce sulfur dioxide and nitrogen oxides emissions from coal-fired power plants. On July 11, 2008, United States Court of Appeals for the District of Columbia Circuit remanded CAIR back to EPA for further review and clarification. Thus the rule remains in effect; however, EPA is in the process of developing a replacement rule that will address the Court’s concerns.

1.2.1. Current Air Pollution Control Technologies

A range of pollution control technologies is used to reduce particulate, SO_2, and NO_x and these technologies also impact the emission of mercury and other metals. The pollution control technology type and configurations vary across facilities. [18]

Table 2 shows the current and projected coal-fired capacity by air pollution control technology configuration using data published in a 2005 report (EPA, 2005). Although the projected capacity information is considered dated, the projections for air pollution control appear relevant. The major finding from this report is the projected usage for wet scrubbers which are expected to double or triple in response to implementation of CAIR. Post-combustion particulate matter controls used at coal-fired utility boilers in the United States can include electrostatic precipitators (ESPs), fabric filters (FFs), particulate scrubbers (PSs), or mechanical collectors (MCs). Post-combustion SO_2 controls can consist of a wet scrubber (WS), spray dryer adsorber (SDA), or duct injection. Post-combustion NO_x controls typically involve selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR).

In response to current and proposed NO_x and SO_2 control requirements, additional post-combustion NO_x control and flue gas desulfurization (FGD) systems for SO_2 control are expected to be installed and more widely used in the future. Some estimates project a doubling or tripling of the number of wet scrubbers as a result of CAIR implementation. Over half of the U.S. coal-fired capacity is projected to be equipped with SCR and, or, FGD technology by 2020. Currently, some power plants only use post-combustion NO_x controls during summer months or when tropospheric ozone is more of a concern. However, likely changes will involve using post-combustion NO_x control year-round.

The mercury capture efficiency of existing ESPs and FFs appears to be heavily dependent on the partitioning of mercury between the particulate and vapor phases and the distribution of mercury species (e.g., elemental or oxidized) in the vapor phase. In general, ESPs and FFs which are designed for particulate control are quite efficient at removing mercury in the particulate phase; however, the overall mercury removal efficiency in these devices may be low if most of the mercury entering the device is in the vapor phase (MTI, 2001). Many factors contribute to the observed differences in mercury removal efficiency, such as the mercury oxidation state. Differences in mercury contents of U.S. coals also result in a range of mercury concentrations in the flue gas from the boiler. In general, it is easier to achieve higher mercury percent removal with higher mercury inlet concentrations (MTI, 2001). Further, the chlorine content of the coal may have an impact on mercury removal because the oxidation state of mercury is strongly affected by the presence of halides in the flue gas. In general, the higher the chlorine content of the coal, the more likely the mercury will be present in its oxidized state, enhancing the likelihood of its removal from the gas stream. The addition of post-combustion NO_x controls may improve mercury capture efficiency of particulate collection devices for some cases as a result of the oxidation of elemental mercury (EPA, 2001).

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[18] Concerns regarding carbon dioxide emissions from coal fired power plants are beyond the scope of this report.

Table 2. Projected coal-fired capacity by air pollution control configuration as per data collection in 1999 (EPA, 2005). CCR samples evaluated in this report are from configurations indicated by shaded (light gray) rows. 2005 capacity reflects date of data collection for EPA report (EPA, 2005).

Air Pollution Control Configuration	**2005 Capacity, MW**	**2010 Capacity, MW (projected)**	**2020 Capacity, MW (projected)**
Cold-side ESP	111,616	75,732	48,915
Cold-side ESP + Wet Scrubber	41,745	34,570	33,117
Cold-side ESP + Wet Scrubber + ACI	-	379	379
Cold-side ESP + Dry Scrubber	2,515	3,161	5,403
Cold-side ESP + SCR	45,984	35,312	22,528
Cold-side ESP + SCR + Wet Scrubber	27,775	62,663	98,138
Cold-side ESP + SCR + Dry Scrubber	-	11,979	13,153
Cold-side ESP + SNCR	7,019	4,576	2,534
Cold-side ESP + SNCR + Wet Scrubber	317	2,830	6,088
Fabric Filter	11,969	10,885	7,646
Fabric Filter + Dry Scrubber	8,832	8,037	9,163
Fabric Filter + Wet Scrubber	4,960	4,960	4,960
Fabric Filter + Dry Scrubber + ACI	-	195	195
Fabric Filter + SCR	2,210	2,950	1,330
Fabric Filter + SCR + Dry Scrubber	2,002	2,601	4,422
Fabric Filter + SCR + Wet Scrubber	805	805	2,363
Fabric Filter + SNCR	267	267	345
Fabric Filter + SNCR + Dry Scrubber	559	557	557
Fabric Filter + SNCR + Wet Scrubber	932	932	1,108
Hot-side ESP	18,929	11,763	10,160
Hot-side ESP + Wet Scrubber	8,724	10,509	10,398
Hot-side ESP + Dry Scrubber	-	538	538
Hot-side ESP + SCR	5,952	3,233	1,847
Hot-side ESP + SCR + Wet Scrubber	688	6,864	9,912
Hot-side ESP + SNCR	684	1,490	1,334
Hot-side ESP + SNCR + Wet Scrubber	474	474	627
Existing or Planned Retrofit Units	**~305,000**	**~298,000**	**297,000**
New Builds of Coal Steam Units	**2005 Capacity, MW**	**2010 Capacity, MW**	**2020 Capacity, MW**
Fabric Filter + SCR + Wet Scrubber	-	221	17,292
Total All Units	**~305,000**	**~298,500**	**~314,400**

Note: IGCC units are not included as part of this list.
Note: Current capacity includes some SCR and FGD projected to be built in 2005 and 2006.
Note: 2010 and 2020 is capacity projected for final CAIR rule.
Note: Integrated Planning Model (IPM) projects some coal retirements and new coal in 2010 and 2020. (http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html)

1.2.2. Wet Scrubbers, NO_x Controls and Multi-pollutant Controls

Wet FGD scrubbers are the most widely used technology for SO_2 control. Scrubbers are typically installed downstream of particulate control (i.e., ESP or FF). Removal of PM from the flue gas before it enters the wet scrubber reduces solids in the scrubbing solution and minimizes impacts to the fly ash that might affect its beneficial use.

FGD technology uses sorbents and chemical reactants such as limestone (calcium carbonate) or lime (hydrated to form calcium hydroxide) to remove sulfur dioxide from the flue gas created from coal combustion. Limestone is ground into a fine powder and then combined with water to spray the slurry into combustion gases as they pass through a scrubber vessel. The residues are collected primarily as calcium sulfite (a chemically reduced material produced in natural oxidation or inhibited oxidation scrubbers), or can be oxidized to form calcium sulfate or FGD gypsum (using forced oxidation). The most widely used FGD systems use either forced oxidation scrubbers with limestone addition, or natural/inhibited oxidation scrubbers with lime or Mg-lime addition[19]. Wet scrubbers that use forced oxidation produce calcium sulfate (gypsum) and are expected to be the most prevalent technology because of the potential beneficial use of gypsum and easier management and handling of the residues. There are also dry FGD systems that include spray dryer absorbers, usually in combination with a FF (EPA, 2001; Srivastava et al., 2001).

NO_x emissions are controlled through the use of low NO_x producing burners and use of a selective catalytic reduction (SCR) system in the flue gas that is capable of a 90% reduction of flue gas NO_x emissions. SCR is typically installed upstream of the PM control device. Sometimes selective non-catalytic reduction (SNCR) is used for NO_x control, although use of SNCR is less common.

Figure 2 illustrates options for multi-pollutant control at power plants.

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[19] As of 1999: Total FGD units–151; limestone forced oxidation (FO)-38 units (25%); limestone natural/inhibited oxidation - 65 (43%); lime FO (all forms other than Mg-lime) - 1 (<1%); lime natural/inhibited oxidation (all forms other than Mg-lime) - 23 (15%); Mg-lime FO - 0 (0%); Mg-lime natural/inhibited oxidation - 25 (17%). It is estimated that the numbers of natural/inhibited systems has remained nearly the same since 1999, and the limestone FO units have increased significantly. In the future, limestone FO units will increase significantly, and all types of natural/inhibited units will likely decrease (Ladwig, 2007).

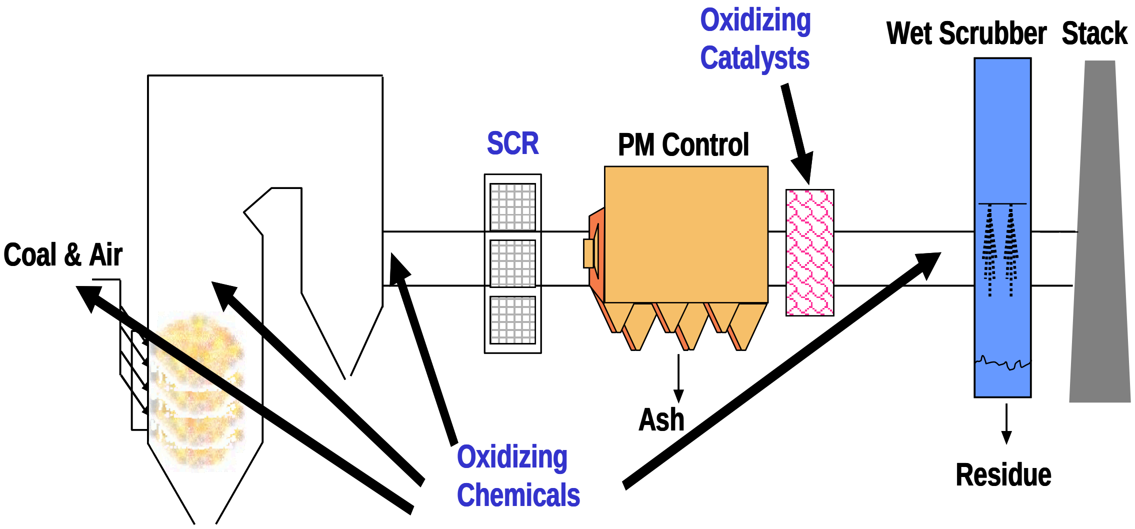

Figure 2. Illustration of available technology for multi-pollutant control at coal-fired power plants.

Improvements in wet scrubber performance to enhance mercury capture depend on oxidizing elemental mercury (Hg^0) to Hg^{2+} by using additives to the flue gas or scrubber. A DOE-funded study found that wet scrubbers can remove as much as 90% of the oxidized gaseous mercury (Hg^{2+}) in the flue gas but none of the elemental mercury (Pavlish et al., 2003). The percentage of total Hg removed by multi-pollutant controls (particulate and scrubber devices) is influenced by coal chlorine content, which determines the Hg oxidation status exiting the particulate control and entering the scrubber. Fuel blending, addition of oxidizing chemicals, controlling unburned carbon content in the fly ash, and addition of a mercury-specific oxidizing catalyst downstream of the particulate matter control can help improve mercury capture (EPA, 2005).

1.2.3. Mercury Control Using Sorbent Injection

Injection of dry sorbents, such as powdered activated carbon (PAC), has been used for control of mercury emissions from waste combustors and has been tested at numerous utility units in the United States. There are different approaches that can be used to increase mercury capture efficiency as illustrated in Figure 3 and Figure 4. Figure 3 presents a coal-fired boiler with sorbent injection and spray cooling. Figure 4 presents a power plant with a hot-side ESP (HS-ESP), carbon injection, and a compact hybrid particle collector (COHPAC^{TM}). Dry sorbent is typically injected into the ductwork upstream of a PM control device – normally either an ESP or FF. Usually the sorbent is pneumatically injected as a powder. The injection location is determined by the existing plant configuration. Another approach, designed to segregate collected fly ash from collected sorbent, would be to retrofit a pulse-jet FF (PJFF) downstream of an existing ESP and inject the sorbent between the ESP and the PJFF. This type includes of COHPAC^{TM} and when combined with sorbent injection is referred to as Toxic Emission Control (TOXECON^{TM}). The TOXECON configuration can be useful because it avoids commingling the larger fly ash stream with mercury recovered on the injected sorbent. Implementation of sorbent injection for mercury control will likely entail either:

- Injection of powdered sorbent upstream of the existing PM control device (ESP or FF); or
- Injection of powdered sorbent downstream of the existing ESP and upstream of a retrofit fabric filter, the TOXECON^{TM} option; or
- Injection of powdered sorbent between ESP fields (TOXECON-II^{TM} approach).

In general, factors that affect the performance of sorbent technology for mercury methods include:

- Injection rate of the sorbent measured in lb/MMacf[20];
- Flue gas conditions, including temperature and concentrations of HCl and sulfur trioxide (SO_3), and oxidation state of the mercury present;
- The air pollution control configuration;
- The characteristics of the sorbent (e.g., conventional or halogenated); and
- The method of injecting the sorbent.

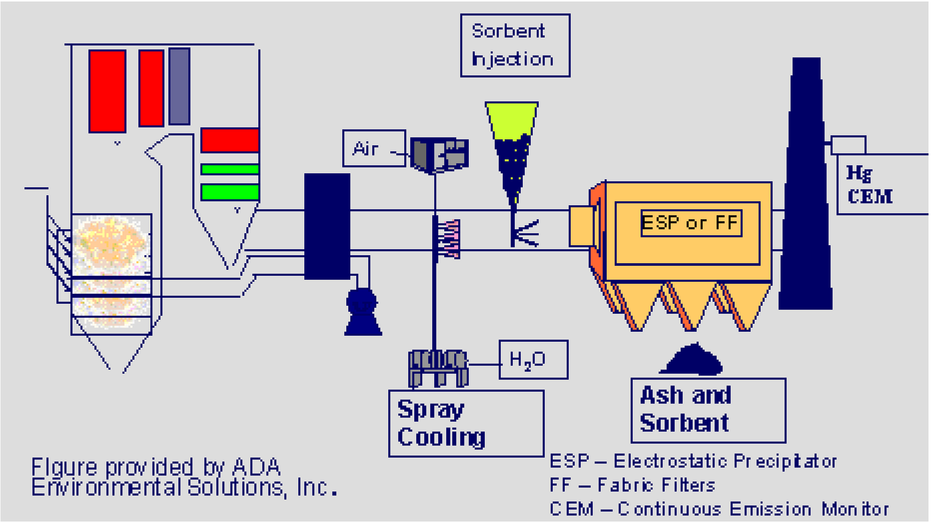

Figure 3. Coal-fired boiler with sorbent injection and spray cooling (Senior et al., 2003).

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[20] Sorbent injection rate is expressed in lb/MMacf, i.e., pounds of sorbent injected for each million actual cubic feet of gas. For a 500 MW boiler, a sorbent rate of 1.0 lb/MMacf will correspond to approximately 120 lb/hour of sorbent.

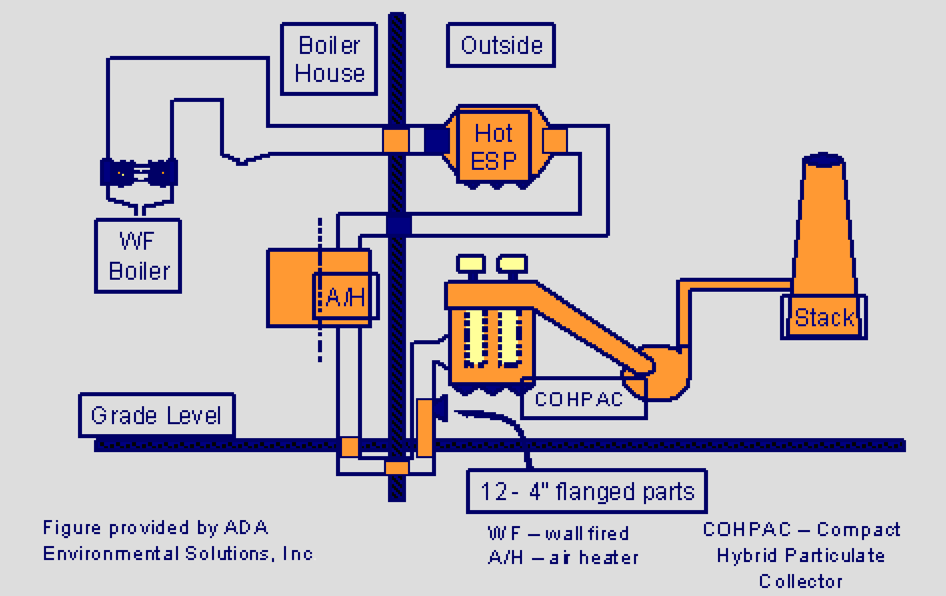

Figure 4. Flow diagram for power plant with a hot ESP, carbon injection, and a compact hybrid particulate collector (Senior et al., 2003).

1.2.4. Mercury Control by Conventional PAC Injection

The most widely tested sorbent for mercury control at utility boilers is PAC.

In general, the efficacy of mercury capture using standard PAC increases with the relative amount of Hg^{2+} (compared with Hg^0) in flue gas[21], the number of active sites[22] in the PAC, and lower temperature. The amount of Hg^{2+} in flue gas is usually directly influenced by the amount of chlorine present in the flue gas, with higher chlorine content enhancing Hg^{2+} formation. Based on these factors, standard PAC injection appears to be generally effective for mercury capture on low-sulfur bituminous coal applications, but less effective for the following applications:

- Low-rank coals with ESP (current capacity of greater than 150 GW; the capacity with this configuration is not expected to increase significantly in the future). Lower chlorine and higher calcium contents in coal lead to lower levels of chlorine in flue gas, which results in reduced oxidation of mercury and, therefore, lower Hg^{2+} in flue gas;
- Low-rank coals with SDA and FF (current capacity of greater than 10 GW; the number of facilities with this configuration is expected to increase significantly in the future). Similar effect as above, except lime reagent from the SDA scavenges even more chlorine from flue gas;

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[21] Standard PAC binds mercury via physical (i.e., weak) bonds, which are formed more easily with Hg^{2+}. There have been results that show a similar removal for both elemental and oxidized mercury. However, the results do not account for surface catalyzed oxidation of Hg^0 followed by sorption on the carbon (EPA, 2005).

[22] These are collection of atoms/radicals such as oxygen, chlorine, hydroxyls, which provide binding sites.

- High-sulfur coal (current capacity with wet FGD of approximately 100 GW; the number of facilities with this configuration is likely to increase to more than 150 GW). Relatively high levels of SO_3 compete for active sites on PAC, which reduces the number of sites available for mercury. Generally, plants will use wet FGD and, in many cases, SCR; PAC injection may be needed to meet mercury reduction limits; and
- Hot-side ESPs (current capacity of approximately 30 GW; the number of facilities with this configuration is not likely to increase). Weak (physical) bonds get ruptured at higher temperatures resulting in lower sorption capacity.

1.2.5. Mercury Control by Halogenated PAC Injection

Some situations, as described above, may not have adequate chlorine present in the flue gas for good mercury capture by standard PAC. Pre-halogenated PAC sorbents have been developed to overcome some of the limitations associated with PAC injection for mercury control in power plant applications (Nelson, 2004; Nelson et al., 2004).

Halogenated PACs offer several potential benefits. Relative to standard PAC, halogenated PAC use:

- may expand the usefulness of sorbent injection to many situations where standard PAC may not be as effective;
- may avoid the need for installation of downstream FF, thereby improving cost-effectiveness of mercury capture;
- would, in general, be at lower injection rates, which potentially will lead to fewer plant impacts and a lower carbon content in the captured fly ash;
- may result in somewhat better performance with low-sulfur (including low-rank) coals because of less competition from SO_3; and,
- may be a relatively inexpensive and attractive control technology option for technology transfer to developing countries as it does not involve the capital intensive FF installation.

Performance of a halogenated sorbent such as brominated PAC appears to be relatively consistent regardless of coal type and appears to be mostly determined by whether or not the capture is in-flight (as in upstream of a CS-ESP) or on a fabric filter.

1.3. COAL COMBUSTION RESIDUES

In 2006, 125 million tons of coal combustion residues were produced with ~54 million tons being used in commercial, engineering, and agricultural applications (ACAA, 2007). CCRs result from unburned carbon and inorganic materials in coals that do not burn, such as oxides of silicon, aluminum, iron, and calcium. Fly ash is the unburned material from coal combustion that is light enough to be entrained in the flue gas stream, carried out of the process, and collected as a dry material in the APC equipment. Bottom ash and boiler slag are not affected by post-combustion APC technology and, therefore, these materials are not being evaluated as part of this study. Bottom ash is the unburned material that is too heavy to be entrained in the flue gas stream and drops out in the furnace. Boiler slag, unburned carbon or inorganic material in coal that does not burn, falls to the bottom of the furnace and melts.

The properties of fly ash and flue gas desulfurization residues are likely to change as a result of APC changes to reduce emissions of concern from coal-fired power plants. The chemical and physical properties may also change as a result of sorbents and other additives being used to improve air pollution control.

1.4. RESIDUE MANAGEMENT PRACTICES

CCRs can be disposed in landfills or surface impoundments or used in commercial applications to produce concrete and gypsum wallboard, among other products. Research on the impact of CCR disposal on the environment has been conducted by many researchers and has been summarized by the (EPA, 1988; EPA, 1999). However, most of the existing CCR data are for CCRs prior to implementation of mercury or multi-pollutant controls.

1.4.1. Beneficial Use

In the United States, approximately 43% percent (or 54 million tons out of total 125 million tons produced) of all CCRs produced are reused in commercial applications or other uses that are considered beneficial and avoid landfilling. Of the 125 million tons of CCRs produced as of 2006, about 60 percent (72.4 million tons of fly ash out of 125 million tons of CCRs) of CCRs is fly ash which is potential candidate for use in commercial applications such as making concrete/grout, cement, structural fill, and highway construction (ACAA, 2007; Thorneloe, 2003). Twelve million tons of the FGD gypsum was produced in 2006 with 7.6 million tons (i.e., 62% or 7.6 million out of 12 million) used in making wall board (ACAA, 2007). Table 3 and Figure 5 present the primary commercial uses of CCRs, and a breakdown of U.S. production and usage by CCR type.

Some beneficial uses may involve high temperature processing that may increase the potential for release of mercury and other metals. In cement manufacturing, for example, CCRs may be raw feed for producing clinker in cement kilns. Because of the high temperatures (~1450 ^{o}C), virtually all mercury will be volatilized from CCRs when they are used as feedstock to cement kilns. EPA has proposed (74 FR 21136m May 6, 2009) regulations to reduce mercury emissions from cement kilns, which may result in use of air pollution control technology similar to that used at coal-fired power plants (e.g, wet scrubbers and sorbents for enhanced Hg capture). The addition of air pollution control at cement kilns should not affect the ability to use fly ash or FGD gypsum in the production of clinker. However, to avoid installation of air pollution control, kiln inputs (such as fly ash) containing mercury may be avoided which could impact usage of some CCRs.

Through a separate study by EPA’s Air Pollution Prevention and Control Division, three high-temperature processes using coal ash have been evaluated for stability of mercury and other COPCs found in coal ash. This research is documented in a separate EPA report (Thorneloe, 2009).

The fate of mercury and other metals is also a potential concern when CCRs are used on the land (mine reclamation, building highways, soil amendments, agriculture and in making concrete, cement) or to make products that are subsequently disposed (e.g., disposal of wallboard in unlined landfill). The potential for leaching is a function of the characteristics of the material and the conditions under which it is managed.

For some commercial uses, it appears unlikely that mercury in CCRs will be reintroduced into the environment, at least during the lifetime of the product (e.g., encapsulated uses such as in the production of concrete). However, the impact of advanced mercury emissions control technology (e.g., activated carbon injection) on beneficial use applications is uncertain. There is concern that the presence of increased concentrations of mercury, certain other metals, or high carbon content may reduce the suitability of CCRs for use in some applications (e.g., carbon content can limit fly ash use in Portland cement concrete).

1.4.2. Land Disposal

There are approximately 600 land-based CCR waste disposal units (landfills or surface impoundments) being used by the approximately 500 coal-fired power plants in the United States (EPA, 1999). About 60% of the 125 million tons of CCRs generated annually are land disposed. Landfills may be located either on-site or off-site while surface impoundments are almost always located on-site with the combustion operations. Although the distribution of units is about equal between landfills and surface impoundments, there is a trend toward increased use of landfills as the primary disposal method.

Table 3. Beneficial uses of CCRs (ACAA, 2007). Total production of CCRs during 2006 was 124,795,124 short tons (values indicated are as reported in the primary reference and precision should not be inferred from the number of significant figures reported).

CCR Categories (Short Tons)	**Fly Ash**	**Bottom Ash**	**FGD Gypsum**	**FGD Wet Scrubbers**	**Boiler Slag[1]**	**FGD Dry Scrubbers[1]**	**FGD Other**
CCR Production Category Totals[2]	72,400,000	18,600,000	12,100,000	16,300,000	2,026,066	1,488,951	299,195
CCR Used Category Totals[3]	32,423,569	8,378,494	9,561,489	904,348	1,690,999	136,639	29,341
CCR Use By Application[4]	**Fly Ash**	**Bottom Ash**	**FGD Gypsum**	**FGD Wet Scrubbers**	**Boiler Slag [1]**	**FGD Dry Scrubbers[1]**	**FGD Other**
1. Concrete/Concrete Products/Grout	15,041,335	597,387	1,541,930	0	0	9,660	0
2. Cement/Raw Feed for Clinker	4,150,228	925,888	264,568	0	17,773	0	0
3. Flowable Fill	109,357	0	0	0	0	9,843	0
4. Structural Fills/Embankments	7,175,784	3,908,561	0	131,821	126,280	0	0
5. Road Base/Sub-base/Pavement	379,020	815,520	0	0	60	249	0
6. Soil Modification/Stabilization	648,551	189,587	0	0	0	299	1,503
7. Mineral Filler in Asphalt	26,720	19,250	0	0	45,000	0	0
8. Snow and Ice Control	0	331,107	0	0	41,549	0	0
9. Blasting Grit/Roofing Granules	0	81,242	0	232,765	1,445,933	0	0
10. Mining Applications	942,048	79,636	0	201,011	0	115,696	0
11. Wallboard	0	0	7,579,187	0	0	0	0
12. Waste Stabilization/Solidification	2,582,125	105,052	0	0	0	0	27,838
13. Agriculture	81,212	1,527	168,190	0	0	846	846
14. Aggregate	271,098	647,274	0	0	416	0	0
15. Miscellaneous/Other	1,016,091	676,463	7,614	338,751	13,988	46	46
CCR Category Use Tools	**32,423,569**	**8,378,494**	**9,561,489**	**904,348**	**1,690,999**	**136,639**	**29,341**
Application Use to Production Rate	44.8%	45.0%	79.0%	5.5%	83.5%	9.2%	9.8%

[1] As submitted based on 54 percent coal burn.

[2] CCR Production totals for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are extrapolated estimates rounded off to nearest 50,000 tons.

[3] CCR Used totals for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are per extrapolation calculations (not rounded off).

[4] CCR Uses by application for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are calculated by proportioning the CCR Used Category Totals by the same percentage as each of the individual application types' raw data contributions to the as-submitted raw data submittal total (not rounded off).

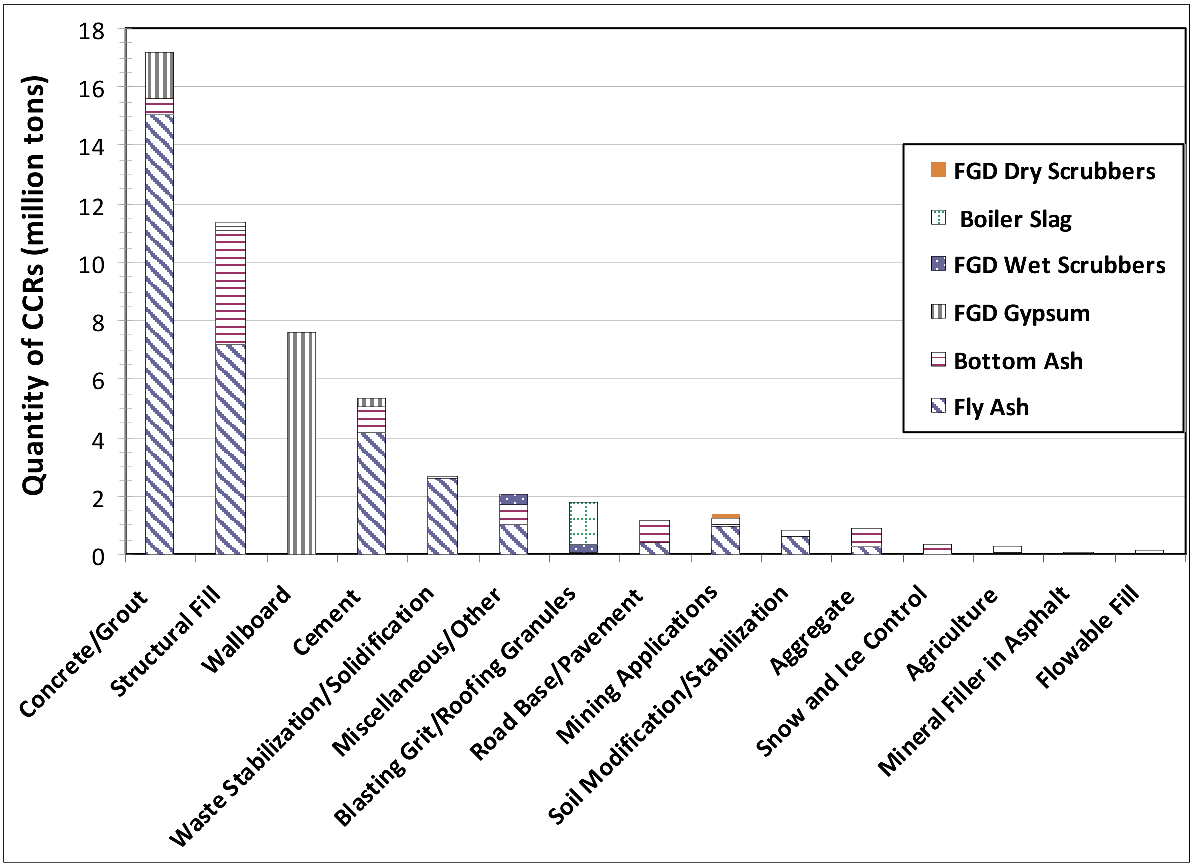

Figure 5. Uses of CCRs based on 2006 industry statistics (ACAA, 2007).

1.5. LEACHING PROTOCOL

One of the major challenges initially facing this research was identification of an appropriate test protocol for evaluating the leaching potential of CCRs that may have increased levels of several metals, particularly mercury. The goal of this research is to develop more accurate estimates of likely constituent leaching when CCRs are used or disposed on land. These estimates of leaching need to be appropriate for assessing at a national level the likely impacts through leaching of pollutants from CCRs that is a consequence of installation of enhanced mercury and, or, multi-pollutant controls. Because management conditions are known to affect the leaching of many metals, evaluation of leaching potential for CCRs over a range of test conditions is needed to consider a range of as managed scenarios (to the degree this is known), and provide leach testing results that can be appropriately extrapolated to a national assessment. A significant consideration in this research has been to identify and evaluate CCR samples collected from the most prevalent combinations of power plant design (with a focus on air pollution control technology configurations) and coal rank used. In addition, the resulting data set is expected to serve as foundation for evaluation of CCR management options for different types of CCRs at specific sites.

As a key part of this assessment approach, data have been collected on the actual disposal conditions for CCRs. These conditions are determined by a number of factors, and conditions will vary over time, which also needs to be considered when evaluating leaching (EPA, 1999; EPA, 2002; EPA, 2007b). When disposed, CCRs are typically monofilled[23] or disposed with other CCRs, so initial conditions may be determined largely by the tested material, and any co-disposed CCRs. However, CCR composition can change over time, due to reactions with the atmosphere (e.g., carbonation and oxidation), leaching out of soluble species, creation of reducing conditions at lower landfill levels, changes in the source of coal or coal rank burned, or due to installation of additional pollution control equipment.

Many leaching tests have been developed by regulatory agencies, researchers, or third-party technical standards organizations, and are described in the published literature. States and others have expressed concern with the variety of leaching protocols in use, the lack of correlation of test results with field conditions and actual leaching, and lack of comparability of available data because of incomplete reporting of test conditions. There is also limited or no quality assurance (QA) information for many of these tests. Leaching tests such as the Toxicity Characterization Leaching Procedure (TCLP)[24] (which reflects municipal solid waste co-disposal conditions) or the synthetic precipitation leaching procedure (SPLP), or any number of deionized water based tests may be inappropriate, or are at least not optimal for evaluating the leaching potential of CCRs as they are actually managed (i.e., monofilled or co-disposed with other CCRs). These tests either presume a set of prevailing landfill conditions (which may or may not exist at CCR disposal sites; e.g., TCLP), try to account for an environmental factor considered to be important in leaching (e.g., SPLP), or presume that the waste as tested in the laboratory will define the disposal conditions [such as deionized (DI) water tests]. Most existing leaching tests are empirical, in that results are presented simply as the contaminant concentrations leached when using the test, and without measuring or reporting values for factors that may occur under actual management and affect waste leaching, or that provide insight into the chemistry that is

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[23] The term “monofilled” refers to when a CCR is the only or dominant component in a landfill or disposal scenario.

[24] The Toxicity Characterization Leaching Procedure (TCLP) was not included as part of this study for several reasons. First, EPA previously made a waste status determination under RCRA that coal combustion residues are non-hazardous (65 FR 32214, May 22, 2000). Therefore, use of TCLP was not required as indicated under the RCRA toxicity characteristic regulation for determination of whether or not CCRs were hazardous. Second, TCLP was developed to simulate co-disposal of industrial waste with municipal solid waste as a mismanagement scenario, and to reflect conditions specific to this scenario. However, although MSW co-disposal of CCRs is plausible, the vast majority of CCRs are not being managed through co-disposal with municipal solid waste, and the test conditions for TCLP are different from the actual management practices for most CCRs. Third, SAB and NAS expressed concerns that a broader set of conditions and test methods other than TCLP are needed to evaluate leaching under conditions other than co-disposal with municipal solid waste. In seeking a tailored, “best-estimate” of CCR leaching, the leaching framework is responsive to SAB and NAS concerns and provides the flexibility to consider the effects of actual management conditions on these wastes, and so will be more accurate in this case.

occurring in leaching. Most tests are performed as a single batch test, and so do not consider the effect of variations in conditions on waste constituent leaching[25].

In searching for a reliable procedure to characterize the leaching potential of metals from the management of CCRs, EPA sought an approach that (i) considers key aspects of the range of known CCR chemistry and management conditions (including re-use); and (ii) permits development of data that are comparable across U.S. coal and CCR types. Because the data resulting from this research will be used to support regulations, scrutiny of the data is expected. Therefore, the use of a published, peer-reviewed (but not promulgated) protocol is also considered to be an essential element of this work.[26]

EPA ORD has worked closely with EPA's Office of Solid Waste and Emergency Response (OSWER) to identify an appropriate leaching protocol for evaluating CCRs. The protocol that has been adopted is the "Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials" (Kosson et al., 2002) and referred to here as the "leaching framework." The leaching framework consists of a tiered approach to leaching assessment. The general approach under the leaching framework is to use laboratory testing to measure intrinsic leaching characteristics of a material (i.e., liquid-solid equilibrium partitioning as a function of pH and LS ratio, mass transfer rates) and then use this information in conjunction with mass transfer models to estimate constituent release by leaching under specific management scenarios (e.g., landfilling). Unlike other laboratory leaching tests, under this approach, laboratory testing is not intended to directly simulate or mimic a particular set of field conditions. Development work to-date on the leaching framework has focused on assessing metals leaching, and this work includes equilibrium batch testing (over a range of pH and LS ratio values), diffusion-controlled mass transfer, and percolation-controlled (column) laboratory test methods in conjunction with mass transfer models, to estimate release for specific management scenarios based on testing results from a common set of leaching conditions. EPA OSWER and ORD believe that this approach successfully addresses the concerns identified above, in that it seeks to consider the effect of key disposal conditions on constituent leaching, and to understand the leaching chemistry of wastes tested.

The following attributes of the leaching framework were considered as part of the selection process:

- The leaching framework will permit development of data that are comparable across U.S. coal and CCR types;
- The leaching framework will permit comparison with existing laboratory and field leaching data on CCRs;

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[25] Many factors are known or may reasonably be expected to affect waste constituent leaching. The solubility of many metal salts is well known to vary with pH; adsorption of metals to the waste matrix varies with pH; redox conditions may determine which metal salts are present in wastes; temperature may affect reaction rates; water infiltration can affect the leaching rate, and also affect leaching chemistry and equilibrium.

[26] EPA is working to include the leaching test methods used in this research as part of standard methods in SW-846.

- The leaching framework was published in the peer-reviewed scientific literature (Kosson et al., 2002);
- On consultation with EPA's OSWER, it was recommended as the appropriate protocol based on review of the range of available test methods and assessment approaches; and
- On consultation with the Environmental Engineering Committee of the Science Advisory Board (SAB, 2003), the committee considered the leaching framework responsive to earlier SAB criticisms of EPA's approach to leaching evaluation, and also was considered broadly applicable and appropriate for this study

For this study, the primary leaching tests used from the leaching framework were Solubility and Release as a Function of pH (SR002.1) and Solubility and Release as a Function of the Liquid-Solid Ratio (LS) (SR003.1)[27]. These tests represent equilibrium-based leaching characterization (Kosson et al., 2002). The range of pH and LS ratio used in the leaching tests is within the range of conditions observed for current CCR management practices. Results of these tests provide insights into the physical-chemical mechanisms controlling constituent leaching. When used in conjunction with mass transfer and geochemical speciation modeling, the results can provide conservative[28] but realistic estimates of constituent leaching under a variety of environmental conditions (pH, redox, salinity, carbonation) and management scenarios.

This test set is considered Tier 2 testing (equilibrium-based) for detailed characterization, which was selected to develop a comprehensive data set of CCR characteristics (Kosson et al., 2002). Mass transfer rate testing (Tier 3, detailed characterization) may be carried out in the future for specific cases where results from equilibrium-based characterization indicate a need for detailed assessment.

Eluates from leaching tests were analyzed for more than 35 constituents (e.g., elements, anions, DIC, DOC) and characteristics (e.g., pH and conductivity), however, 13 constituents were selected to be the focus of this report based on input from OSWER due to potential concern for human health and the environment.

Laboratory testing for leaching assessment was carried out at EPA's National Risk Management Research Laboratory (Research Triangle Park, NC) with technical assistance from Vanderbilt University.

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[27] LS refers to liquid to solid ratio (mL water/g CCR or L water/kg CCR) occurring during laboratory leaching tests or under field conditions. SR002.1 is carried out at LS=10 with several parallel batch extractions over a range of pH, while SR003.1 is carried out using several parallel batch extractions with deionized water at LS= 0.5, 1, 2, 5 and 10. Under field conditions, LS refers to the cumulative amount of water passing through the total mass of CCR subject to leaching. SR002.1 and SR003.1 are Vanderbilt University test method designations. An appropriately defined and structured version of test method SR002.1 is being proposed as SW-846 Draft Method 1313 – Leaching Test (Liquid-Solid Partitioning as a Function of Extract pH) of Constituents in Solid Materials Using a Parallel Batch Extraction Test; similarly, test method SR003.1 is being proposed as SW-846 Draft Method 1316 – Leaching Test (Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ration) of Constituents in Solid Materials Using a Parallel Batch Extraction Test.

[28] In this report, "conservative" implies that the constituent release estimates are likely to be equal to or greater than actual expected release under field conditions.

2. MATERIALS AND METHODS

The following sections discuss the specific CCR materials evaluated in this report and the specific methods of characterization, including physical and chemical properties, elemental composition and leaching characteristics. The Quality Assurance Project Plan supporting this work is provided as Appendix B and assessment of quality assurance results is discussed in section 2.4.

2.1. CCR MATERIALS FOR EVALUATION

The 73 CCR samples tested in this study (inclusive of all three reports) include 27 fly ashes without Hg sorbent injection, 7 fly ashes with Hg sorbent injection, 2 spray dryers with fabric filter, 11 unwashed gypsum, 9 washed gypsum, 5 scrubber sludges, 8 blended CCRs (7 mixed fly ash and scrubber sludges; 1 mixed fly ash and gypsum) from 31 coal fired power plants (Table 4). Most coal fired power plants providing samples are identified by a single or two letter code (i.e., Facility T or Facility Ba) to allow specific facilities to remain anonymous. In addition, 4 filter cake samples from the waste water treatment process associated with the management of CCRs were evaluated. Table 5 summarizes the CCR samples evaluated, grouped by residue type, coal type and air pollution control (APC) configuration. Description of the facilities and CCR sampling points is provided in Appendix A.

The facilities and CCRs that were sampled were selected to allow comparisons:

1. Between fly ashes for different coal types (bituminous *vs*. sub-bituminous *vs*. lignite[29]), particulate control devices (cold-side ESP *vs*. hot-side ESP *vs*. fabric filter), and NO_x control (none or by passed, SNCR or SCR);
2. Between fly ashes from the same facility without and with Hg sorbent injection (Brayton Point, Salem Harbor, Pleasant Prairie, and Facilities J, L, C, and Ba);
3. Between unwashed and washed gypsum from the same facility (Facilities N, O, S, T, W, X, and Aa); and,
4. On the impact of different FGD scrubber types on scrubber sludge (Facilities A, B, and K), blended fly ash and scrubber sludge (Facilities A, B, K and M), and blended fly ash and gypsum (Facility U).

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[29] This project had a difficult time obtaining coal ash samples from lignite coal. Samples (fly ash and FGD gypsum) were obtained from one facility using Gulf Coast lignite. For facility Ba, the obtained fly ash was from a coal blend of PRB and North Dakota lignite.

Table 4. Summary of facility configurations, CCR sample types and sample codes.

Facility Information						**CCR Sample Types and Sample Codes**								
Facility Code	**Coal Type**	**NO_x Control**	**PM Control**	**FGD Scrubber**		**Fly Ash**	**Spray Dryer Ash**	**Gypsum**		**ScS**	**Blended CCRs**			**Filter Cake**
				Limestone or Mg Lime	**Oxidation**			**Gyp-U**	**Gyp-W**		**FA+ Gyp**	**FA+ ScS**	**FA+ ScS+ Lime**	
[1]Brayton Point	East-Bit	None	CS-ESP	None	None	BPB								
[1]Brayton Point	East-Bit	None	ACI+ CS-ESP	None	None	BPT								
[1]Pleasant Prairie	PRB Sub-Bit	None	CS-ESP	None	None	PPB								
[1]Pleasant Prairie	PRB Sub-Bit	None	ACI+ CS-ESP	None	None	PPT								
[1]Salem Harbor	Low S East-Bit	SNCR	CS-ESP	None	None	SHB								
[1]Salem Harbor	Low S East-Bit	SNCR	ACI+ CS-ESP	None	None	SHT								
[2]A	East-Bit	SNCR-BP[3]	Fabric Filter	Limestone	Natural	CFA						CCC		
[2]A	East-Bit	SNCR	Fabric Filter	Limestone	Natural	AFA			CGD			ACC		
[2]B	East-Bit	SCR-BP*	CS-ESP	Mg Lime	Natural	BFA				BGD			BCC	
[2]B	East-Bit	SCR	CS-ESP	Mg Lime	Natural	DFA			AGD				DCC	
[1]C	Low S Bit	None	HS-ESP with COHPAC	None	None	GAB			DGD					
[1]C	Low S Bit	None	HS-ESP + ACI + COHPAC	None	None	GAT								
E	Med S East-Bit	SCR (in use and BP)	CS-ESP	None	None	EFA, EFB								

Table 4. Summary of facility configurations, CCR sample types and sample codes.

Facility Information						**CCR Sample Types and Sample Codes**								
Facility Code	**Coal Type**	**NO$_x$ Control**	**PM Control**	**FGD Scrubber**		**Fly Ash**	**Spray Dryer Ash**	**Gypsum**		**ScS**	**Blended CCRs**			**Filter Cake**
				Limestone or Mg Lime	**Oxidation**			**Gyp-U**	**Gyp-W**		**FA+ Gyp**	**FA+ ScS**	**FA+ ScS+ Lime**	
E	High S East-Bit	SCR (in use and BP)	CS-ESP	None	None	EFC								
F	Low S Bit	None	CS-ESP	None	None	FFA								
G	Low S Bit	SNCR	CS-ESP	None	None	GFA								
H	High S Bit	SCR	CS-ESP	Limestone	Forced	HFA								
^{1}J	Sub-Bit	None	CS-ESP	None	None	JAB								
^{1}J	Sub-Bit	None	Br-ACI + CS-ESP	None	None	JAT								
^{2}K	Sub-Bit	SCR	CS-ESP	Mg Lime	Natural	KFA							KCC	
^{1}L	Southern Appala-chian	SOFA^{4}	HS-ESP	None	None	LAB			KGD					
^{1}L	Southern Appala-chian	SOFA	Br-ACI + HS-ESP	None	None	LAT								
^{2}M	Bit	SCR-BP	CS-ESP	Limestone	Inhibited								MAD	
^{2}M	Bit	SCR	CS-ESP	Limestone	Inhibited								MAS	
^{2}N	Bit	None	CS-ESP	Limestone	Forced			NAU	NAW					
^{2}O	Bit	SCR	CS-ESP	Limestone	Forced			OAU	OAW					
^{2}P	Bit	SCR & SNCR^{5}	CS-ESP	Limestone	Forced			PAD						
^{2}Q	Sub-Bit	None	HS-ESP	Limestone	Forced			QAU						
R	Sub-Bit PRB	None	CS-ESP	Wet Limestone	Forced			RAU						

Table 4. Summary of facility configurations, CCR sample types and sample codes.

Facility Information						**CCR Sample Types and Sample Codes**								
Facility Code	**Coal Type**	**NO_x Control**	**PM Control**	**FGD Scrubber**		**Fly Ash**	**Spray Dryer Ash**	**Gypsum**		**ScS**	**Blended CCRs**			**Filter Cake**
				Limestone or Mg Lime	**Oxidation**			**Gyp-U**	**Gyp-W**		**FA+ Gyp**	**FA+ ScS**	**FA+ ScS+ Lime**	
S	High S Bit	SCR	CS-ESP	Limestone	Forced			SAU	SAW					
T	East-Bit	SCR	CS-ESP	Lime	Forced	TFA		TAU	TAW					TFC
U	Low S Bit	SCR	CS-ESP	Limestone	Forced	UFA		UAU			UGF			
V	Sub-Bit PRB	SCR	Spray Dryer / Baghouse	slaked lime	None		VSD							
W	East-Bit	SCR-BP	CS-ESP	Limestone Trona	Forced	WFA		WAU	WAW					WFC
X	Sub-Bit PRB	SCR	CS-ESP	Limestone	Forced	XFA		XAU	XAW					XFC
Y	Sub-Bit PRB	SCR before air preheater	Baghouse	Slaked Lime / Spray Dryer Adsorber	Natural		YSD							
Z	Sub-Bit PRB	None	CS-ESP	None	None	ZFA ZFB (totals only)								
Aa	East-Bit	SCR	CS-ESP	Limestone	Forced	AaFA AaFB AaFC		AaAU	AaAW					

Table 4. Summary of facility configurations, CCR sample types and sample codes.

Facility Information						**CCR Sample Types and Sample Codes**								
Facility Code	**Coal Type**	**NO$_x$ Control**	**PM Control**	**FGD Scrubber**		**Fly Ash**	**Spray Dryer Ash**	**Gypsum**		**ScS**	**Blended CCRs**			**Filter Cake**
				Limestone or Mg Lime	**Oxidation**			**Gyp-U**	**Gyp-W**		**FA+ Gyp**	**FA+ ScS**	**FA+ ScS+ Lime**	
Ba	Sub-Bit PRB / Lignite (Gulf Coast)		CS-ESP w/ COHPAC NH$_3$ inj. before ESP for flue gas conditioning	None	None	BaFA								
Ca	Gulf Coast Lignite	Low NO$_x$ burner	CS-ESP	Wet Limestone	Forced	CaFA			CaAW					
Da	East-Bit	SCR	CS-ESP	Limestone	Forced	DaFA			DaAW					DaFC

[1] (Sanchez et al., 2006)

[2] (Sanchez et al., 2008)

[3] BP – designates that the post-NO$_x$ combustion control (either SCR or SNCR) was not in use or by-passed during sample collection. Clean Air Interstate Rule requires year-round use of post-NO$_x$ combustion whereas previously if used, then it was seasonal during the summer months.

[4] SOFA - Separate overfire air, it is often added above the burner level to stage combustion.

[5] Facility P has one wet scrubber for two boilers. Both boilers have post-combustion NO$_x$ control – one with SCR and the other with SNCR. The sample collected for this facility is from the wet scrubber.

Table 5. CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Coal Source (Region)	PM Capture	NO_x Control	Hg Sorbent Injection	SO_3 Control
Fly Ash without Hg Sorbent Injection						
Bituminous, Low S						
Brayton Point	BPB	Eastern bituminous	CS ESP	None	None	None
Facility F	FFA	Eastern bituminous	CS ESP	None	None	None
Facility B	DFA	Eastern bituminous	CS ESP	SCR-BP	None	None
Facility A	CFA	Eastern bituminous	Fabric F.	SNCR-BP	None	None
Facility B	BFA	Eastern bituminous	CS ESP	SCR	None	None
Facility U	UFA	Southern Appalachian	CS ESP	SCR	None	None
Salem Harbor	SHB	Eastern bituminous	CS ESP	SNCR	None	None
Facility G	GFA	Eastern bituminous	CS ESP	SNCR	None	None
Facility A	AFA	Eastern bituminous	Fabric F.	SNCR	None	None
Facility L	LAB	Southern Appalachian	HS ESP	SOFA	None	None
Facility C	GAB	Eastern bituminous	HS ESP w/ COHPAC	None	None	None
Bituminous, Med S						
Facility T	TFA	Eastern bituminous	CS ESP	None	None	None
Facility E	EFB	Eastern bituminous	CS ESP	SCR-BP	None	None
Facility W	WFA	Eastern bituminous	CS ESP	SCR-BP	None	Duct Sorbent injection - Trona
Facility E	EFA	Eastern bituminous	CS ESP	SCR	None	None
Facility K	KFA	Eastern bituminous	CS ESP	SCR	None	None
Facility Aa	AaFA	Eastern bituminous	CS ESP	SCR	None	None
Facility Aa	AaFB	Eastern bituminous	CS ESP	SCR	None	None
Facility Da	DaFA	Eastern bituminous	CS ESP	SCR	None	None
Facility Aa	AaFC	Eastern bituminous	HS ESP	SCR	None	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Coal Source (Region)	PM Capture	NO_x Control	Hg Sorbent Injection	SO_3 Control
Fly Ash without Hg Sorbent Injection						
Bituminous, High S						
Facility E	EFC	Eastern bituminous	CS ESP	SCR	None	None
Facility H	HFA	Eastern bituminous	CS ESP	SCR	None	None
Sub-Bituminous & Sub-bit/bituminous mix						
Pleasant Prairie	PPB	Powder River Basin	CS ESP	None	None	None
Facility J	JAB	PRB (85%)/Bit (15%)	CS ESP	None	None	None
Facility Z	ZFA	Powder River Basin	CS ESP	None	None	None
Facility X	XFA	Powder River Basin	CS ESP	SCR	None	None
Lignite						
Facility Ca	CaFA	Gulf Coast	CS ESP	None	None	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Coal Source (Region)	PM Capture	NO_x Control	Hg Sorbent Injection	SO_3 Control
Fly Ash without and with Hg Sorbent Injection Pairs						
Bituminous, Low S						
Brayton Point	BPB	Eastern bituminous	CS ESP	None	None	None
Brayton Point	BPT	Eastern bituminous	CS ESP	None	PAC	None
Salem Harbor	SHB	Eastern bituminous	CS ESP	SNCR	None	None
Salem Harbor	SHT	Eastern bituminous	CS ESP	SNCR	PAC	None
Facility L	LAB	Southern Appalachian	HS ESP	SOFA	None	None
Facility L	LAT	Southern Appalachian	HS ESP	SOFA	Br-PAC	None
Facility C	GAB	Eastern bituminous	HS ESP w/ COHPAC	None	None	None
Facility C	GAT	Eastern bituminous	HS ESP w/ COHPAC	None	PAC	None
Sub-bituminous						
Pleasant Prairie	PPB	Powder River Basin	CS ESP	None	None	None
Pleasant Prairie	PPT	Powder River Basin	CS ESP	None	PAC	None
Facility J	JAB	Other	CS ESP	None	None	None
Facility J	JAT	Other	CS ESP	None	Br-PAC	None
Lignite						
Facility Ba	BaFA	PRB/Lignite blend	CS ESP w/ COHPAC+ Ammonia Injection	None	PAC	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Coal Source (Region)	PM Capture	NO_x Control	Hg Sorbent Injection	FGD Scrubber additive	SO_3 Control
Spray dryer with Fabric Filter (fly ash and FGD collected together)							
Sub-Bituminous							
Facility V	VSD	Powder River Basin	Fabric F.	SCR	None	Slaked Lime	None
Facility Y	YSD	Powder River Basin	Fabric F.	SCR	None	Slaked Lime	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Region	Residue type	PM Capture	NO_x Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control
Gypsum, unwashed and washed								
Bituminous, Low S								
Facility U	UAU	Southern Appalachian	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
Bituminous, Med S								
Facility T	TAU	Eastern bituminous	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None
Facility T	TAW	Eastern bituminous	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None
Facility W	WAU	Eastern bituminous	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Trona
Facility W	WAW	Eastern bituminous	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Trona
Facility Aa	AaAU	Eastern bituminous	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
Facility Aa	AaAW	Eastern bituminous	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None
Facility Da	DaAW	Eastern bituminous	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None
Facility P	PAD	Eastern bituminous	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Region	Residue type	PM Capture	NO_x Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control
Gypsum, unwashed and washed								
Bituminous, High S								
Facility N	NAU	Eastern bituminous	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None
Facility N	NAW	Eastern bituminous	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None
Facility S	SAU	Illinois Basin	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
Facility S	SAW	Illinois Basin	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None
Facility O	OAU	Other	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
Facility O	OAW	Other	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None
Sub-bituminous								
Facility R	RAU	Powder River Basin	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None
Facility Q	QAU	Powder River Basin	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other
Facility X	XAU	Powder River Basin	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
Facility X	XAW	Powder River Basin	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None
Lignite								
Facility Ca	CaAW	Gulf Coast	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Region	Residue type	PM Capture	NO_x Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control
Scrubber Sludge								
Bituminous, Low S								
Facility B	DGD	Eastern bituminous	Scrubber sludge	Cold-side ESP	SCR-BP	Natural Ox.	Mg lime	None
Facility A	CGD	Eastern bituminous	Scrubber sludge	Fabric Filter	SNCR-BP	Natural Ox.	Limestone	None
Facility B	BGD	Eastern bituminous	Scrubber sludge	Cold-side ESP	SCR	Natural Ox.	Mg lime	None
Facility A	AGD	Eastern bituminous	Scrubber sludge	Fabric Filter	SNCR	Natural Ox.	Limestone	None
Bituminous, Med S								
Facility K	KGD	Eastern bituminous	Scrubber sludge	Cold-side ESP	SCR	Natural Ox.	Mg lime	None

Table 5 (continued). CCR samples evaluated in this study, grouped by residue type, coal type and air pollution control configuration.

Facility	Sample ID	Region	Residue type	PM Capture	NO_x Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control
Mixed Fly Ash and Scrubber Sludge (as managed)								
Bituminous, Low S								
Facility B	DCC	Eastern bituminous	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None
Facility A	CCC	Eastern bituminous	FA+ScS	Fabric Filter	SNCR-BP	Natural Ox.	Limestone	None
Facility B	BCC	Eastern bituminous	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None
Facility A	ACC	Eastern bituminous	FA+ScS	Fabric Filter	SNCR	Natural Ox.	Limestone	None
Bituminous Med S								
Facility K	KCC	Eastern bituminous	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None
Bituminous Med S								
Facility M	MAD	Illinois Basin	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None
Facility M	MAS	Illinois Basin	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None

2.2. LEACHING ASSESSMENT PROTOCOLS

Laboratory testing for this study focused on leaching as a function of pH and LS ratio as defined by the leaching framework. This test set is considered Tier 2 testing (equilibrium-based) for detailed characterization, which was selected to develop a comprehensive data set of CCR characteristics. Mass transfer rate testing (Tier 3, detailed characterization) may be carried out in the future for specific cases where results from equilibrium-based characterization indicate a need for detailed assessment.

2.2.1. Alkalinity, Solubility and Release as a Function of pH (SR002.1)

Alkalinity, solubility and release as a function of pH were determined according to method SR002.1 (Kosson et al., 2002). This method is currently under review as a preliminary version of Method 1313[30] for publication in SW-846. This protocol consists of 11 parallel extractions of particle size reduced material, at different pH values ranging from pH 2-13, and at a LS ratio of 10 mL extractant/g dry sample. In this method, particle-size reduction is used when necessary to prepare large-grained samples for extraction so that the approach toward liquid-solid equilibrium concentrations of the COPCs is enhanced. For the samples evaluated in this study, particle size reduction was required infrequently. Each extraction condition was carried out with replication as appropriate[31] using 40 g of material for each material evaluated. In addition, three method blanks were included, consisting of the DI water, nitric acid and potassium hydroxide used for extractions. Typical particle size of the tested materials was less than 300 µm using standard sieves according to ASTM E-11-70 (1995). An acid or base addition schedule is formulated based on initial screening for eleven eluates with final solution pH values between 3 and 12, through addition of aliquots of nitric acid or potassium hydroxide as needed. The exact schedule is adjusted based on the nature of the material; however, the range of pH values includes the natural pH of the matrix that may extend the pH domain (e.g., for very alkaline or acidic materials). The final LS ratio is 10 mL extractant/g dry sample which includes DI water, the added acid or base, and the amount of moisture that is inherent to the waste matrix as determined by moisture content analysis. The eleven extractions were tumbled in an end-over-end fashion at 28 ± 2 rpm for 24 hours followed by filtration separation of the solid phase from the eluate using a 0.45 µm polypropylene filter. Each eluate then was analyzed for constituents of interest. The acid and base neutralization behavior of the materials is evaluated by plotting the pH of each eluate as a function of equivalents of acid or base added per gram of dry solid. Concentration of constituents of interest for each eluate is plotted as a function of eluate final pH to provide liquid-solid partitioning equilibrium as a function of pH. Initially, the SR002.1 test was carried out in triplicate; however, replication was reduced to two replicates of the test method for later

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[30] Preliminary version denotes that this method has not been endorsed by EPA but is under consideration for inclusion into SW-846. This method has been derived from published procedures (Kosson et al, 2002) using reviewed and accepted methodologies (USEPA 2006, 2008, 2009). The method has been submitted to the USEPA Office of Resource Conservation and Recovery and is currently under review for development of interlaboratory validation studies to develop precision and bias information.

[31] Initial replication was in triplicate (as indicated in Report 1 and for some of the samples in Report 2), which was reduced to duplicate based on quality assurance review of the triplicate analyses results.

samples based on good replication and consistency amongst the early results (Sanchez et al., 2006).

2.2.2. Solubility and Release as a Function of LS Ratio (SR003.1)

Solubility and release as a function of LS ratio was determined according to method SR003.1 (Kosson et al., 2002). This method is currently under review as a preliminary version of Method 1314[32] for promulgation in SW-846. This protocol consists of five parallel batch extractions over a range of LS ratios (i.e., 10, 5, 2, 1, and 0.5 mL/g dry material), using DI water as the extractant with aliquots of material that has been particle size reduced. Typical particle size of the material tested was less than 300 µm. Between 40 and 200 g of material were used for each extraction, based on the desired LS ratio. All extractions are conducted at room temperature (20 ± 2 °C) in leak-proof vessels that are tumbled in an end-over-end fashion at 28 ± 2 rpm for 24 hours. Following gross separation of the solid and liquid phases by centrifuge or settling, leachate pH and conductivity measurements are taken and the phases are separated by pressure filtration using 0.45-µm polypropylene filter membrane. The five leachates are collected, and preserved as appropriate for chemical analysis. Initially, the SR003.1 test was carried out in triplicate; however, replication was reduced to two replicates of the test method for later samples based on good replication and consistency amongst the early results.

2.3. ANALYTICAL METHODS

2.3.1. Surface Area and Pore Size Distribution

A Quantachrome Autosorb-1 C-MS chemisorption mass spectrometer was used to perform 5-point Brunauer, Emmett, and Teller (BET) method surface area, pore volume, and pore size distribution analyses on each as-received and size-reduced CCR. A 200 mg sample was degassed under vacuum at 200 ºC for at least one hour in the sample preparation manifold prior to analysis with N_2 as the analysis gas. Standard materials with known surface area were routinely run as a QC check. Tabular results for each CCR are provided in Appendix C.

2.3.2. pH and Conductivity

pH and conductivity were measured for all aqueous eluates using an Accumet 925 pH/ion meter. The pH of the leachates was measured using a combined pH electrode accurate to 0.1 pH units. A 3-point calibration was performed daily using pH buffer solutions at pH 4.0, 7.0 and 10.0. Conductivity of the leachates was measured using a standard conductivity probe. The conductivity probe was calibrated using appropriate standard conductivity solutions for the conductivity range of concern. Conductivity meters typically are accurate to ± 1% and have a precision of ± 1%.

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[32] Method SR003.1 was developed into a preliminary version of Method 1314: Leaching Test (Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio) for Constituents in Solid Materials using an Up-flow Percolation Column Test, 2009 (submitted to EPA Office of Solid Waste; under review for inclusion in SW-846).

2.3.3. Moisture Content

Moisture content of the “as received” CCRs was determined using American Society for Testing and Materials (ASTM) D 2216-92. This procedure supersedes the method indicated in the version of the leaching procedure published by (Kosson et al., 2002). Tabular results are provided in Appendix C.

2.3.4. Carbon Content - Organic Carbon/Elemental Carbon Analyzer

Organic carbon (OC) and elemental carbon (EC) content of each CCR tested was measured using a Sunset Lab thermal-optical EC/OC analyzer using the thermal/optical method (NIOSH Method 5040). The sample collected on quartz fiber filters is heated under a completely oxygen-free helium atmosphere in a quartz oven in four increasing temperature steps (375 °C, 540 °C, 670 °C and 870 °C) at 60 second ramp times for the first three temperatures and a ramp time of 90 seconds for the final temperature. The heating process removes all organic carbon on the filter. As the organic compounds are vaporized, they are immediately oxidized to carbon dioxide in an oxidizer oven which follows the sample oven. The flow of helium containing the produced carbon dioxide then flows to a quartz methanator oven where the carbon dioxide is reduced to methane. The methane is then detected by a flame ionization detector (FID). After the sample oven is cooled to 525 ºC, the pure helium eluent is switched to an oxygen/helium mixture in the sample oven. At that time, the sample oven temperature is stepped up to 850 ºC. During this phase, both the original elemental carbon and the residual carbon produced by the pyrolysis of organic compounds during the first phase are oxidized to carbon dioxide due to the presence of oxygen in the eluent. The carbon dioxide is then converted to methane and detected by the FID. After all carbon has been oxidized from the sample, a known volume and concentration of methane is injected into the sample oven. Thus, each sample is calibrated to a known quantity of carbon as a means of checking the operation of the instrument. The calibration range for these analyses was from 10 to 200 µg/cm^2 of carbon using a sucrose solution as the standard. The detection limit of this instrument is approximately 100 ng/cm^2 with a linear dynamic range from 100 ng/cm^2 to 1 g/cm^2. Tabular results of OC and EC content are presented in Appendix C.

2.3.5. Dissolved Inorganic Carbon (DIC) and Dissolved Organic Carbon (DOC)

Analyses of total organic carbon and inorganic carbon were performed on a Shimadzu model TOC-V CPH/CPN. Five-point calibration curves, for both dissolved inorganic carbon (DIC) and non-purgeable dissolved organic carbon (DOC) analyses, were generated for an analytical range between 5 ppm and 100 ppm and are accepted with a correlation coefficient of at least 0.995. An analytical blank and check standard at approximately 10 ppm were run every 10 samples. The standard was required to be within 15% of the specified value. A volume of approximately 16 mL of undiluted sample was loaded for analysis. DIC analysis was performed first for the analytical blank and standard and then the samples. DOC analysis was carried out separately after completion of DIC analysis. DOC analysis began using addition of 2 M (mole/L) of hydrochloric acid to achieve a pH of 2 along with a sparge gas flow rate of 50 mL/min to purge inorganic carbon prior to analysis. Method detection limit (MDL) and minimum level of quantification (ML) are shown in Table 6. All DIC and DOC results will be made available separately through an electronic format as part of the leaching assessment tool (LeachXS Lite®).

Table 6. MDL and ML of analysis of DIC and DOC.

	MDL (µg/L)	ML (µg/L)
DIC	130	410
DOC	170	550

2.3.6. Mercury (CVAA, Method 3052, and Method 7473)

Liquid samples were preserved for mercury analysis by additions of nitric acid and potassium permanganate and then prepared prior to analysis according to the following method. For each 87 mL of sample, 3 mL of concentrated nitric acid and 5 mL of 5 wt% aqueous potassium permanganate solution were added prior to storage. Immediately before cold vapor atomic absorption (CVAA) analysis, 5 mL of hydroxylamine were added to clear the sample and then the sample was digested according to ASTM Method D6784-02 (i.e., Ontario Hydro) as described for the permanganate fraction (ASTM, 2002). On completion of the digestion, the sample was analyzed for mercury by CVAA. Samples with known additions of mercury for matrix analytical spikes also were digested as described above prior to CVAA analysis.

Sample preparation of the solids and filters was carried out by HF/HNO_3 microwave digestion according to Method 3052 (EPA, 1996) followed by CVAA analysis as indicated above. No additional preservation or digestion was carried out prior to CVAA analysis.

Mercury analysis of each digest, eluate and leachate was carried out by CVAA according to EPA SW846 Method 7470A “Mercury in Liquid Waste (Manual Cold Vapor Technique)” (EPA, 1998a). A Perkin Elmer FIMS 100 Flow Injection Mercury System was used for this analysis. The instrument was calibrated with known standards ranging from 0.025 to 1 µg/L mercury.

Solids also were analyzed by Method 7473 “Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry” (EPA, 1998b). A Nippon MD-1 mercury system was used for this analysis. The instrument was calibrated with known standards ranging from 1 to 20 ng of mercury. The method detection limit for mercury in solids is 0.145 µg/kg.

2.3.7. Other Metals (ICP-MS, ICP-AES, Method 3052, Method 6020, and Method 6010)

Liquid samples for ICP-MS and ICP-AES analysis were preserved through addition of 3 mL of concentrated nitric acid (trace metal grade) per 97 mL of sample. Known quantities of each analyte were also added to sample aliquots for analytical matrix spikes. Solid samples were digested by EPA Method 3052 (EPA, 1996) prior to ICP-MS and ICP-AES analysis. Table 7 indicates the switch from ICP-MS to ICP-AES for specific elements and samples.

Table 7. ICP instrument used for each element.* Elements indicated in bold are discussed in this report; results for all other indicated elements will be available through the leaching assessment tool.

Symbol	Instrument	Used	Switch Date
Al		ICP-OES	Report 3 Samples
Sb	ICP-MS	ICP-OES*	Only SR003.1 Report 1 Samples*
As	ICP-MS		
Ba	ICP-MS		
Be	ICP-MS		
B		ICP-OES	Report 1 and 3 Samples
Cd	ICP-MS		
Ca		ICP-OES	Report 3 Samples
Cr	ICP-MS		
Co	ICP-MS		
Cu	ICP-MS		
Fe		ICP-OES	Report 3 Samples
Pb	ICP-MS		
Mg		ICP-OES	Report 3 Samples
Mn	ICP-MS		
Mo	ICP-MS	ICP-OES*	*Only Report 1 Samples
Ni	ICP-MS		
K		ICP-OES	Report 3 Samples
Re	ICP-MS		
Se	ICP-MS		
Si		ICP-OES	Report 3 Samples
Na		ICP-OES	Report 3 Samples
Sr		ICP-OES	Report 3 Samples
Tl	ICP-MS	ICP-OES*	Only SR003.1 Report 1 Samples*
Sn	ICP-MS		
Ti		ICP-OES	Report 3 Samples
U	ICP-MS		
V	ICP-MS		
Zn	ICP-MS		

*Samples were analyzed on the ICP-OES for the indicated elements. Measurements for the same elements on Facility T samples (TFA, TFC, TAW, and TAU) were also completed on the ICP-MS for comparison. Precision of results was within 15% for concentrations above 100 µg/L and within 25% for concentrations below 100 µg/L.

2.3.7.1. ICP-MS Analysis (SW-846 Method 6020)

ICP-MS analyses of aqueous samples from laboratory leaching tests were carried out at Vanderbilt University (Department of Civil and Environmental Engineering) using a Perkin Elmer model ELAN DRC II in both standard and dynamic reaction chamber (DRC) modes. Standard analysis mode was used for all analytes except for As and Se, which were run in DRC mode with 0.5 mL/min of oxygen as the reaction gas. Seven-point standard curves were used for an analytical range between approximately 0.5 µg/L and 500 µg/L and completed before each analysis. Analytical blanks and analytical check standards at approximately 50 µg/L were run every 10 to 20 samples and required to be within 15% of the specified value. Samples for analysis were diluted gravimetrically to within the targeted analytical range using 1% v/v Optima grade nitric acid (Fisher Scientific). Initially, analyses for 10:1 dilutions were performed to minimize total dissolved loading to the instrument. Additional dilutions at 100:1 and 1000:1 were analyzed if the calibration range was exceeded with the 10:1 dilution. 50 µL of a 10 mg/L internal standard consisting of indium (In) (for mass range below 150) and bismuth (Bi) (for mass range over 150) was added to 10 mL of sample aliquot prior to analysis. Analytical matrix spikes were completed for one of each of the replicate eluates from SR002.1. For each analytical matrix spike, a volume between 10 µL and 100 µL of a 10 mg/L standard solution was added to 10 mL of sample aliquot. Table 8 provides the element analyzed, method detection limit (MDL) and minimum level of quantification (ML). Analyte concentrations measured that are less than the ML and greater than the MDL are reported as estimated value using the instrument response. The values reflect the initial 10:1 dilution used for samples from laboratory leaching tests.

Table 8. Method detection limits (MDLs) and minimum level of quantification (ML) for ICP-MS analysis on liquid samples. Elements indicated in bold are discussed in this report; results for all other indicated elements will be available through the leaching assessment tool.

Symbol	Units	MDL	ML
Al	µg/L	0.96	3.06
Sb	µg/L	0.08	0.25
As	µg/L	0.64	2.04
Ba	µg/L	0.57	1.82
Be	µg/L	0.64	2.03
B	µg/L	0.65	2.06
Cd	µg/L	0.17	0.54
Ca	µg/L	1.02	3.24
Cr	µg/L	0.50	1.58
Co	µg/L	0.41	1.32
Cu	µg/L	0.70	2.23
Fe	µg/L	0.94	3.00
Pb	µg/L	0.23	0.73
Mg	µg/L	0.57	1.83
Mn	µg/L	0.34	1.09
Mo	µg/L	0.76	2.41
Ni	µg/L	0.73	2.31
K	µg/L	1.38	4.38
Re	µg/L	0.24	0.77
Se	µg/L	0.52	1.65
Si	µg/L	1.56	4.97
Na	µg/L	0.74	2.35
Sr	µg/L	0.52	1.66
Tl	µg/L	0.51	1.61
Sn	µg/L	0.70	2.22
Ti	µg/L	0.52	1.66
U	µg/L	0.30	0.95
V	µg/L	0.31	0.98
Zn	µg/L	0.92	2.94
Zr	µg/L	0.47	1.48

2.3.7.2. ICP-OES Analysis (SW-846 Method 6010)

ICP-OES analyses of aqueous samples from laboratory leaching tests were carried out at Vanderbilt University (Department of Civil and Environmental Engineering) using a Varian ICP Model 720-ES. Five-point standard curves were used for an analytical range between approximately 0.1 mg/L and 25 mg/L for trace metals. Seven-point standard curves were used for an analytical range between approximately 0.1 mg/L and 500 mg/L for minerals. Analytical blanks and analytical check standards at approximately 0.5 mg/L were run every 10 to 20 samples and required to be within 15% of the specified value. Initially, analyses were performed on undiluted samples to minimize total dissolved loading to the instrument. Samples for analysis were diluted gravimetrically to within the targeted analytical range using 1% v/v Optima grade nitric acid (Fisher Scientific) if the maximum calibration was exceeded. Yttrium at 10 mg/L was used as the internal standard. Analytical matrix spikes were completed for three test positions from one of the replicate eluates from SR002.1. For each analytical matrix spike, a volume of 500 µL of a 10 mg/L standard solution was added to 5 mL of sample aliquot. Table 9 provides the element analyzed, method detection limit (MDL), and minimum level of quantification (ML). Analyte concentrations measured that are less than the ML and greater than the MDL are reported as estimated value using the instrument response.

Table 9. Method detection limits (MDLs) and minimum level of quantification (ML) for ICP-OES analysis on liquid samples.

Symbol	Units	MDL	ML
Al	µg/L	1.00	3.18
Sb	µg/L	8.00	25.4
As	µg/L	15.0	47.7
Ba	µg/L	1.00	3.18
Be	µg/L	5.00	15.9
B	µg/L	1.00	3.18
Cd	µg/L	6.00	19.1
Ca	µg/L	3.50	11.1
Cr	µg/L	1.00	3.18
Co	µg/L	1.00	3.18
Cu	µg/L	4.1	13.0
Fe	µg/L	2.90	9.22
Pb	µg/L	7.00	22.3
Li	µg/L	6.00	19.1
Mg	µg/L	1.00	3.18
Mn	µg/L	3.60	11.4
Mo	µg/L	1.00	3.18
Ni	µg/L	2.20	7.00
K	µg/L	1.50	4.77
P	µg/L	6.2	19.7
Se	µg/L	17.0	54.1
Si	µg/L	2.80	8.90
Ag	µg/L	18.00	57.2
Na	µg/L	3.50	11.1
Sr	µg/L	1.00	3.18
S	µg/L	8.30	26.4
Tl	µg/L	5.00	15.9
Sn	µg/L	17.0	54.1
Ti	µg/L	6.40	20.3
V	µg/L	1.30	4.13
Zn	µg/L	2.50	7.95
Zr	µg/L	2.70	8.59

2.3.8. X-Ray Fluorescence (XRF)

XRF analysis was performed on each CCR to provide additional information on each CCR total elemental composition. For each CCR two pellets were prepared as follows. 3000 mg of material was weighed and mixed with 1.5 mL (100 mg dry solids) of liquid binder to give a 32 mm diameter pellet weighing 3150 mg with a material-to-diluent ratio of 0.05. For high carbon content samples 3.0 ml (100 mg dry solids) of liquid binder was used to give a 32 mm diameter pellet weighing 3300 mg with a material-to-diluent ratio of 0.1. XRF intensities were collected on each side of each pellet using Philips SuperQ data collection software and evaluated using Omega Data System’s UniQuant 4 XRF “standardless” data analysis software. The UQ/fly ash calibration was used to analyze the samples. The pellets were evaluated as oxides. Known fly ash Standard Reference Materials (SRMs) were also run to assess the accuracy of the analysis. This information is useful in supplementing CVAA and ICP results.

X-Ray Fluorescence Spectrometry was used in the Research Triangle Park laboratories of EPA-NRMRL to analyze these samples. A Philips model PW 2404 wavelength dispersive instrument, equipped with a PW 2540 VRC sample changer, was used for these analyses. The manufacturer’s software suite, “SuperQ”, was used to operate the instrument, collect the data, and perform quantification.

The instrument was calibrated at the time of installation of the software plus a new X-ray tube using a manufacturer-supplied set of calibration standards. On a monthly basis, manufacturer-supplied drift correction standards were used to create an updated drift correction factor for each potential analytical line. On a monthly basis, a dedicated suite of QC samples were analyzed before and after the drift correction procedure. This data was used to update and maintain the instrument’s QC charts.

The software suite’s “Measure and Analyze” program was used to collect and manage the sample data. Quantification was performed post-data collection using the program “IQ+”. IQ+ is a “first principles” quantification program that includes complex calculations to account for a wide variety of sample-specific parameters. For this reason, sample-specific calibrations were not necessary. This program calculates both peak heights and baseline values. The difference is then used, after adjustment by drift correction factors, for elemental quantification versus the calibration data. Inter-element effects are possible and the software includes a library of such parameters. Data from secondary lines may be used for quantification where inter-element effects are significant or the primary peak is overloading the data acquisition system. Where the difference between the calculated peak height and baseline is of low quality, the program will not identify a peak and will not report results. IQ^+ permits the inclusion of data from other sources by manual entry. Carbon was an example of this for these samples. Entry of other source data for elements indeterminable by XRF improves the mass balance.

Table 10 presents detection limit data in two forms. The two forms are not mutually exclusive. The “reporting limit” is built into the software and reflects the manufacturer’s willingness to report low-level data. Data listed in the “detection limit” column were based upon the short-term reproducibility of replicate analyses (two standard deviations, 2σ) and were sample matrix specific. These calculations are likely to report higher detection limits for elements present at high concentrations than what would be reported if the same element was present at trace levels. In this data set, calcium is a likely example of this behavior.

Table 10. XRF detection limits.

Analyte	**Reporting Limit** mg/kg	**Detection Limit, wt %** 2σ (wt. %)
Al	20	0.016
As	20	0.038
Ba	20	0.0084
Br	20	0.02
Ca	20	0.1
Cd	20	0.064
Ce	20	0.022
Cl	20	0.0046
Co	20	0.0024
Cr	20	0.0028
Cu	20	0.0014
F	20	0.082
Fe	20	0.034
Ga	20	0.0016
Ge	20	0.0014
K	20	0.0048
La	20	0.0054
Mg	20	0.01
Mn	20	0.0032
Mo	20	0.0026
Na	20	0.0076
Nb	20	0.0018
Ni	20	0.0048
Pb	20	0.0034
Px	20	0.004
Rb	20	0.0016
Sc	20	0.0016
Se	20	0.0018
Si	20	0.092
Sr	20	0.0016
Sx	20	0.05
Ti	20	0.003
V	20	0.0038
W	20	0.0036
Y	20	0.0018
Zn	20	0.0014
Zr	20	0.0024

2.3.9. XAFS

XANES and EXAFS spectra were collected using the MR-CAT (Sector 10 ID) beamline at the Advanced Photon Source (APS) at Argonne National Laboratory (ANL, Argonne, IL) and beamline X18B at the National SynchrotronLight Source (NSLS) at Brookhaven National Laboratory (BNL, Upton, NY) and analyzed according to the methods previously described (Hutson et al., 2007).

2.3.10. Determination of Hexavalent Chromium (Cr^{6+}) and Total Chromium Species in CCR Eluates

Fly ash samples were leached at three different pH values in duplicate using the SR002.1.1 leaching procedure for the determination of hexavalent and total chromium concentrations. The pH target values for the leachates were defined as 7-7.5, 10.5-11, and the natural CCR pH. The eluates were split into three samples for analysis by Eastern Research Group (ERG) and Vanderbilt University. ERG received one unpreserved and one nitric acid preserved sample. Vanderbilt University received one nitric acid preserved sample. Samples were preserved by adding 97 mL of leachate with 3 mL concentrated nitric acid.

Hexavalent chromium concentrations of the un-preserved CCR leachate eluates were determined using ion-chromatography. This procedure was modified from the EPA Urban Air Toxics Monitoring Programs (UATMP) method developed by ERG for the determination of Cr^{6+} in air by analyzing the eluates from sodium-bicarbonate impregnated cellulose filters (EPA, 2007a). The ion chromatography system was comprised of a guard column, an analytical column, a post-column deriviatization module, and a UV/VIS detector. In the analysis procedure, Cr^{6+} exists as chromate due to the near neutral pH of the eluent. After separation through the column, the Cr^{6+} forms a complex with 1,5-diphenylcarbohydrazide (DPC) and was detected at 530 nm (EPA, 2006c). This method had a reporting limit (RL) of 0.03 ng/mL.

The total chromium species for the nitric acid preserved samples were analyzed by ERG and Vanderbilt University using inductively-couples plasma / mass spectroscopy (ICP/MS) found in SW-846 Method 6020.

2.3.11. MDL and ML for Analytical Results

The MDL is defined by 40 CFR Part 136, Appendix B, July 1, 1995, Revision 1.11 as "the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte."

The MDL was determined statistically from data generated by the analysis of seven or more aliquots of a spiked reagent matrix[33] and verified by the analysis of calibration standards near the calculated MDL according to (EPA, 2004). The MDL then was determined by multiplying the

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[33] Establishing spikes in an actual leaching extract matrix is not possible because the sample being extracted dictates the matrix composition by virtue of the constituents that partition into the resulting aqueous extract, which varies by test position and material being tested. However, the extract aliquots are diluted at least 10:1 with 1% nitric acid (prepared from Optima grade nitric acid, Fisher Scientific), and the COPCs are dilute in the resulting analytical sample. Therefore, the 1% nitric acid solution was used as the matrix for MDL and ML determinations.

standard deviation of the replicate measurements by the appropriate Students t value for a 99% confidence level (two tailed) and n-1 (six) degrees of freedom and also multiplying by the minimum dilution factor required for matrix preservation and analysis.

The ML is defined by 40 CFR Part 136, 1994 as “the lowest level at which the entire analytical system must give a recognizable signal and acceptable calibration point for the analyte.” According to (EPA, 2004), the ML is intended to be the nearest integer value (i.e., 1, 2 or $5x10^n$, where n is an integer) to 10 times the standard deviation observed for determination of the MDL. This value is also multiplied by the minimum dilution factor required for preservation and analysis of the sample matrix to obtain the ML reported here.

The above methodology for determination of MDL and ML values was used for all ICP-MS and ICP-OES measurements (Table 8 and Table 9).

Mercury, as measured by CVAA, required modification of the calculation of the MDL and ML because very consistent replication resulted in calculation of a MDL lower than the instrument detection limit. For this case, the standard deviation of seven replicate analyses of 0.025 µg/L was 0.00069. Therefore, the MDL was set equal to the instrument detection limit of 0.001 µg/L times the minimum dilution factor from sample preparation (3.59) to result in an MDL of 0.0036 µg/L. The ML was set to 10 times the instrument detection limit and rounded to the nearest integer value as above. The resulting ML was 0.01 µg/L.

2.4. QUALITY ASSURANCE ASSESSMENT

2.4.1. Homogenization of Individual CCR Samples and Aliquots for Analyses

To ensure sample homogeneity the fly ashes were mixed using a Morse single can tumbler model 1-305 as described in (Sanchez et al., 2006). Scrubber sludges that were flowable slurries were mixed using a paddle mixer. Gypsum and CCRs samples were mixed by repetitively coning and quartering while passing through a mesh screen.[34] After mixing, ten subsamples were taken from sample MAD (blended CCRs) and analyzed by XRF to evaluate the homogeneity of the resultant material; the total content variability for primary and most trace constituents was less than 20% for this set of samples [see Report 2 (Sanchez et al., 2008)].

2.4.2. Leaching Test Methods and Analytical QA/QC

One of the requirements of this project was to establish a QA/QC framework for the leaching assessment approach developed by (Kosson et al., 2002). The developed QA/QC framework incorporates the use of blanks, spiked samples, and replicates. Appendix B provides the complete Quality Assurance Project Plan, as updated for this phase of the study. For each designated leaching test condition (i.e., acid or base addition to establish end-point pH values and LS value), triplicate leaching test extractions were completed (i.e., three separate aliquots of CCR were each extracted at the designated test condition) for early samples, while duplicate extractions were

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[34] "Coning and quartering" is a term used to describe how the material is mixed. The approach is to pass the material through a screen so that a "cone" forms in the collection container. Then the cone is bisected twice into quarters (quarter sections of the cone) and each section then is passed sequentially through the screen again to form a new cone. This sequence is repeated several times to achieve desired mixing.

used after evaluation of initial results. The three types of method blanks were the deionized water case, the most concentrated nitric acid addition case, and the most concentrated potassium hydroxide addition case. Each method blank was carried through the entire protocol, including tumbling and filtration, except an aliquot of CCR was not added.

During analysis for mercury by CVAA and elemental species by ICP-MS and ICP-OES, multipoint calibration curves using at least seven standards and an initial calibration verification (ICV) using a standard obtained from a different source than the calibration standards were completed daily or after every 50 samples, whichever was more frequent. In addition, instrument blanks and continuing calibration verification (CCV) standards were analyzed after every 10 analytical samples and required to be within 10 percent of the expected value based on the standards used. Samples were rerun if they were not within 10 percent of the expected value. CCV standards and instrument blanks also were run at the end of each batch of samples.

For ICP-MS and CVAA analyses, analytical spikes (aliquot of the sample plus a known spike concentration of the element of interest) for the constituents of interest were carried out for one replicate of each test case to assess analytical recoveries over the complete range of pH and liquid matrix conditions. For ICP-OES analyses, analytical matrix spikes were completed for three test positions from one of the replicate eluates. The “spike recovery” was required to be within 80 – 120% of the expected value for an acceptable analytical result.

2.4.3. Improving QA/QC Efficiency

Throughout the study, the approach to QA/QC was regularly reviewed to seek out opportunities for increased evaluation efficiency without unacceptable degradation of precision or accuracy in results. Based on evaluation of results from the first several facilities [Report 1, (Sanchez et al., 2006)], the number of replicates for Method SR002.1 (solubility as a function of pH) and Method SR003.1 (solubility as a function of liquid/solid ratio) was reduced from three to two [Report 2, (Sanchez et al., 2008)]. Results from Report 1 (Sanchez et al., 2006) and Report 2 (Sanchez et al., 2008) show that the precision between duplicate analyses is acceptable and that the triplicate set does not significantly increase the quality of the data set. This finding follows from recognition that (i) the data sets generated by Method SR002.1 and SR003.1 must provide both consistency between replicate extractions and analyses, and internal consistency between results at different pH and LS ratio, and (ii) precision is controlled primarily by the degree of homogeneity of the CCR under evaluation and representative sub-sampling, rather than by the intrinsic variability of the leaching test methods.

Data were screened for outliers based on comparison of individual data points (i) relative to replicate extractions (i.e., parallel extractions of aliquots of the same material under the same extraction conditions), and (ii) relative to the other data points in the extraction series [i.e., parallel extractions of aliquots of the same material at different pH (SR002.1) and LS conditions (SR003.1)] because of the expected systematic response behavior. The pH was considered an outlier when the final pH of the eluate deviated from the other replicates by more than 0.5 pH units and the corresponding constituent analyses did not follow systematic behavior indicated by other eluates across multiple constituents. Individual constituent results were considered outliers when results of constituent analyses deviated from the systematic behavior indicated by results in the extraction series (as a function of pH or as a function of LS) by more than one-half to one order of magnitude. Results were screened through inspection of the appropriately plotted results.

There were more than 80,000 final data observations required to complete this study, not including additional observations required for quality control and quality assurance purposes. Leaching test results required 69,733 observations considering all leaching test eluate analytes. The 13 constituents analyzed in leaching test eluates evaluated in detail in this report required 27,849 final observations.

As part of the QA/QC review of the data, two authors independently reviewed the data. The observations were screened for outliers based on comparison of individual observations as noted above. Anomalous observations were flagged for further review by the other reviewing author before a determination of outlier status was made.

Of the final 27,849 observations, 28 eluate concentration observations were considered as outliers relative to the data set. Additionally, 20 pH observations out of a total of 2,042 pH observations were considered as outliers relative to the data set. A pH observation was considered to be an outlier when the reported pH value was clearly incorrect in the context of the test method and other results. When a pH observation was determined to be an outlier, then all eluate concentration observations associated with the particular eluate were also considered outliers because they would be evaluated as a function of pH at an incorrect pH value. This resulted in an additional 252 eluate concentrations being considered as outliers based on the pH observation. The 300 total outlier observations were excluded from the statistical, graphical, and tabular evaluations. The specific outliers are tabulated in Appendix K.

Overall, these results indicate an error rate of approximately 0.1 percent for determination of constituent concentrations in leaching test eluates and an error rate of less than 1.0 percent for pH measurements.

Data quality indicators (DQIs) were measured for all parameters continuously during the leaching experiments and during analytical tasks. Chemical (ICP, CVAA, XRF, IC, EC/OC) and physical (surface area, pore size distribution and density) characterization data were reduced and reports were generated automatically by the instrument software. The primary analyst reviewed 100% of the report data for completeness to ensure that quality control checks met established criteria. Sample analysis was repeated for any results not meeting acceptance criteria. A secondary review was performed by the Inorganic Laboratory Manager to validate the analytical report.

2.4.4. Data Management

Data quality indicator (DQI) goals for critical measurements in terms of accuracy, precision and completeness are shown in Table 11.

Table 11. Data quality indicator goals.

Measurement	Method	Accuracy	Precision	Completeness
Hg Concentration	CVAA/7470A	80 – 120 %	10%	>90%
Non-Hg Metals Concentration	ICP/6010	80 – 120 %	10%	>90%

Accuracy was determined by calculating the percent bias from a known standard. Precision was calculated as relative percent difference (RPD) between duplicate values and relative standard deviation (RSD) for parameters that have more than two replicates. Completeness is defined as the percentage of measurements that meet DQI goals of the total number measurements taken. Types of QC samples used in this project included blanks, instrument calibration samples, replicates, and matrix spikes.

Accuracy and precision for the samples analyzed for mercury concentration leachate determinations were made using replicates and matrix spike analyses. Data validation for the mercury samples was performed after the analyses and outliers for accuracy were re-analyzed to improve results. Mercury samples not meeting the accuracy goals occurred most often in samples at the alkaline end of the pH testing and with the blank samples. The greatest mercury leaching occurred in the samples with the lower pH where there was greater availability. The samples not meeting the accuracy goals for matrix spiking did not affect the quality of the data. Limited volume of leachate collected for the SR003.1 samples resulted in only one spike being performed per replicate set.

QC samples required for CVAA analysis are detailed in Method 7470A. The mercury analyzer software was programmed with the acceptance criteria for Method 7470A with respect to independent calibration verifications, continuous calibration verifications, and blank solution concentrations. All calibrations and samples analysis parameters passed the QA/ QC criteria and may be considered valid samples.

The pH meter was calibrated daily before each batch of measurements. Standards purchased from Thomas scientific (Swedesboro, NJ) were used to calibrate the probe at pH values of 4, 7, and 10. Each solution was certified to a precision of ±0.01 at 25 °C and was traceable to the National Institute of Standards Technology (NIST) standard reference material (SRM) SRM-186-I-c and 186-II-c.

2.5. INTERPRETATION AND PRESENTATION OF LABORATORY LEACHING DATA

Complete laboratory leaching test results for each facility are presented in Appendix F. For each facility, results are organized by constituent of interest in the alphabetic order of the symbol (aluminum [Al], arsenic [As], boron [B], barium [Ba], cadmium [Cd], cobalt [Co], chromium [Cr], mercury [Hg], molybdenum [Mo], lead [Pb], antimony [Sb], selenium [Se], and thallium [Tl]). For each constituent, results of Solubility and Release as a Function of pH (from test method SR002.1) and results of Solubility and Release as a Function of LS ratio (from test method SR003.1) are presented side by side. Results of pH as a function of acid or base addition (from test method SR002.1) are presented in Appendix G.

In addition, comparisons of results of Solubility and Release as a function of pH (SR002.1) are provided in Section 3.2.1. Comparisons are grouped by residue type (fly ash, gypsum, scrubber sludge, spray dryer absorber residues, and blended CCRs), followed by coal type and air pollution control configurations, and are organized by constituent of interest. For each grouping, selected results of Solubility and Release as a Function of pH (SR002.1) are also presented to illustrate characteristic leaching behaviors.

For Solubility and Release as a Function of pH (SR002.1), results are presented as eluate concentrations as a function of pH. The “own pH[35]” of the system is indicated by a circle surrounding the corresponding data point. Included with each figure are horizontal lines at the drinking water maximum concentration level (MCL) or drinking water equivalent level (DWEL)[36], or action limit (AL, for lead) and analytical limits (ML and MDL) to provide a frame of reference for the results. Also included with each figure are vertical lines indicating the 5th and 95th percentiles of pH from field observations of leachates from landfills and surface impoundments containing combustion residues (see Section 2.5.2). An annotated example of the results is provided as Figure 6. Actual results are presented in the following sections.

For Solubility and Release as a Function of LS ratio (SR003.1), results are presented as eluate concentrations as a function of LS ratio. Also indicated are the relevant ML, MDL, MCL, DWEL, or AL. An annotated example of the results is provided as Figure 7.

2.5.1. Interpretation of Mechanisms Controlling Constituent Leaching

Constituent (e.g., mercury, arsenic, and selenium) concentrations observed in laboratory leach test eluates and in field leachate samples may be the result of several mechanisms and factors. The discussion presented here focuses on constituent leaching and source term modeling approaches. Source term is defined here as the flux or amount of constituent released from the waste or secondary material (e.g., CCRs). Factors controlling constituent release and transport in and within the near field of the CCRs are often distinctly different from the factors and

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[35] The “own pH” of a material refers to the equilibrium pH when the material is placed in deionized water at a ratio of 10 g CCR per 100 mL of water.

[36] MCL, DWEL, and AL values used are as reported in (EPA, 2006a).

mechanisms which are important for subsequent vadose zone or groundwater transport outside of the near field area.

In general, constituents are present in the waste or secondary material either as adsorbed species, co-precipitated as amorphous or crystalline solid phases, or incorporated as trace components in solid phases. These three different cases can often be distinguished from one another based on the results of these leaching tests, either through direct interpretation of leaching results or in conjunction with geochemical speciation modeling. If chemical equilibrium conditions are approached (as is the approximate case for the laboratory and field sample conditions discussed in this report), then the functional behavior of the aqueous solution concentrations reflects the nature of the constituent species in the waste or secondary material, the presence of any co-constituents in the aqueous phase influencing aqueous solution speciation (e.g., effects of high ionic strength, chelating or complexing constituents), and the presence of species in the solution that may compete for adsorption sites if adsorption is the controlling solid phase mechanism. If the constituent is present in the waste or secondary material as an adsorbed species, many different adsorption/desorption characteristic patterns are possible (Duong, 1998; Ruthven, 1984).

The simplest case is when the constituent of interest is present at very low concentration in the waste or secondary material, relatively weakly adsorbed, and the presence of complexing and/or, competing species in solution is at a constant concentration. For this case, leaching test results will indicate a constant concentration as a function of pH at a fixed LS ratio, and linearly increasing concentration as LS ratio decreases at constant pH. This case is represented mathematically as a linear equilibrium partitioning function, where the critical constant of proportionality is the partitioning coefficient, commonly known as K_d. Linear partitioning and use of K_d values is a common approach for mathematically modeling contaminant transport at low contaminant concentrations in soils. Assumption of linear partitioning is a valid and useful approach when the necessary conditions (discussed above) are fulfilled[37].

A different case is when mercury is adsorbed on activated carbon. For mercury adsorbed on activated carbon or char particles in fly ash, a complex combination of adsorption mechanisms is indicated. During laboratory leaching tests, mercury concentrations in the leaching test eluates are relatively constant over the pH range and LS ratio of interest, and independent of total mercury content in the CCR. In addition, the total mercury content in the CCR is very low. These results are indicative of adsorption phenomena where, in the adsorbed state, interactions between adsorbed mercury species are stronger (thermodynamically) than the interactions between the adsorbed mercury species and carbon surface[38]. This observation has been supported by the observation of mercury dimer formation during sorption (Munro et al., 2001) and the occurrence

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[37] Often specific K_d values are a function of pH because of competition for adsorption sites by hydrogen ions. Therefore, in cases where hydrogen ions do compete for binding sites, the varying of pH would violate the condition that competing species are at constant concentration, and the leaching curve would not be linear. However, often a single K_d or range of K_d values are used in contaminant fate and transport models, without accounting for any specific relationship between pH and K_d which can result in misrepresentation of actual contaminant behavior.

[38] For this case, the first mercury molecule is adsorbed more weakly than subsequent mercury molecules because the adsorbed mercury-mercury interaction is stronger than the adsorbed mercury-carbon surface interaction [see (Sanchez et al., 2006) for further discussion].

of chemisorption as the dominant adsorption mechanism at temperatures above 75 ºC (consistent with conditions in air pollution control devices (Vidic, 2002). In other studies, this phenomenon has been observed as the formation of molecular clusters on the adsorbent surface (Duong, 1998; Rudzinski et al., 1997; Ruthven, 1984). For this case, use of a K_d approach would underestimate release because desorption is best represented as a constant aqueous concentration until depletion occurs, rather than the linearly decreasing aqueous concentration indicated by a K_d approach.

A third case is encountered when the constituent of interest is present in the waste or secondary material (e.g., CCR) as a primary or trace constituent in either an amorphous or crystalline solid phase and there may be complexing or chelating co-constituents in the aqueous phase. Observed aqueous concentrations are a non-linear function of pH and LS ratio, and reflect aqueous saturation with respect to the species of interest under the given conditions (pH, co-constituents). For these cases, an approximation of field conditions can be made empirically based on laboratory testing and observed saturation over the relevant domain (as applied in this report), or geochemical speciation modeling coupled with mass transfer modeling can be used to assess release under specific field scenarios (the subject of a future report). Use of a K_d approach would not be appropriate for these cases because constituent concentrations will remain relatively constant at a given pH until the controlling solid phase is depleted and control is shifted to a new solid phase or mechanism.

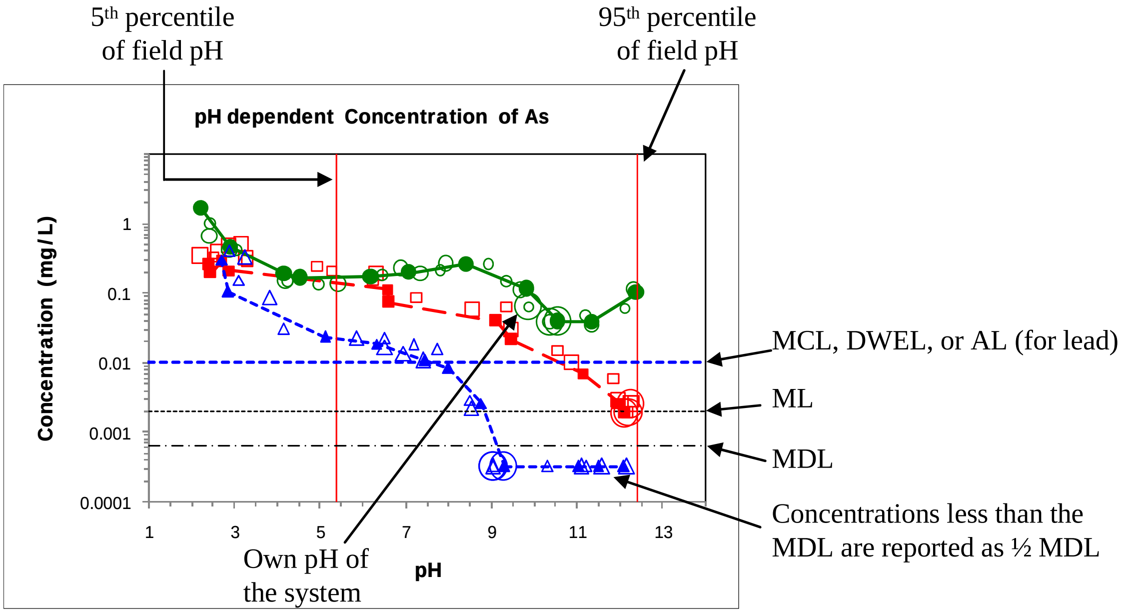


Figure 6. An example of eluate concentrations as a function of pH from SR002.1. Different colors, symbols and line types are used to represent different data sets. In this example figure, green, red, and blue indicate different CCR samples and open symbols are used to represent replicate data.

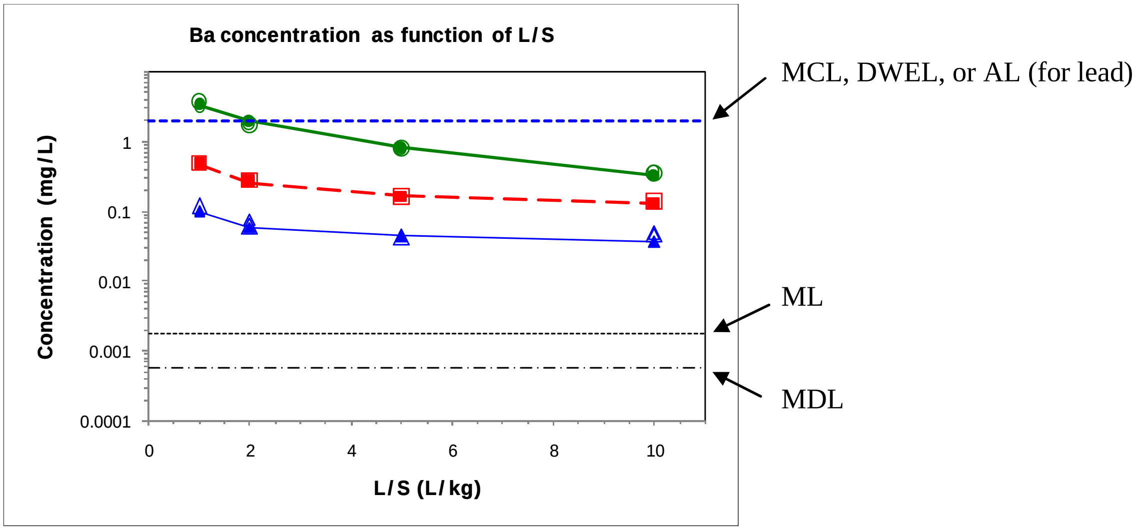


Figure 7. An example of eluate concentrations as a function of LS ratio from SR003.1.

2.5.2. Field pH Probability Distribution

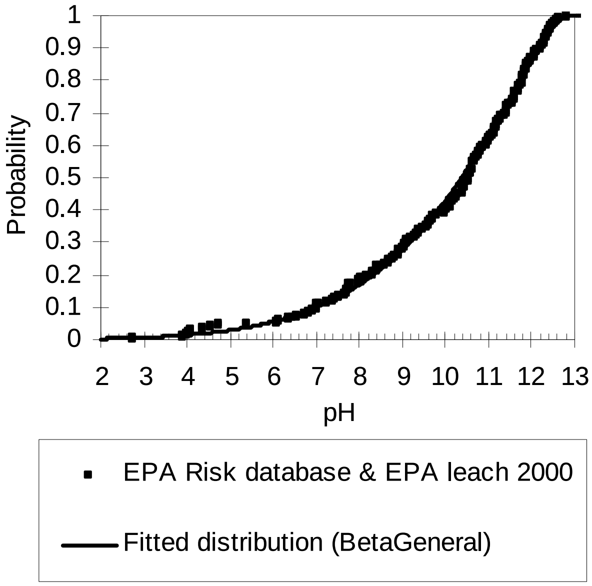
A probability distribution of field leachate pH values from coal combustion waste landfills was derived, as described below, from the set of field pH observations included in the EPA Risk Report (EPA, 2007b). The data set developed for the EPA Risk Report included (i) observations from the comprehensive database of landfill leachate characteristics developed by the EPA's Office of Solid Waste (EPA, 2000), (ii) field observations from literature, primarily from EPRI reports, (iii) additional data reported to EPA, and (vi) pH observations from laboratory leaching tests.

Only pH measurements from field samples (i.e., leachate, pore water) were selected for use in development of the resulting pH probability distribution. The resulting data set included 580 observations from 42 CCR landfill disposal facilities and was highly unbalanced, with some sites having only a few (e.g., less than five) observations and some sites having many observations (e.g., greater than 20). To prevent the unbalanced data from skewing the resulting probability distribution, the minimum, 25th, 50th, 75th percentile, and maximum values of observations for each individual facility were compiled into a single data set. For facilities with fewer than five observations, all observations for that facility were included. This data set then served as the basis for determining a balanced statistical distribution function of field leachate pH values from the disposal sites with reported values. Different distribution functions were used to fit the data and the one providing the best data fit based on the chi-square test was selected. The resulting field pH probability distribution was truncated and normalized to the pH range of the field data (Figure 8) (EPA, 2000; EPA, 2007b; EPRI, 2006).

Field pH observations were also evaluated for surface impoundments that receive CCRs from coal combustion facilities with FGD scrubbers in use. Pore water pH values measured in samples obtained from within the settled CCRs were extracted from the EPRI database. These pH observations were across the same range as the landfill field pH observations, but were insufficient to develop an independent pH probability distribution for surface impoundments.

Therefore, the same pH probability distribution was used for both landfill and surface impoundment facilities.

The resulting 5th and 95th percentiles of observed field pH values, equal to pH 5.4 and 12.4, respectively, are indicated on the figures of eluate concentrations as a function of pH (Figure 6).



pH	Field data	Fitted distribution	Simulated
Min	2.75	-7.42	2.76
5th percentile	5.40	5.84	5.85
50th percentile	10.53	10.38	10.24
90th percentile	12.20	12.18	11.94
95th percentile	12.40	12.43	12.43
Max	12.80	12.81	12.43

Distributions

BetaGeneral(9.0369, 1.5076, -7.4214, 12.814)

Figure 8. Probability distributions for field pH. Summary statistics for the field data and the probability distribution are provided to the right of the graph (EPA, 2000; EPA, 2007b; EPRI, 2006).

3. RESULTS AND DISCUSSION

The EPA Risk Report (EPA, 2007b) identified the following COPCs based on the potential for either human health or ecological impacts using a screening risk assessment: aluminum (Al), arsenic (As), antimony (Sb), barium (Ba), boron (B), cadmium (Cd), cobalt (Co), chromium (Cr), lead (Pb), mercury (Hg), molybdenum (Mo), selenium (Se), and thallium (Tl).[39] Thus, the evaluation provided here focuses on the same thirteen constituents and can be used in future risk and environmental assessments.

3.1. TOTAL ELEMENTAL CONTENT

Total elemental content of CCR samples was analyzed by acid digestion (digestion Method 3052 and ICP-MS analysis by Method 6020; see Section 2.3.7) for constituents of potential concern (Al, As, Ba, Cd, Co, Cr, Mo, Pb, Sb, Se, Tl)[40] and mercury was analyzed by Method 7470 with selected samples also analyzed by Method 7473; results of these analyses are provided in Figure 9 through Figure 21, with tabular results in Appendix D. Total elemental content for boron was not analyzed because of interferences by the sample digestion method. Total elemental content also was analyzed by XRF for major constituents and other detectable constituents (Al, Ba, Ca, Cl, F, Fe, K, Mg, Na, P, S, Si, Sr, Ti) and carbon was analyzed independently; results of these analyses are provided in Figure 22 through Figure 36, with tabular results provided in Appendices E and C. Several of the COPCs analyzed by ICP-MS were below the detection limits for XRF analysis (e.g., As, Sb, Se).

Two elements, Al and Ba, were analyzed by both acid digestion and XRF methods. Measurement accuracy and precision is better by acid digestion for low concentrations (e.g., less than 10,000 µg/g) and better by XRF for higher concentrations (e.g., greater than 10,000 µg/g).

Results suggest higher content for some trace elements in CCRs when SCR is in use, however, these observations are based on single samples from a limited number of facilities and evaluation of additional samples from the same and additional facilities is warranted. Primary observations for the constituents of concern (Figure 9 through Figure 21 and Figure 22 through Figure 36) are as follows:

Aluminum (Al) (Figure 9 and Figure 22). Al content in fly ash was 6-15 percent, in gypsum between 0.3-1 percent, and in scrubber sludges 0.7-20 percent. There is no apparent systematic effect of coal type or air pollution control system on Al content in CCRs. One likely source of variability is the Al content of the additive used for flue gas desulfurization (e.g., limestone or magnesium lime).

Arsenic (As) (Figure 10). As content in fly ash was 10-200 µg/g, with a higher content (500 µg/g) observed in one sample from a COHPAC facility with ACI (Facility C, sample GAT). As content in gypsum was 1-10 µg/g, in scrubber sludge and blended CCRs 3-70 µg/g. There was

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[39] The database used in the EPA Risk Report (EPA, 2007b) for the assessment was based on both measurements of field samples (e.g., leachate, pore water) and single point laboratory leaching tests (e.g., TCLP, SPLP).

[40] The total elemental content of boron in CCRs was not measured for samples reported here because of analytical interference (digestion Method 3052 uses boron as part of the method).

no clear effect of coal type at the high level categorization based on coal rank and region on As content in CCRs, although coal from within a region has been observed to have considerable variability with respect to trace element total content.

Barium (Ba) (Figure 11 and Figure 23). Ba content in fly ash from bituminous and lignite coals was 0.06-0.2 percent, and 0.6-1.5 percent in fly ash from sub-bituminous coals. Ba content in gypsum was 2-80 µg/g, and in scrubber sludges 80-3,000 µg/g. Likely sources of variability of Ba content in gypsum include the source of limestone used in flue gas desulfurization and the extent of carryover of fly ash into the gypsum.

Cadmium (Cd) (Figure 12). Cd content in all CCRs was less than 2 µg/g, with lower content typically in gypsum than fly ash samples. An exception was the fly ash sample from Facility U (UFA) which had Cd content of 15 µg/g.

Cobalt (Co) (Figure 13)**.** Co content in fly ash was 20-70 µg/g, and 0.8-4 µg/g in gypsum. Results for scrubber sludge suggest less Co content in samples from facilities without NOx controls (1-2 µg/g) than for facilities with NO_x controls (SCR or SNCR) in operation (3-40 µg/g, including paired comparisons).

Chromium (Cr) (Figure 14)**.** Cr content in fly ash was 70-200 µg/g, and 1-20 µg/g in gypsum with no apparent relationship to coal type. Higher Cr content in scrubber sludges was associated with facilities using SCR (Facilities B and K, samples BGD and KGD; 50-300 µg/g compared to 9-20 µg/g for other samples).

Mercury (Hg) (Figure 15 and Figure 16)**.** Hg content in all CCRs was from 0.01-20 µg/g with highest Hg content associated with fly ash samples from facilities with ACI and gypsum from a facility burning lignite coal (Facility Ca, sample CaAW).

Molybdenum (Mo) (Figure 17)**.** Mo content in fly ash and scrubber sludges was similar at 8-30 µg/g, with one exception in fly ash at 80 µg/g (Facility U, sample UFA). Mo content in gypsum was 1-10 µg/g. No apparent relationship to coal type or air pollution control system was observed.

Lead (Pb) (Figure 18)**.** Pb content in fly ash was 20-100 µg/g, 0.4-10 µg/g in gypsum and 2-30 µg/g in scrubber sludges. No apparent relationship to coal type or air pollution control system was observed.

Antimony (Sb) (Figure 19)**.** Sb content in fly ash and scrubber sludge was 3-15 µg/g and 0.15-8 µg/g in gypsum. No apparent relationship to coal type or air pollution control system was observed.

Selenium (Se) (Figure 20)**.** Se content in all CCRs was distributed over range with typical content of 2-50 µg/g with two samples with approximately 200 µg/g (Brayton Point, sample BPT; Facility C, sample GAT).

Thallium (Tl) (Figure 21)**.** Tl content was 0.8-15 in fly ash and scrubber sludges, and 0.2-2 µg/g in gypsum. No apparent relationship to coal type or air pollution control system was observed.

Major species analysis by XRF (Figure 22 to Figure 36) indicated that fly ash from facilities burning sub-bituminous coals had greater content of Ba, Ca, Mg, Na, P and Sr than fly ash from facilities burning bituminous or lignite coals. Total Ca content in fly ash can be divided into three groupings related to coal types: (i) sub-bituminous, 10-20%, (ii) high calcium bituminous and lignite, 1-6%, and (iii) low calcium bituminous, 0.3-0.7%. Fly ash samples with low total calcium had acidic own pH values (typically 4 < pH < 5) compared to samples with medium and high calcium content that had alkali own pH values (typically pH > 10). The relationship between total calcium content (by XRF) and own pH for fly ash samples is illustrated in Figure 37. Higher calcium content results in greater fly ash alkalinity, as indicated by higher pH values.

Major species analysis also indicated that gypsum contained up to 5 wt% carbon and up to 7 wt% Si, both indicative of fly ash carry over into the FGD scrubber. Based on Si content in gypsum, this suggests up to 5% of the non-carbon content is comprised of fly ash.

In interpreting these results, please note that the CCRs analyzed in this report are not considered to be a representative sample of all CCRs produced in the U.S. For many of the observations, only a few data points were available. It is hoped that through broader use of the improved leach test methods (as used in this report), that additional data from CCR characterization will become available. That will help better define trends associated with changes in air pollution control at coal-fired power plants.

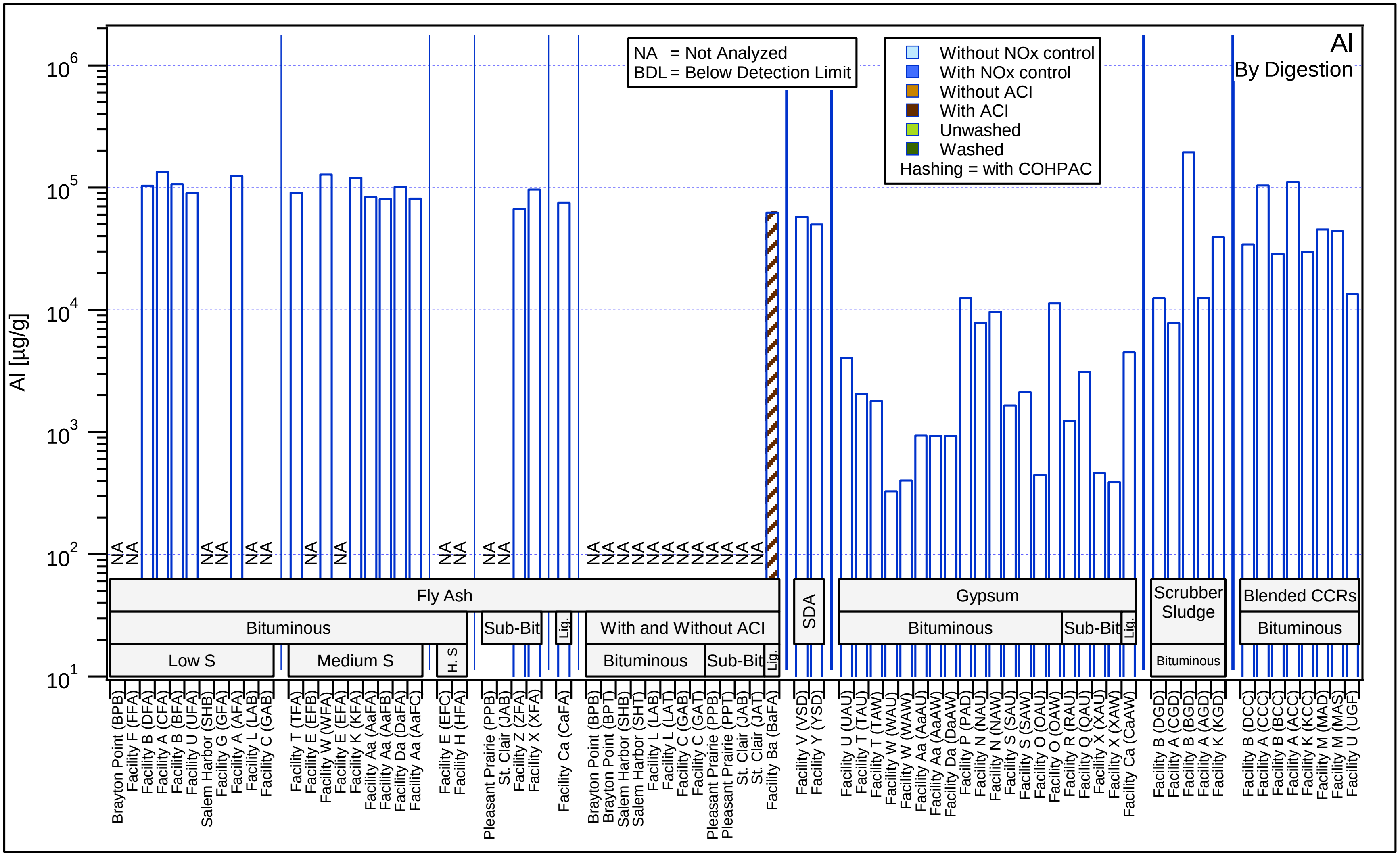

Figure 9. Aluminum. Comparison of total elemental content by digestion (Methods 3052 and 6020).

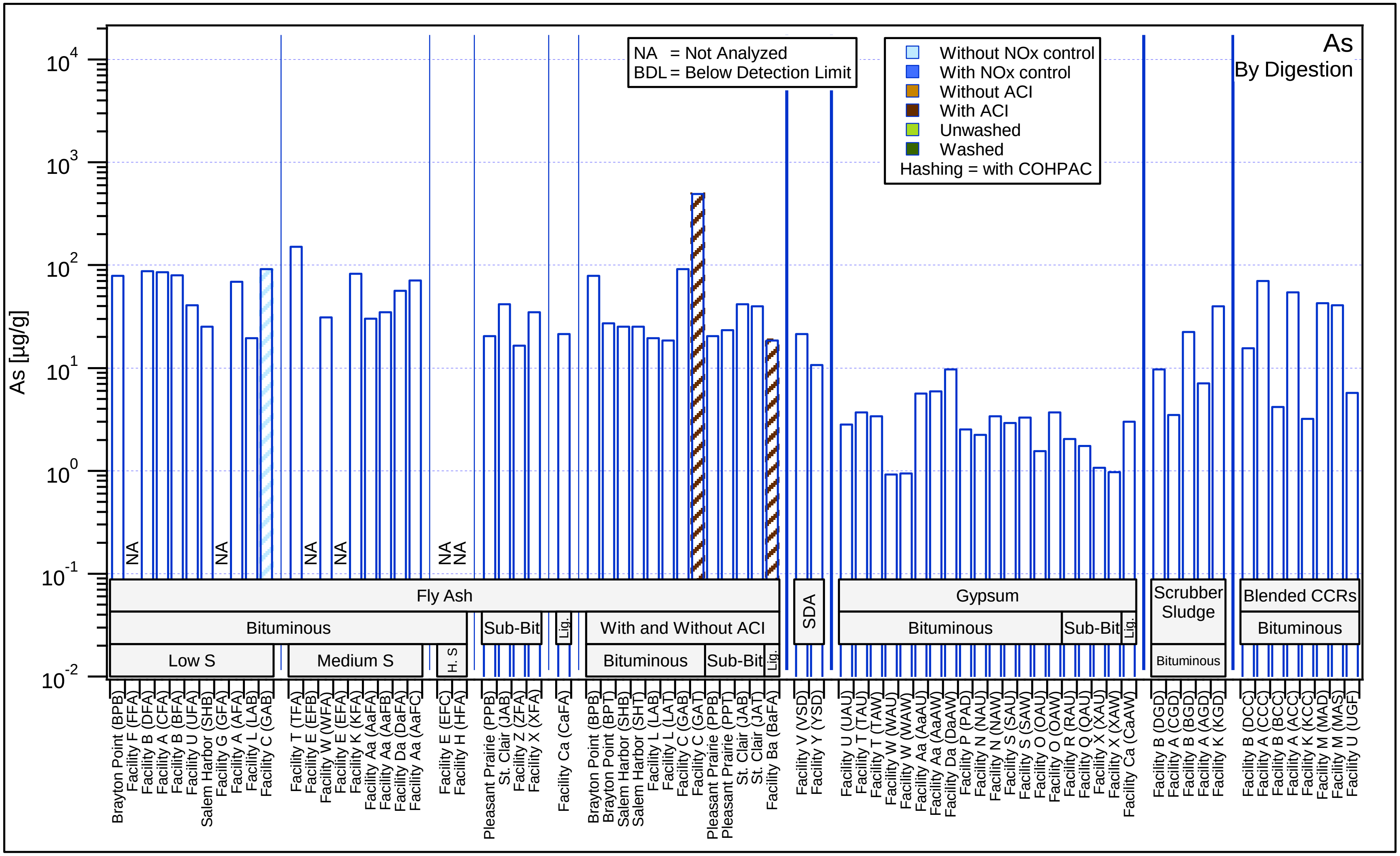

Figure 10. Arsenic. Comparison of total elemental content by digestion (Methods 3052 and 6020).

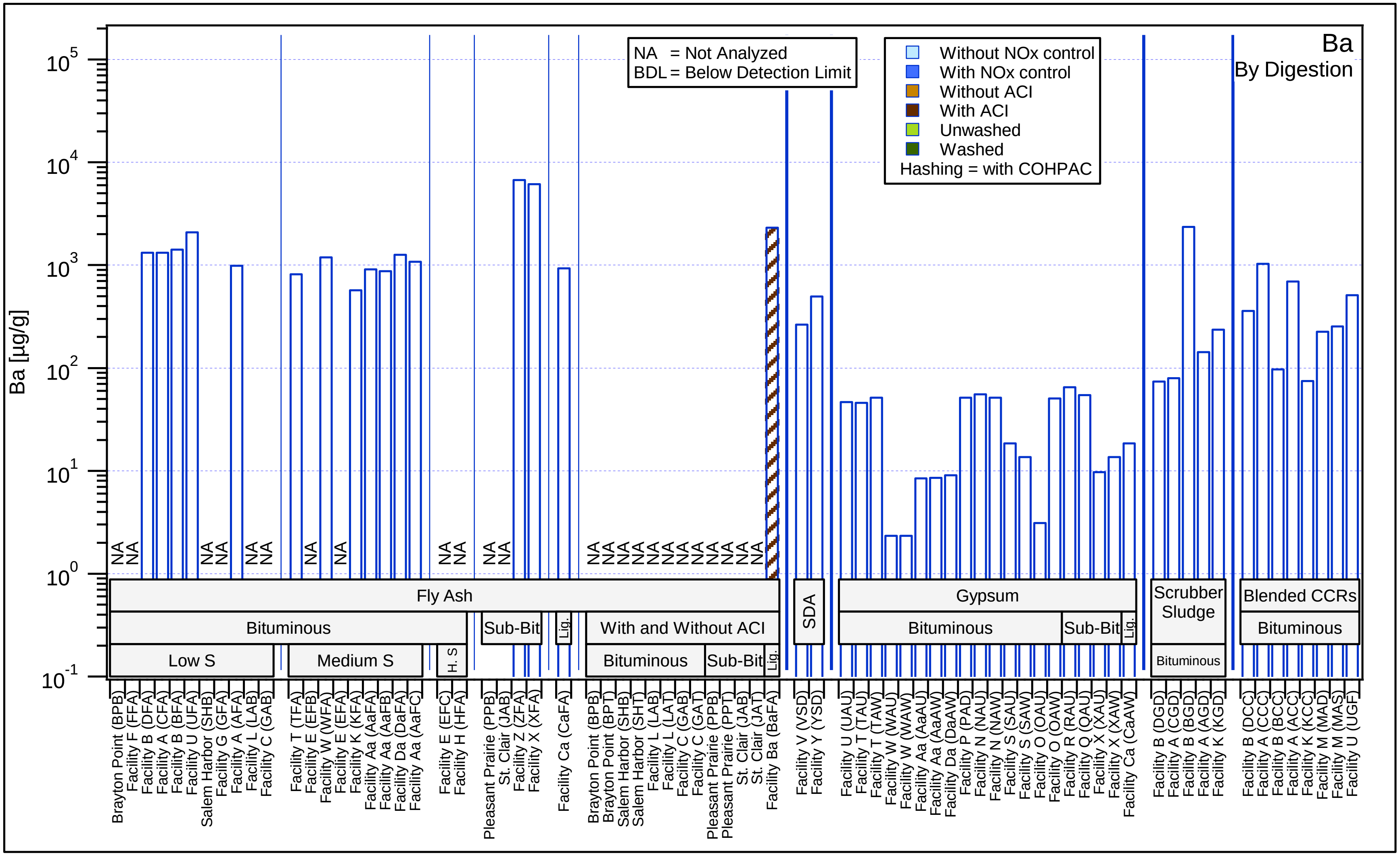

Figure 11. Barium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

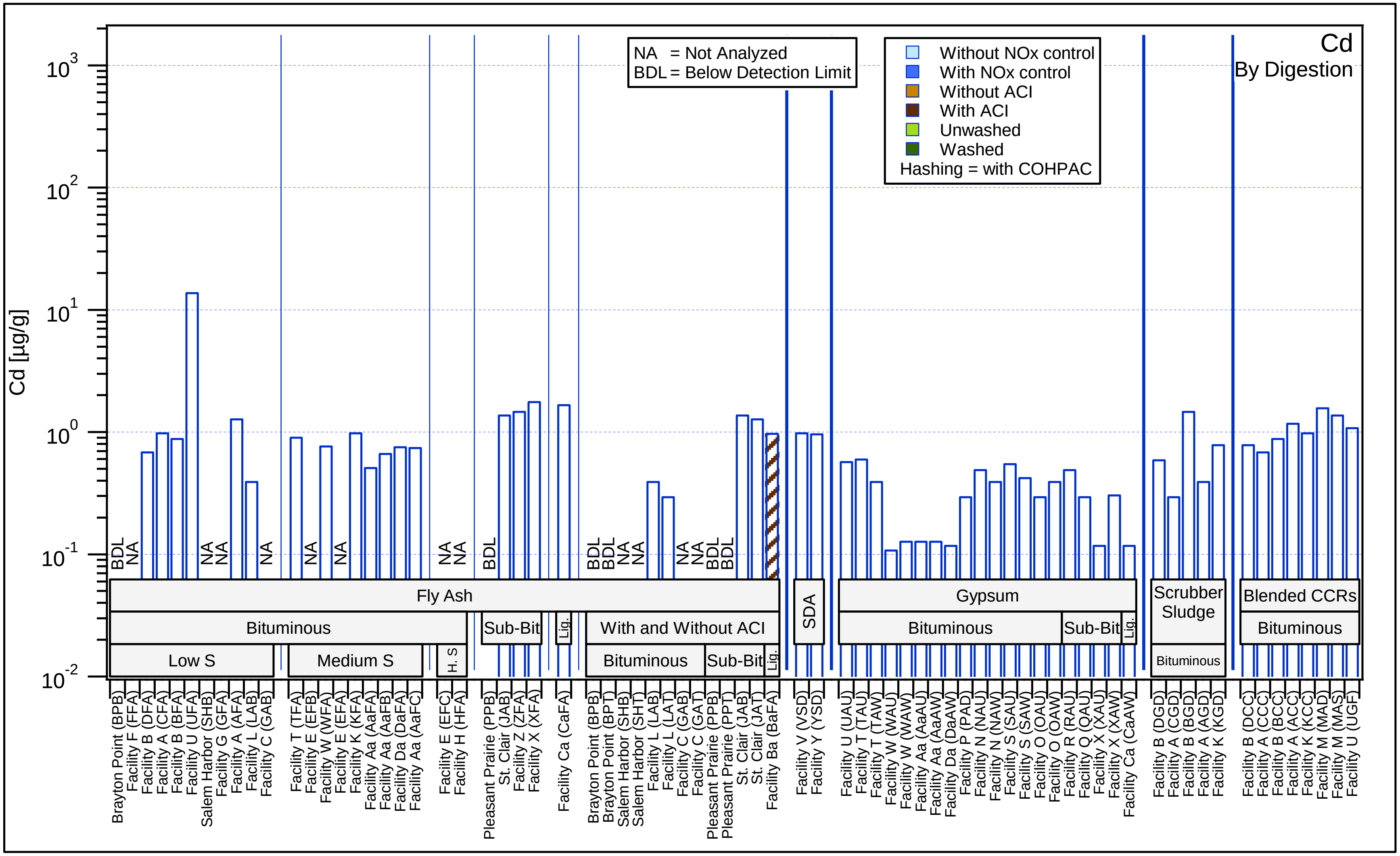

Figure 12. Cadmium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

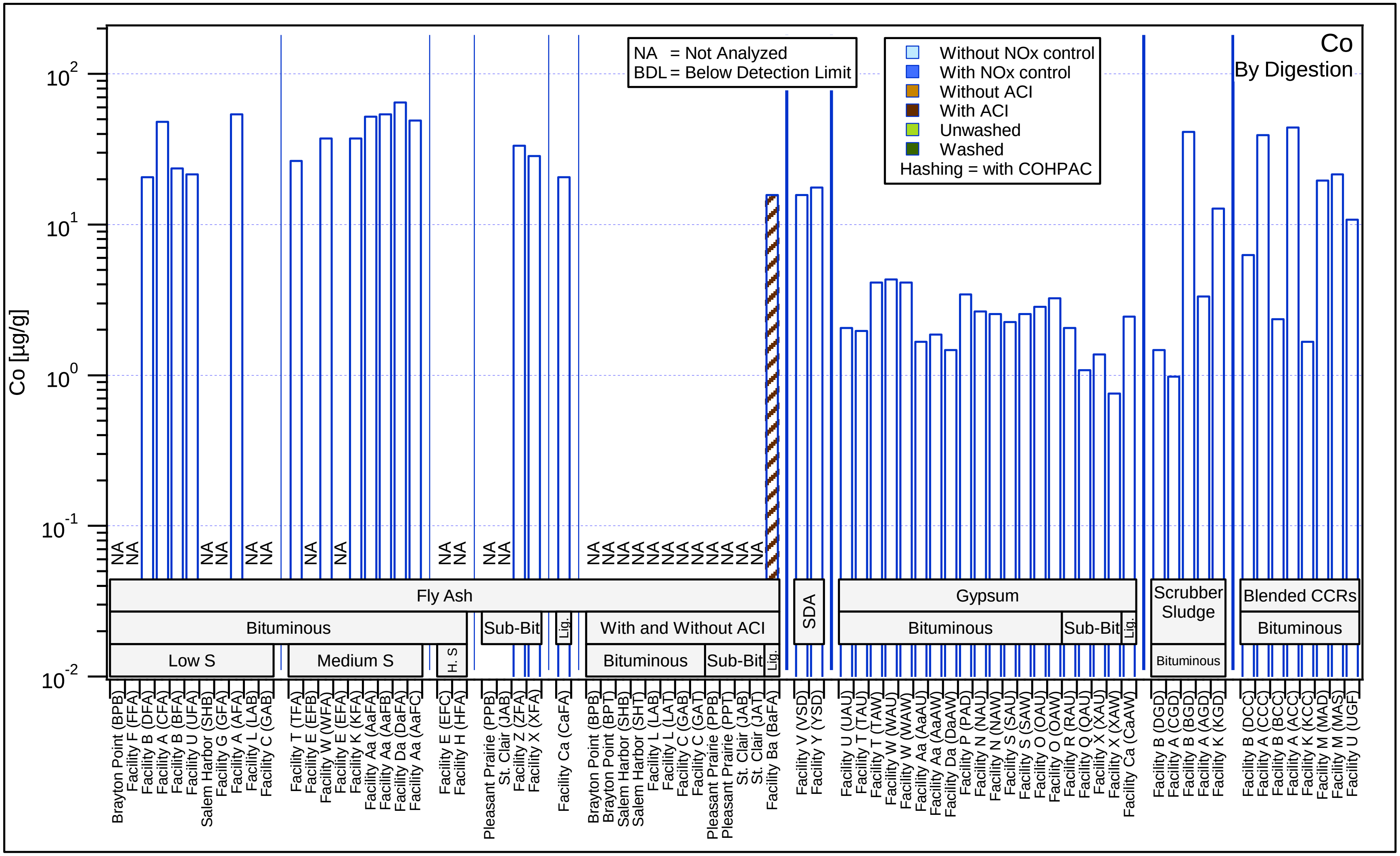

Figure 13. Cobalt. Comparison of total elemental content by digestion (Methods 3052 and 6020).

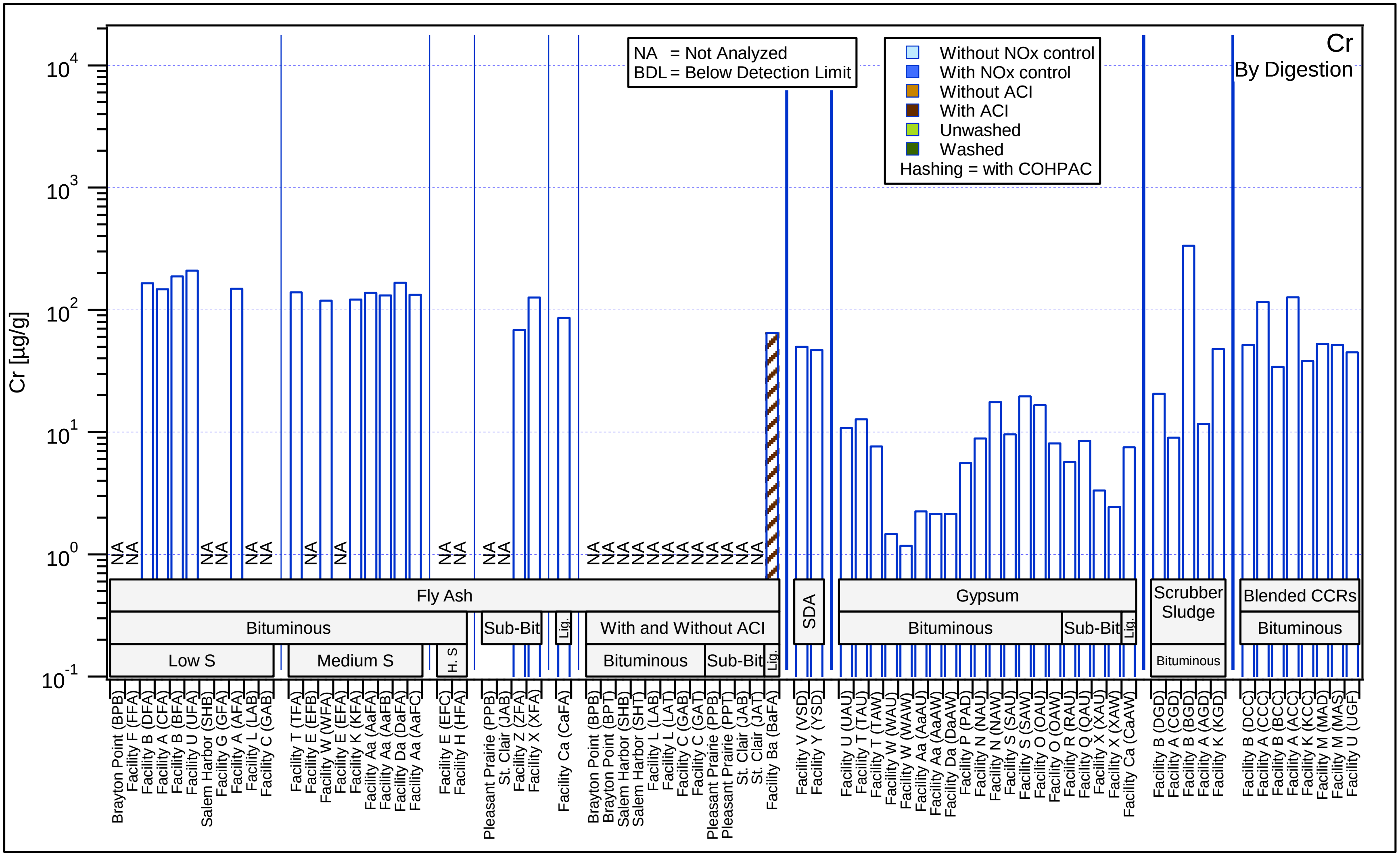

Figure 14. Chromium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

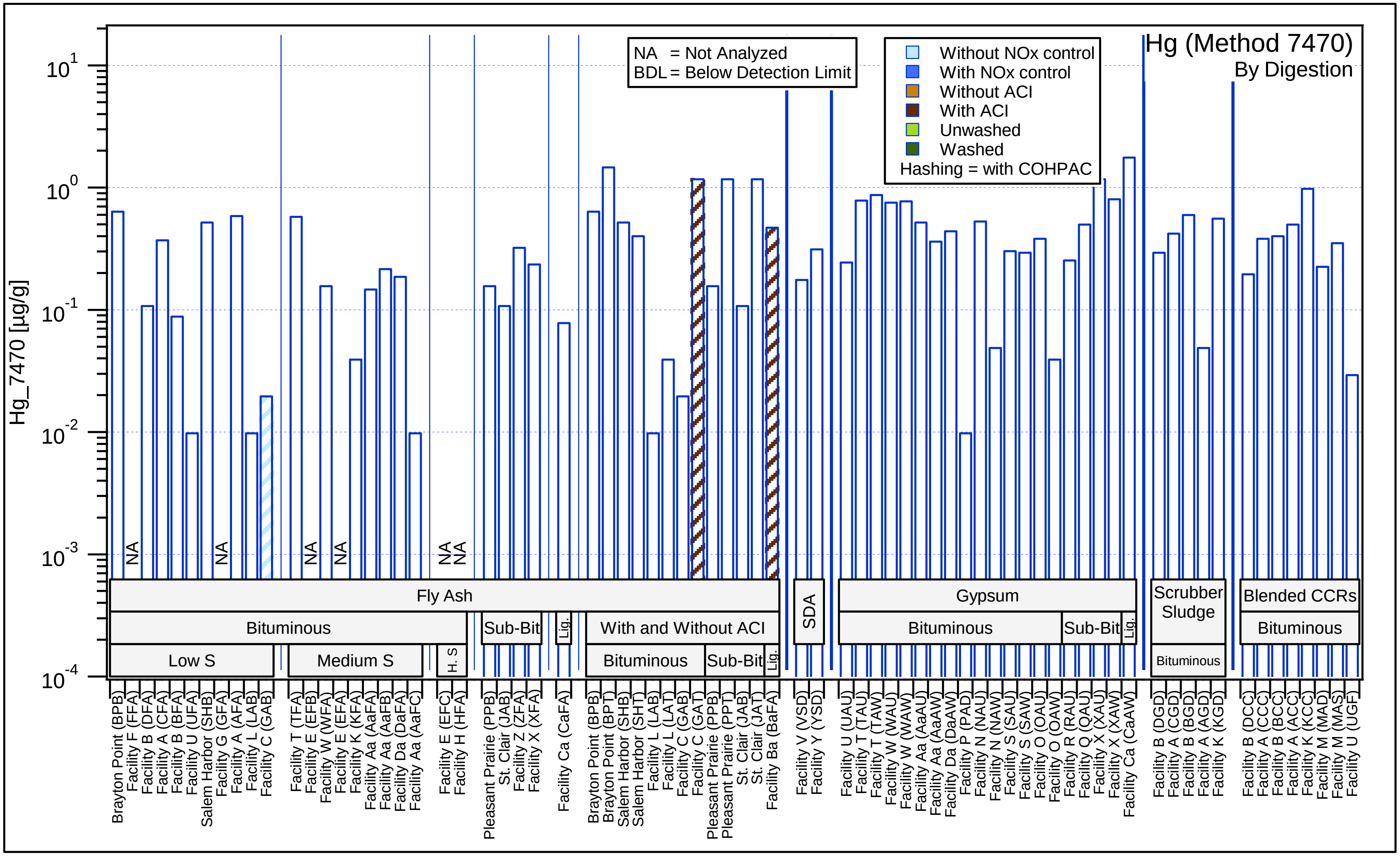

Figure 15. Mercury. Comparison of total elemental content by digestion (Method 7470).

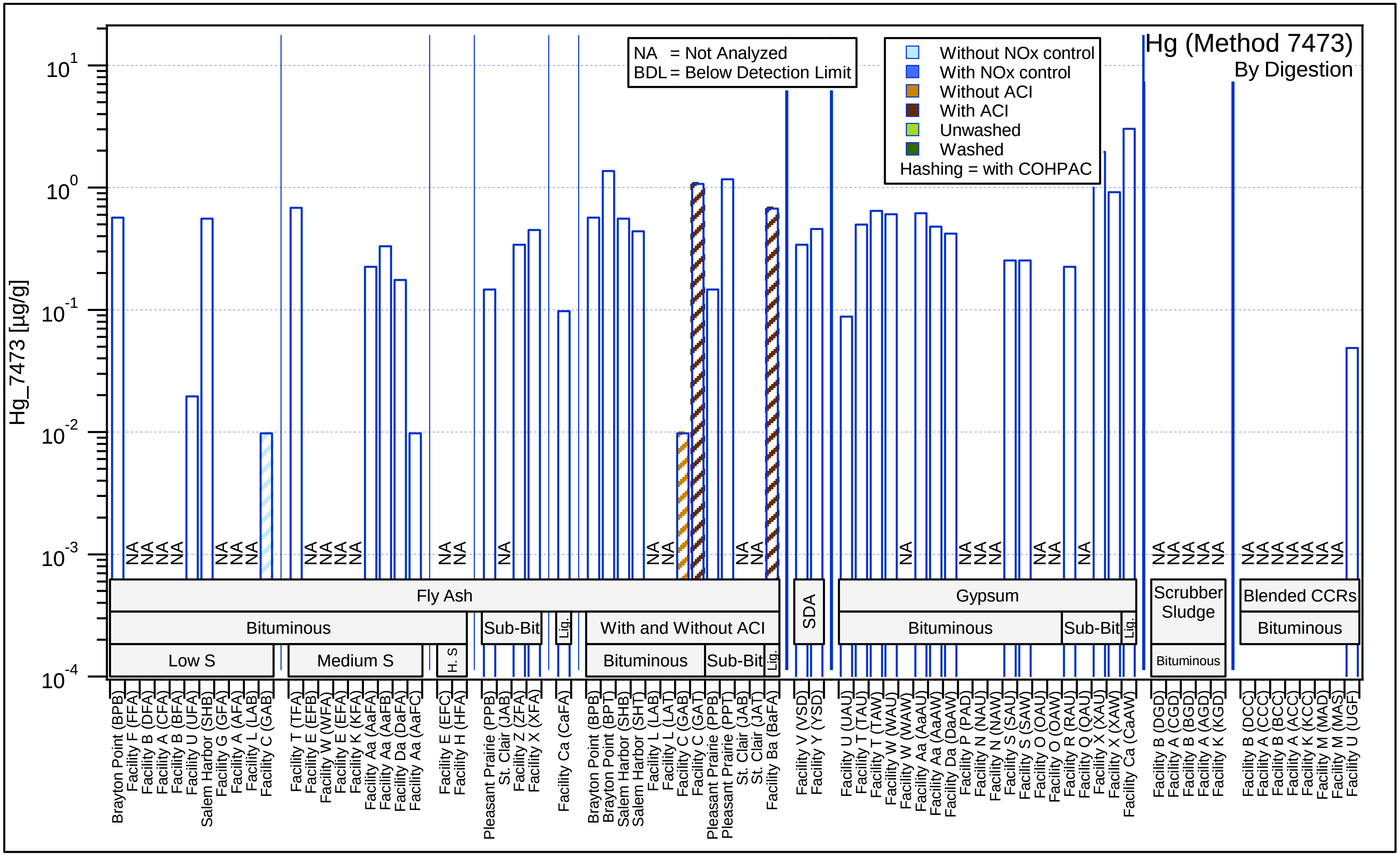

Figure 16. Mercury. Comparison of total elemental content by digestion (Method 7473).

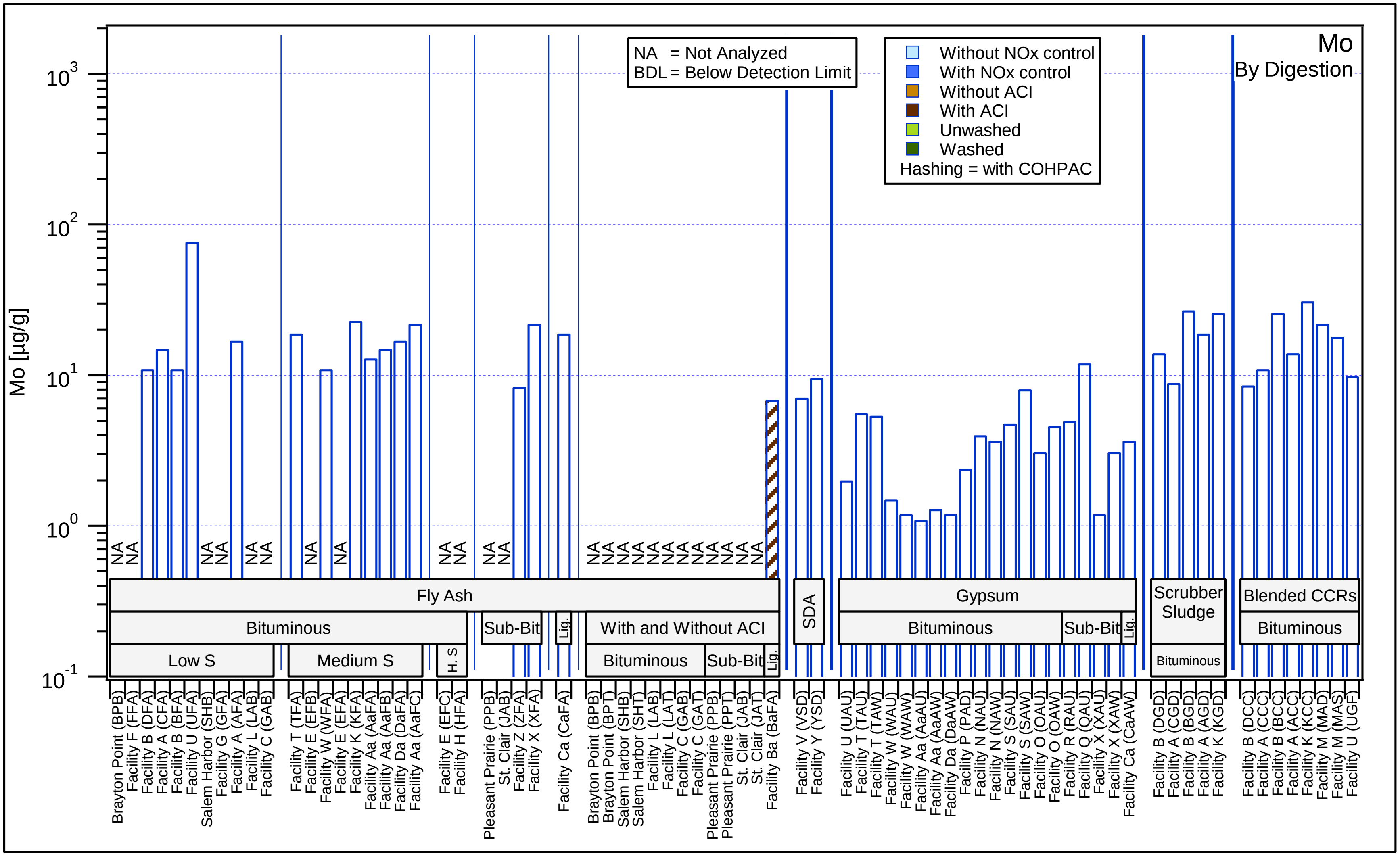

Figure 17. Molybdenum. Comparison of total elemental content by digestion (Methods 3052 and 6020).

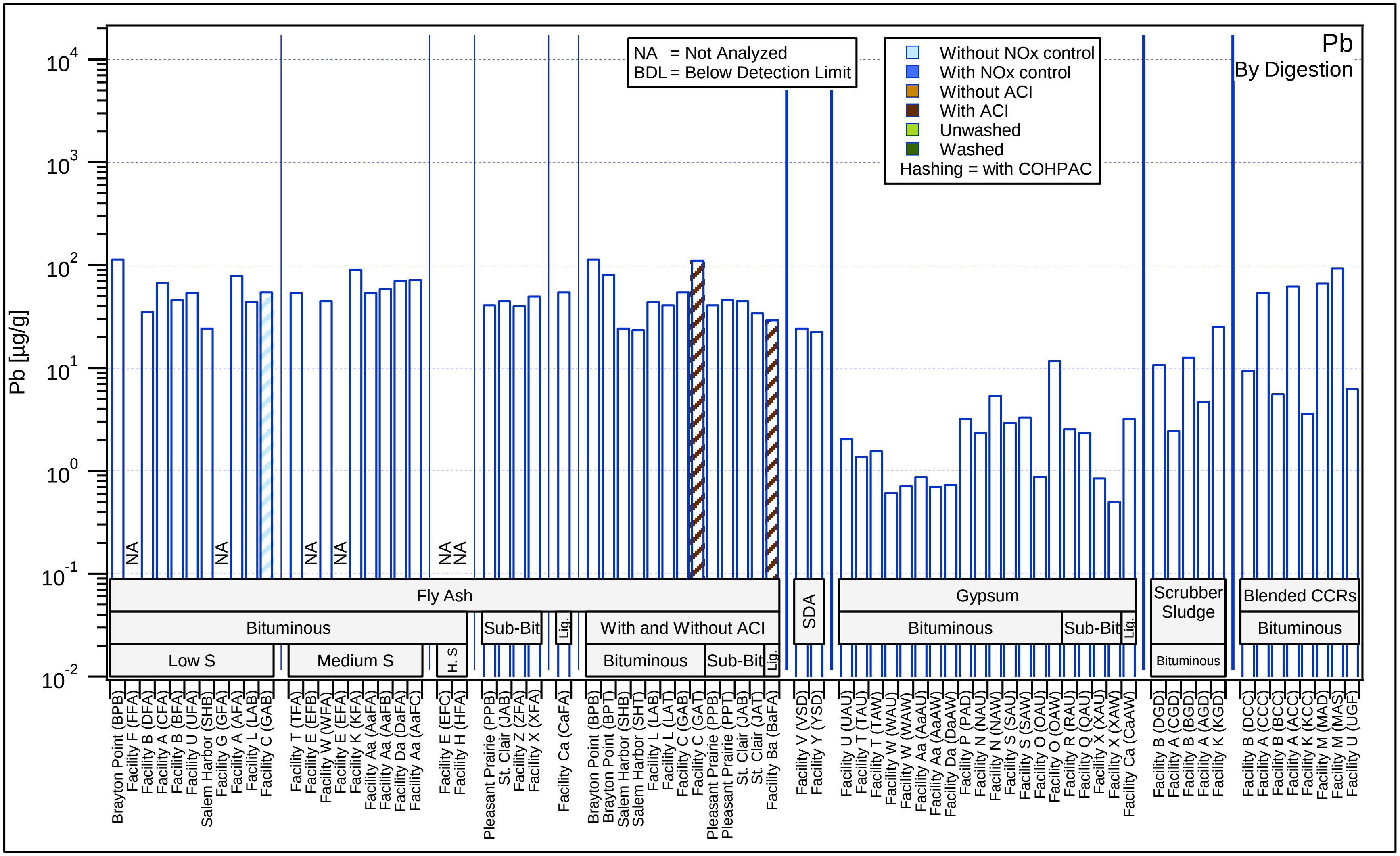

Figure 18. Lead. Comparison of total elemental content by digestion (Methods 3052 and 6020).

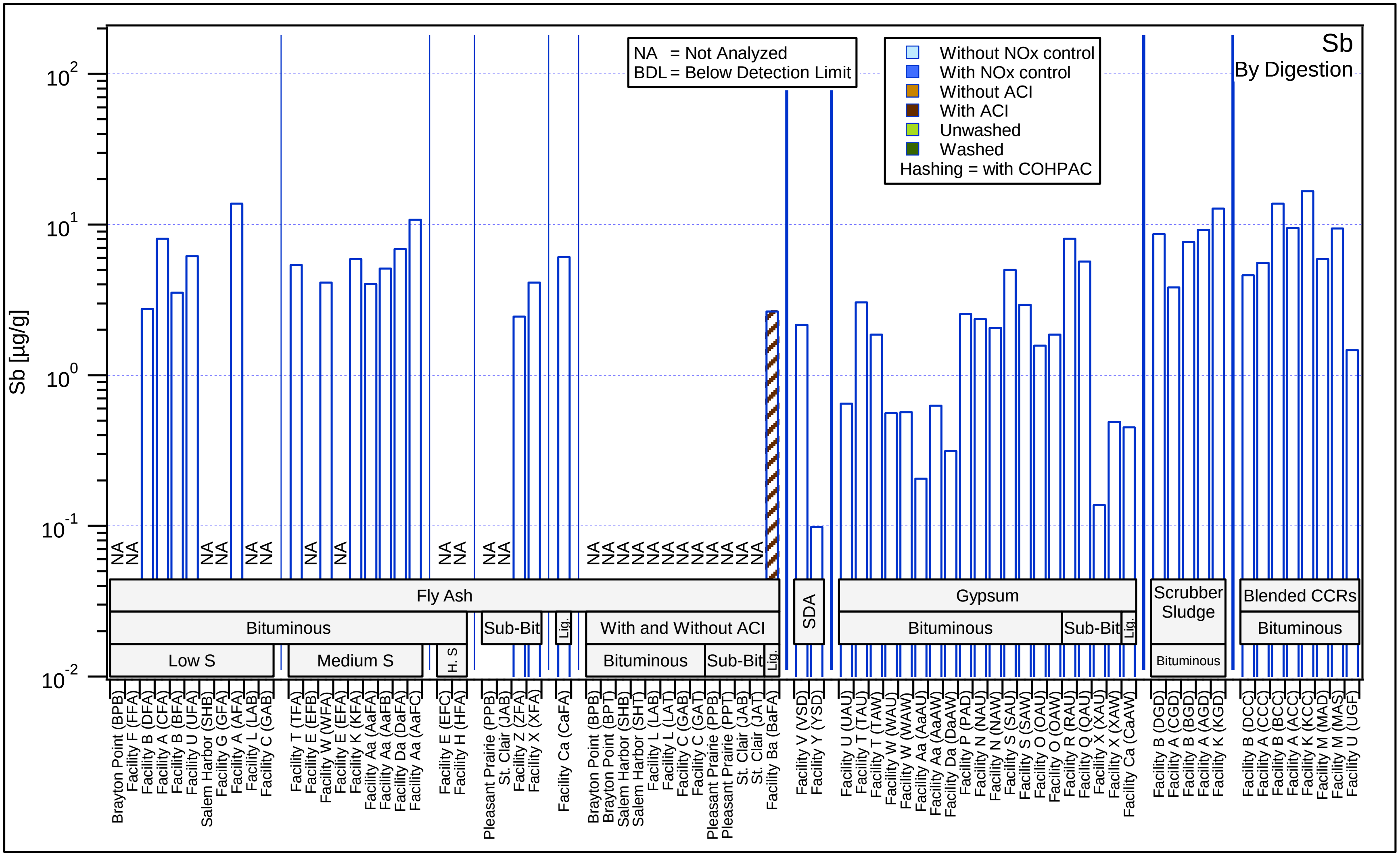

Figure 19. Antimony. Comparison of total elemental content by digestion (Methods 3052 and 6020).

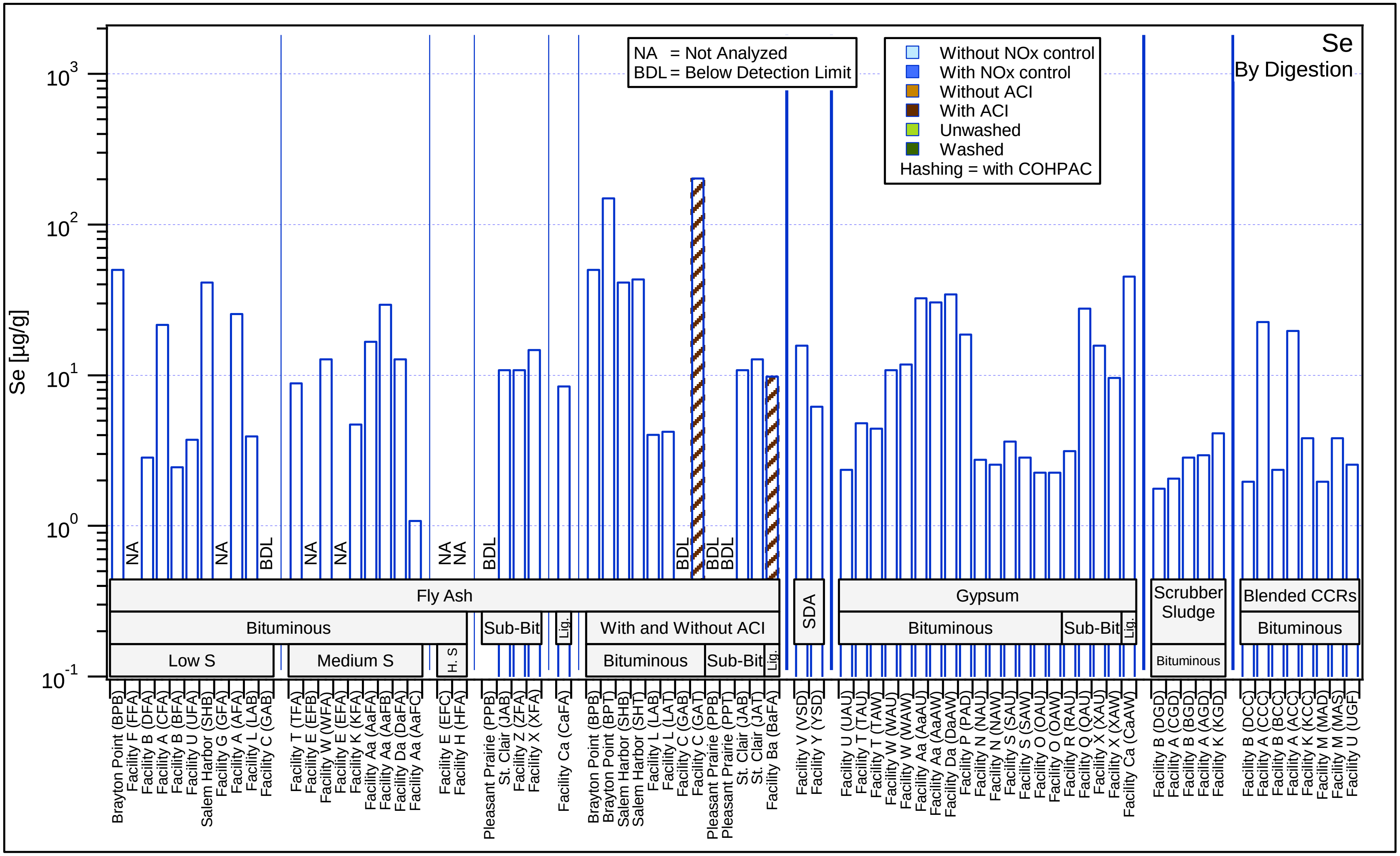

Figure 20. Selenium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

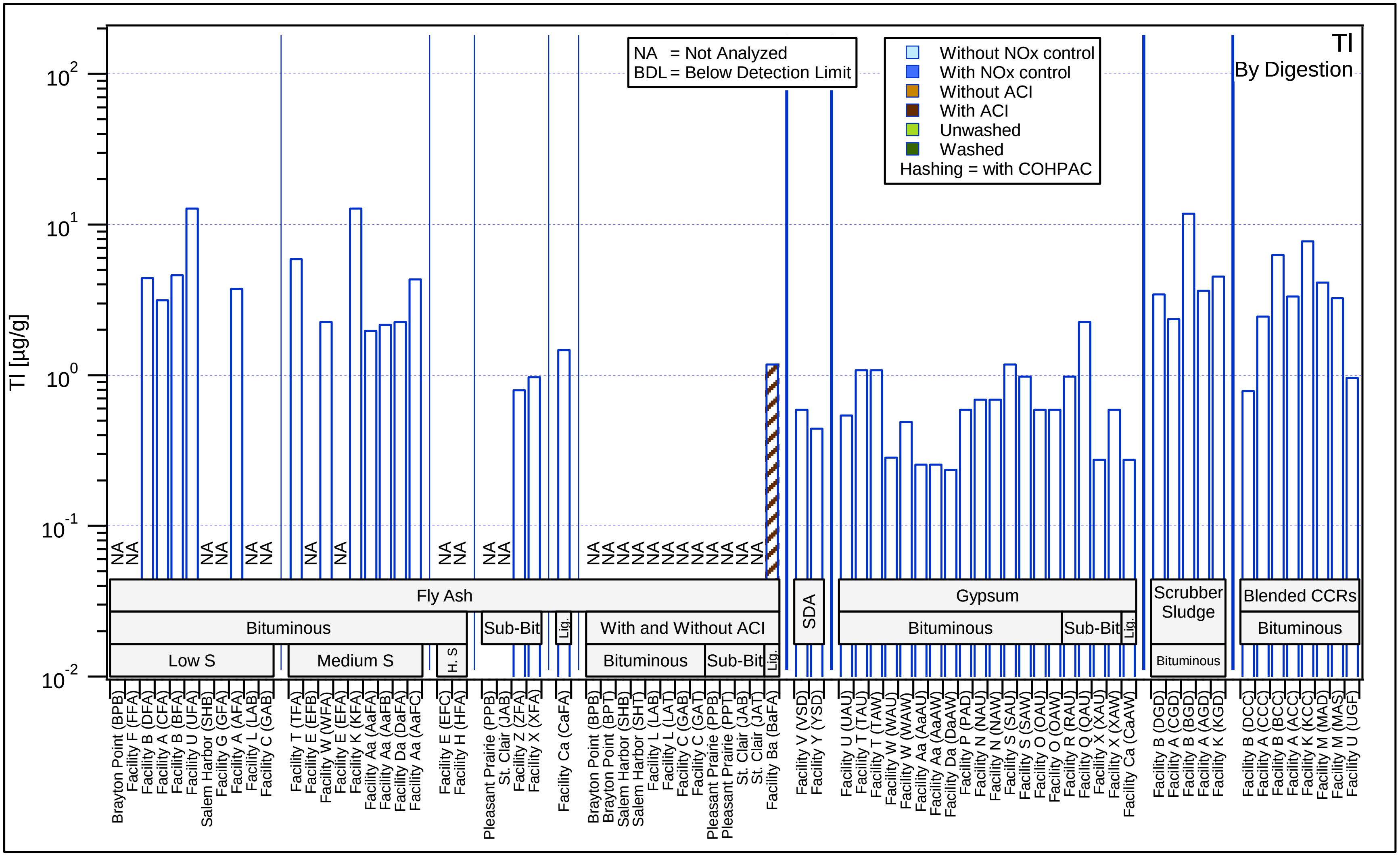

Figure 21. Thallium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

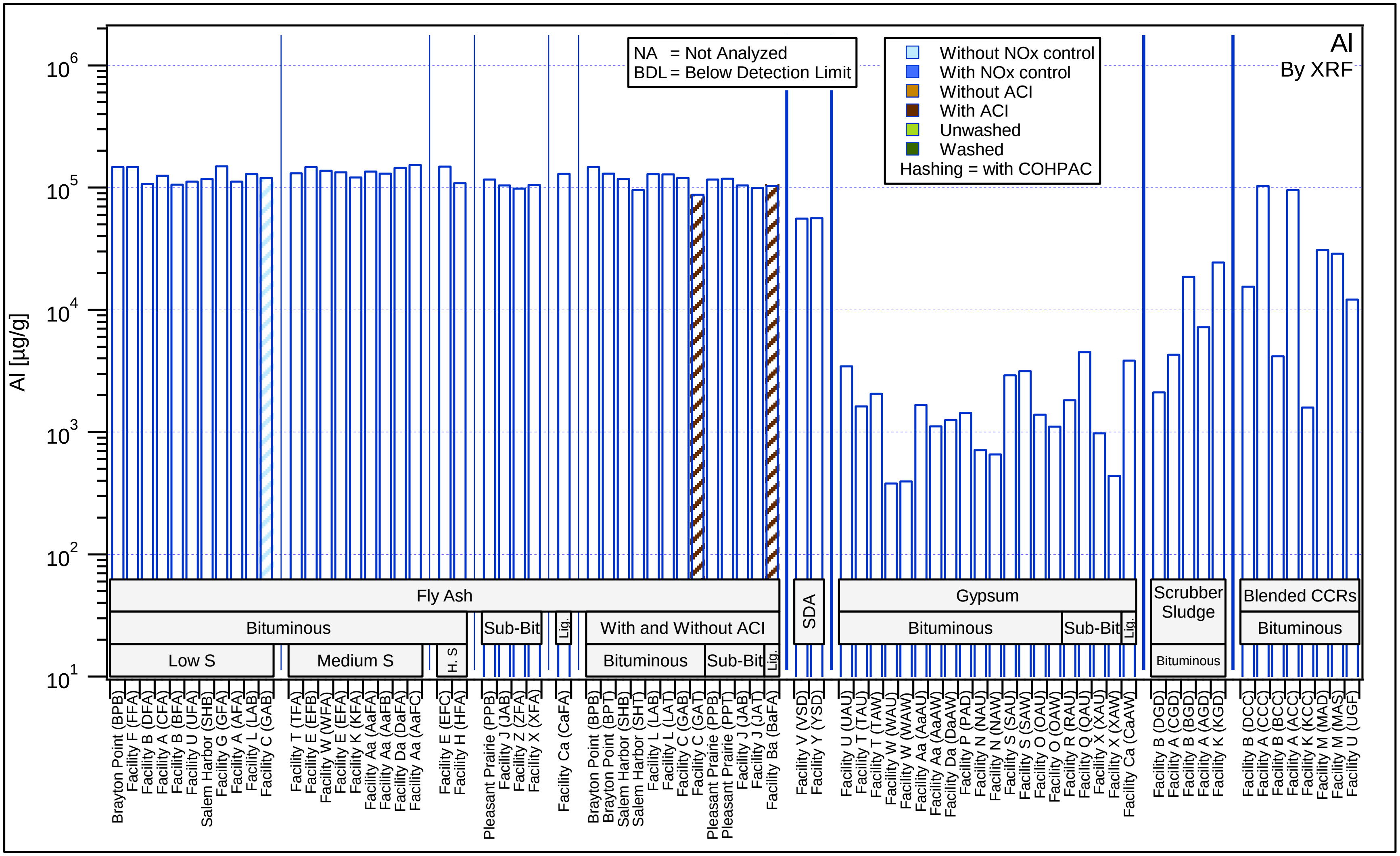

Figure 22. Aluminum. Comparison of total elemental content by XRF.

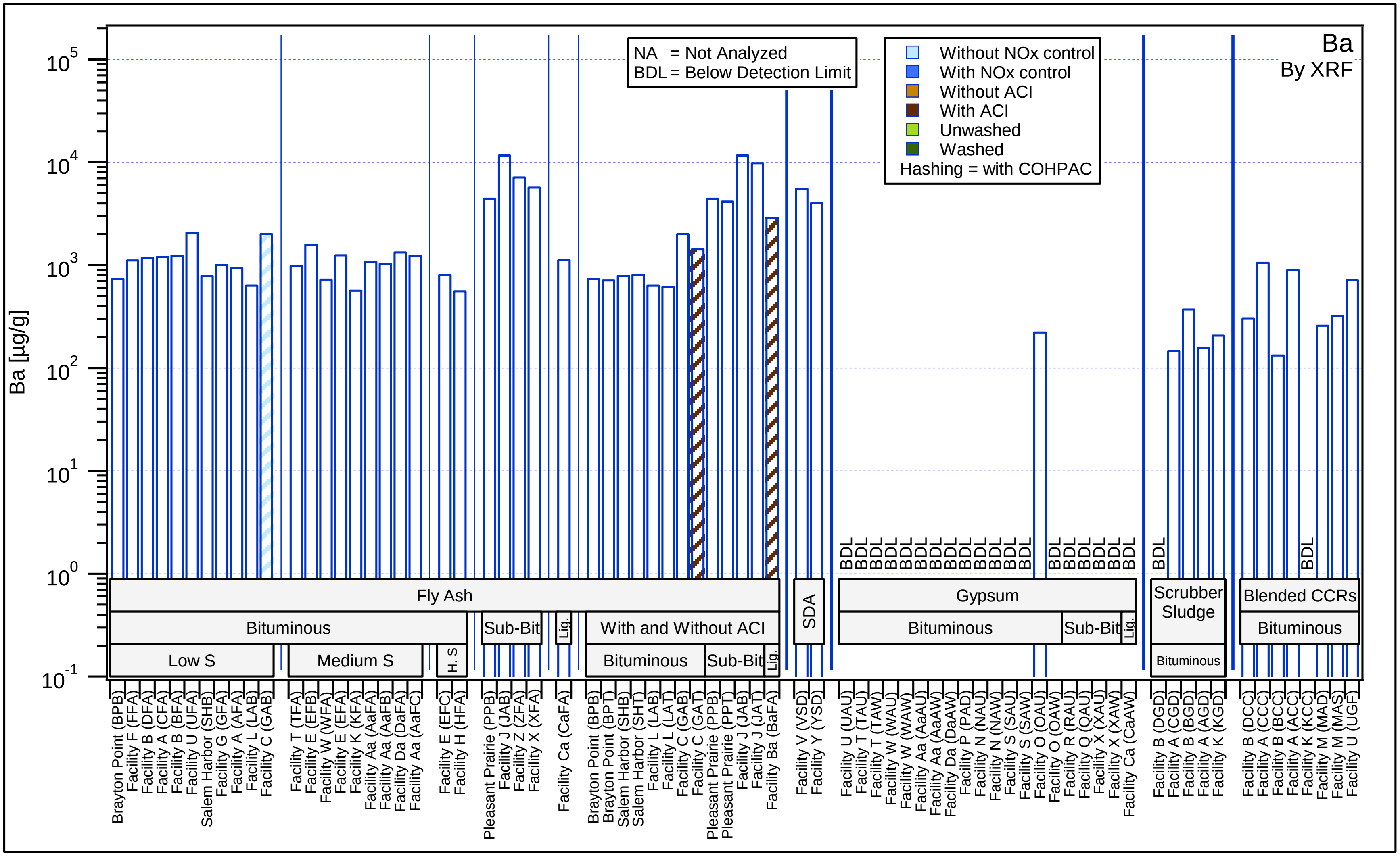

Figure 23. Barium. Comparison of total elemental content by XRF.

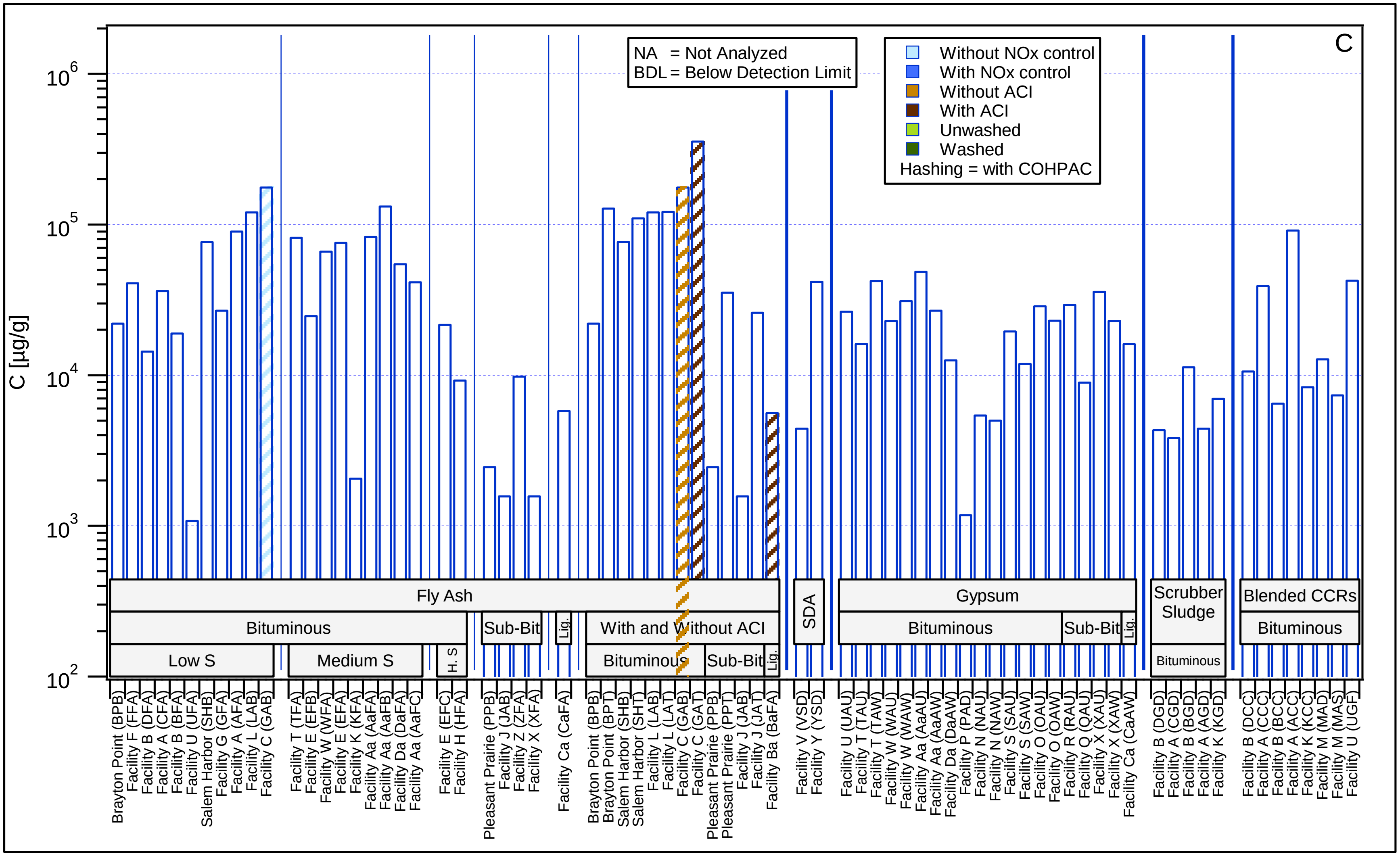

Figure 24. Carbon. Comparison of total elemental content.

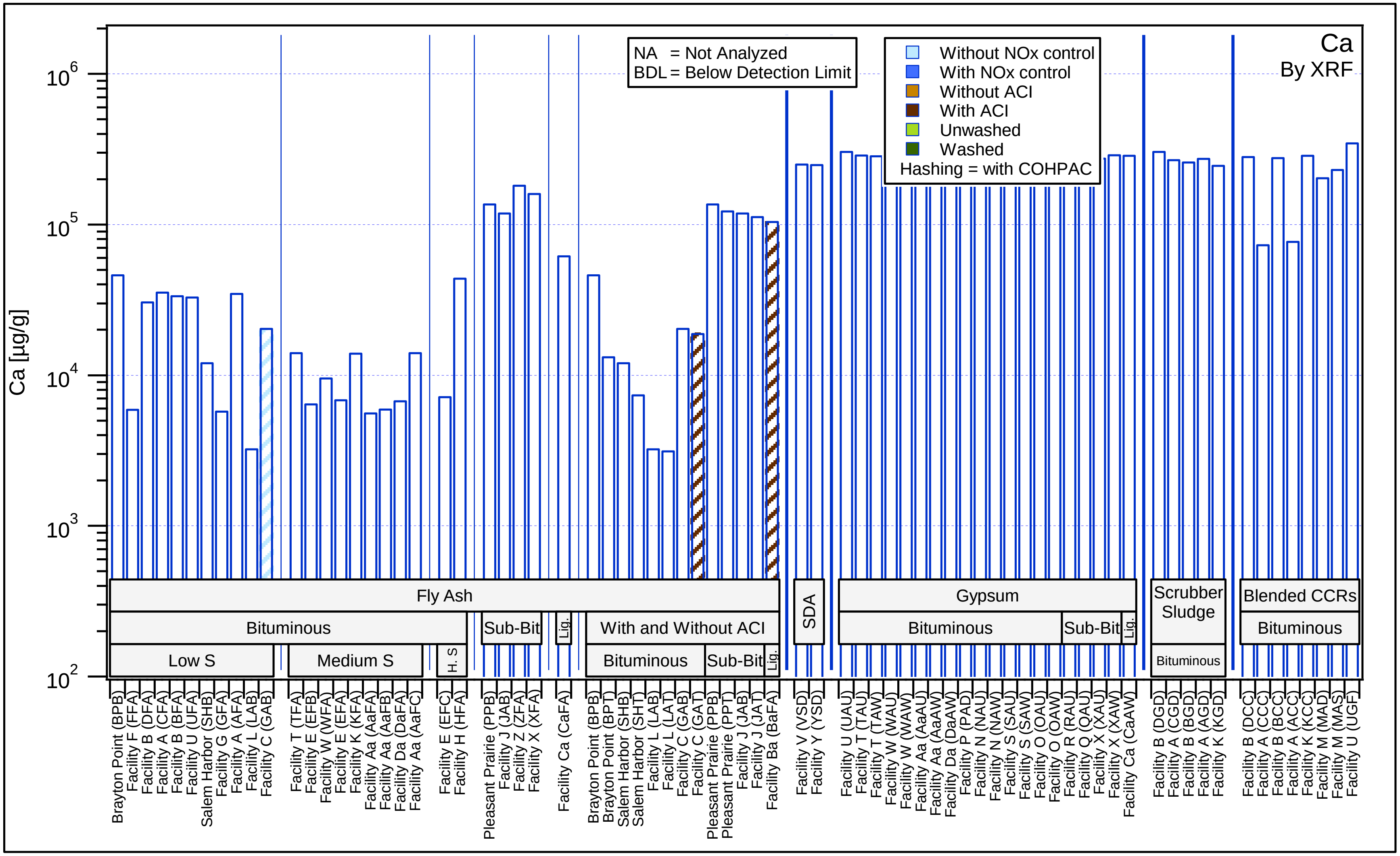

Figure 25. Calcium. Comparison of total elemental content by XRF.

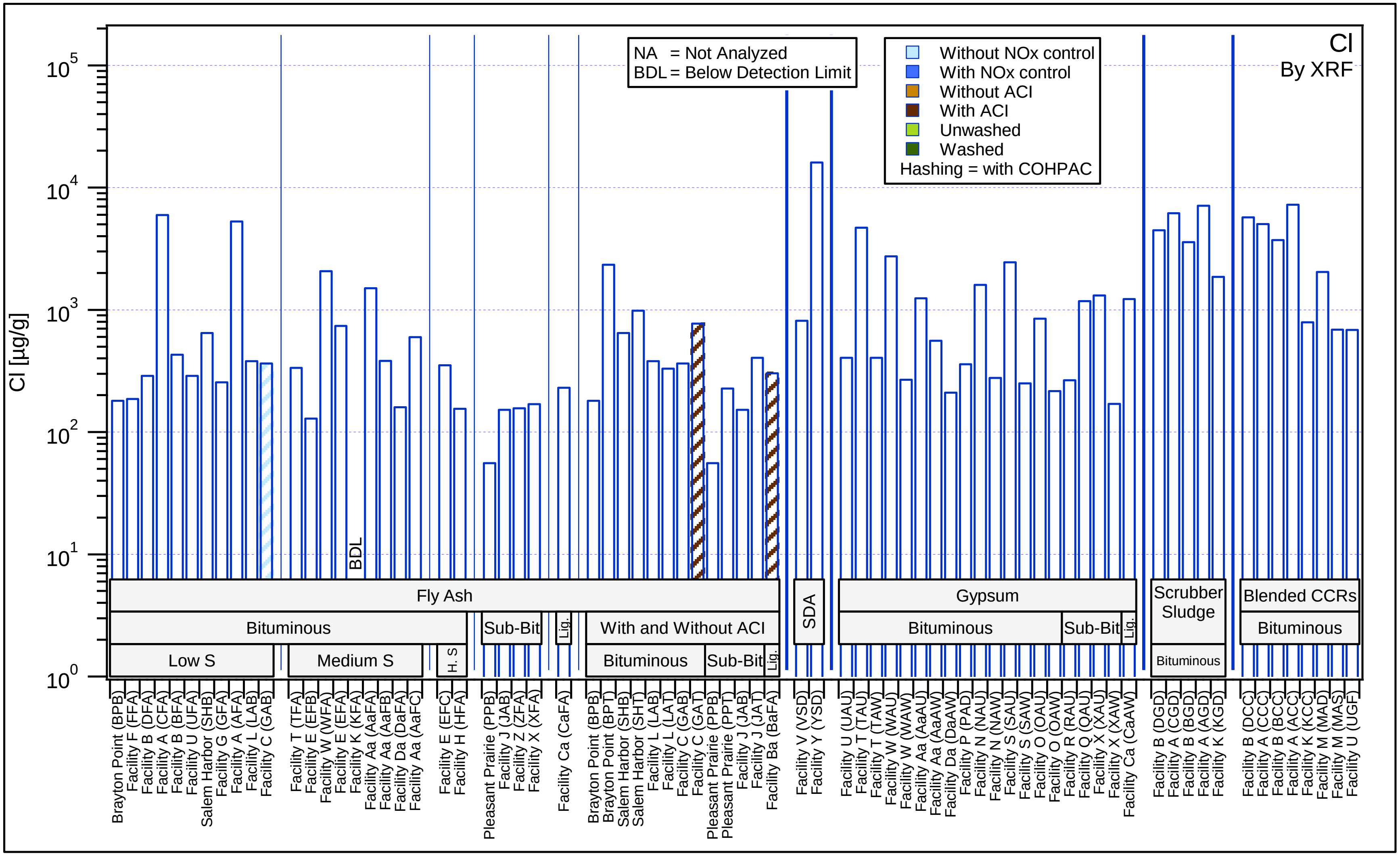

Figure 26. Chloride. Comparison of total elemental content by XRF.

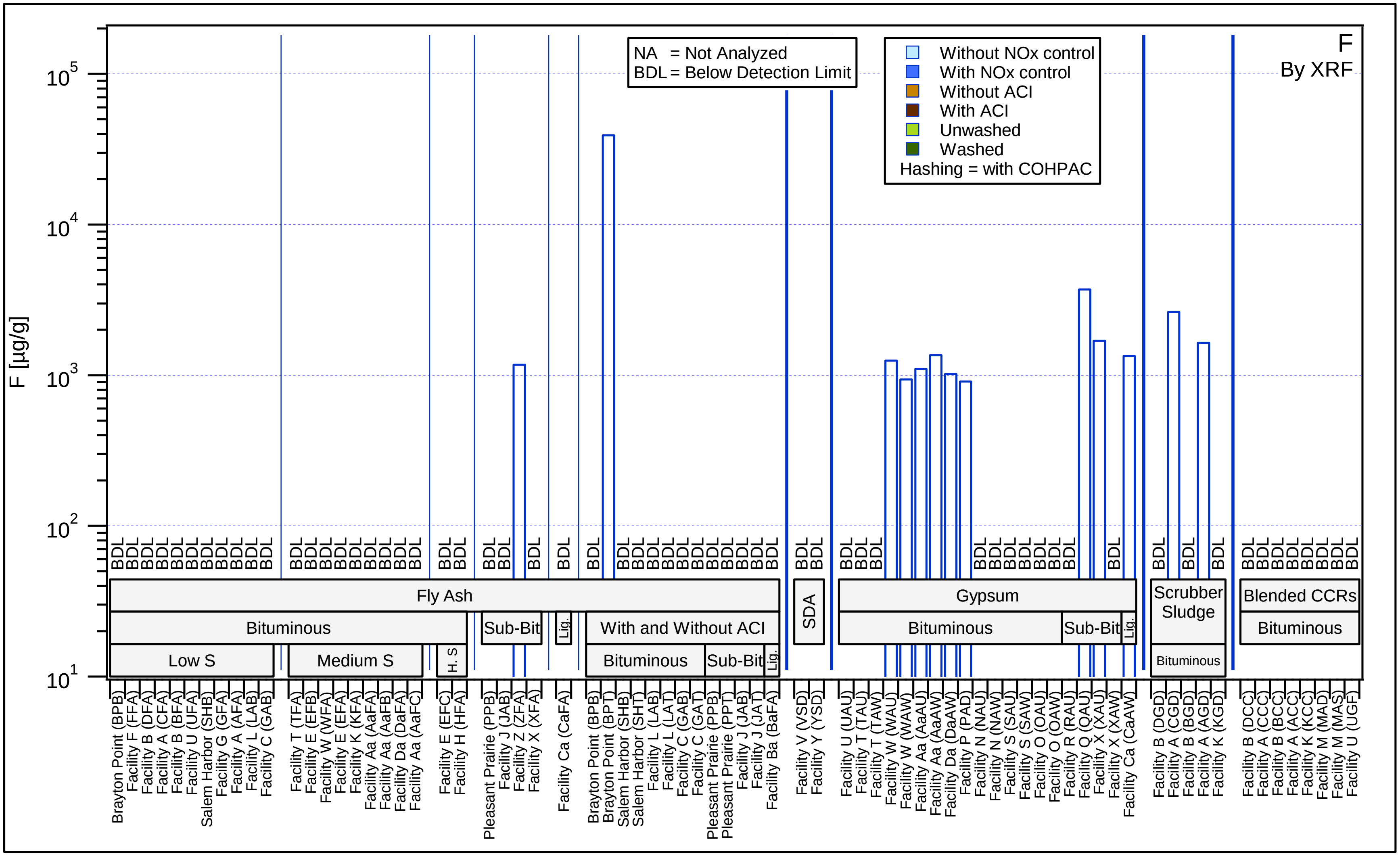

Figure 27. Fluoride. Comparison of total elemental content by XRF.

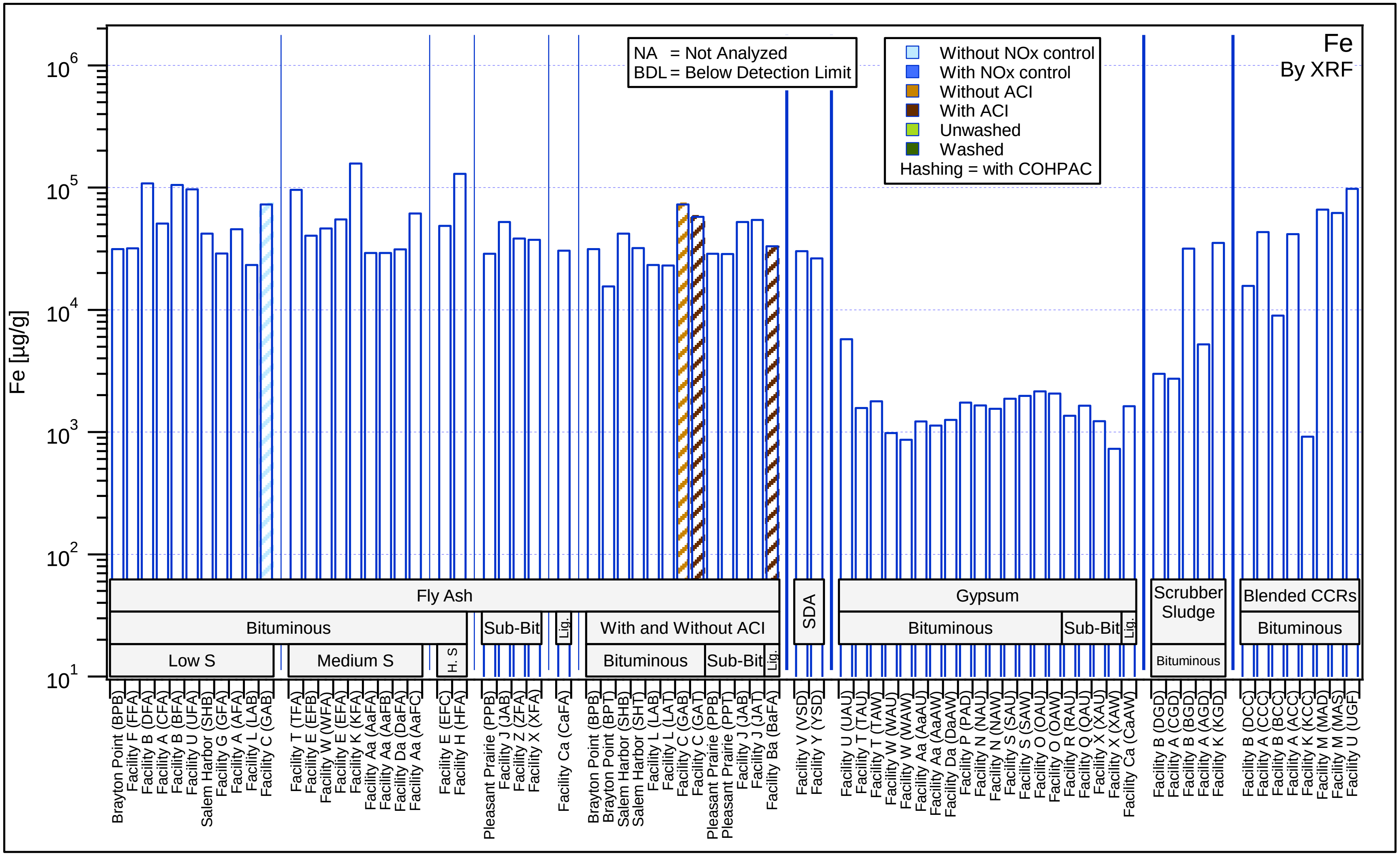

Figure 28. Iron. Comparison of total elemental content by XRF.

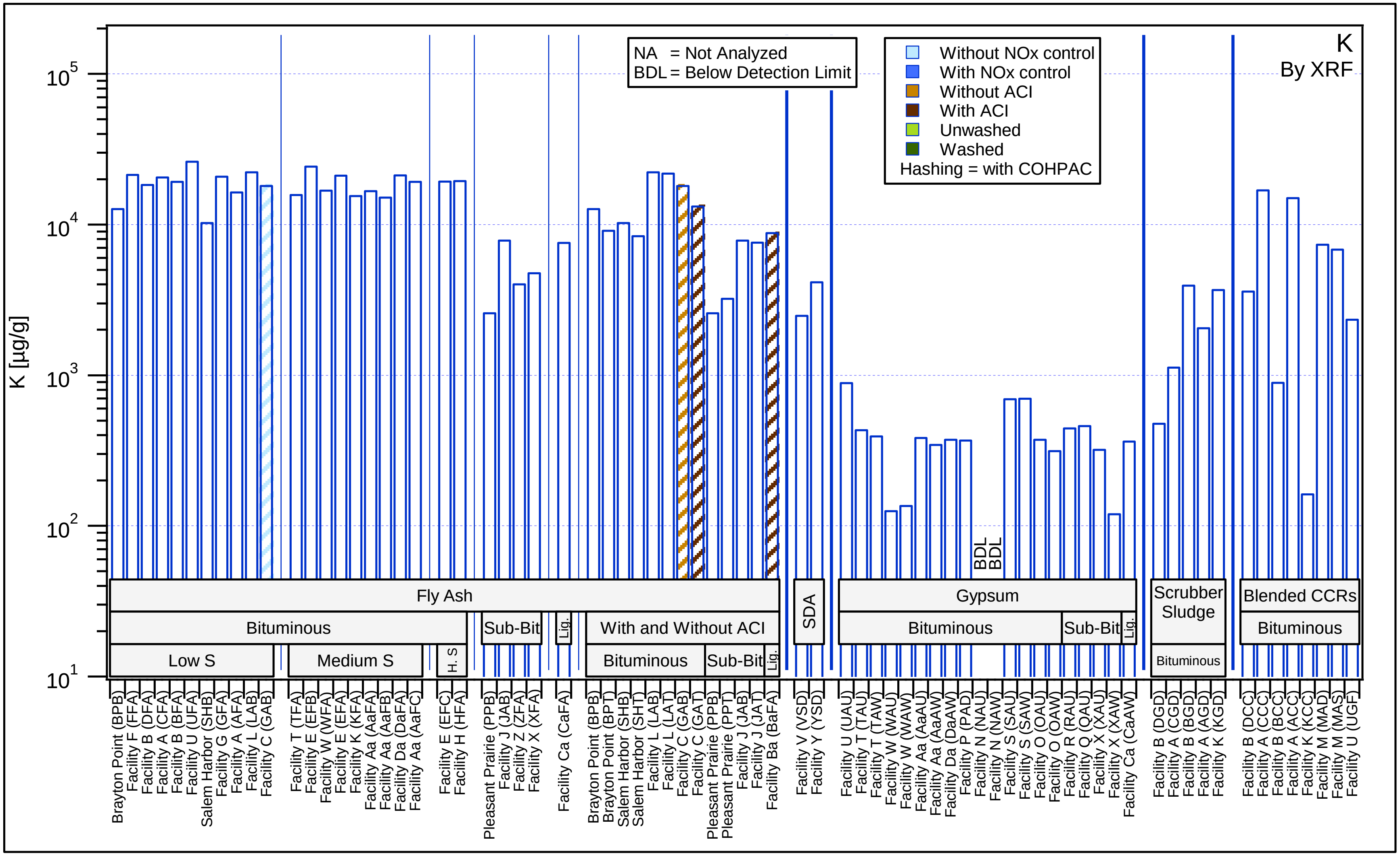

Figure 29. Potassium. Comparison of total elemental content by XRF.

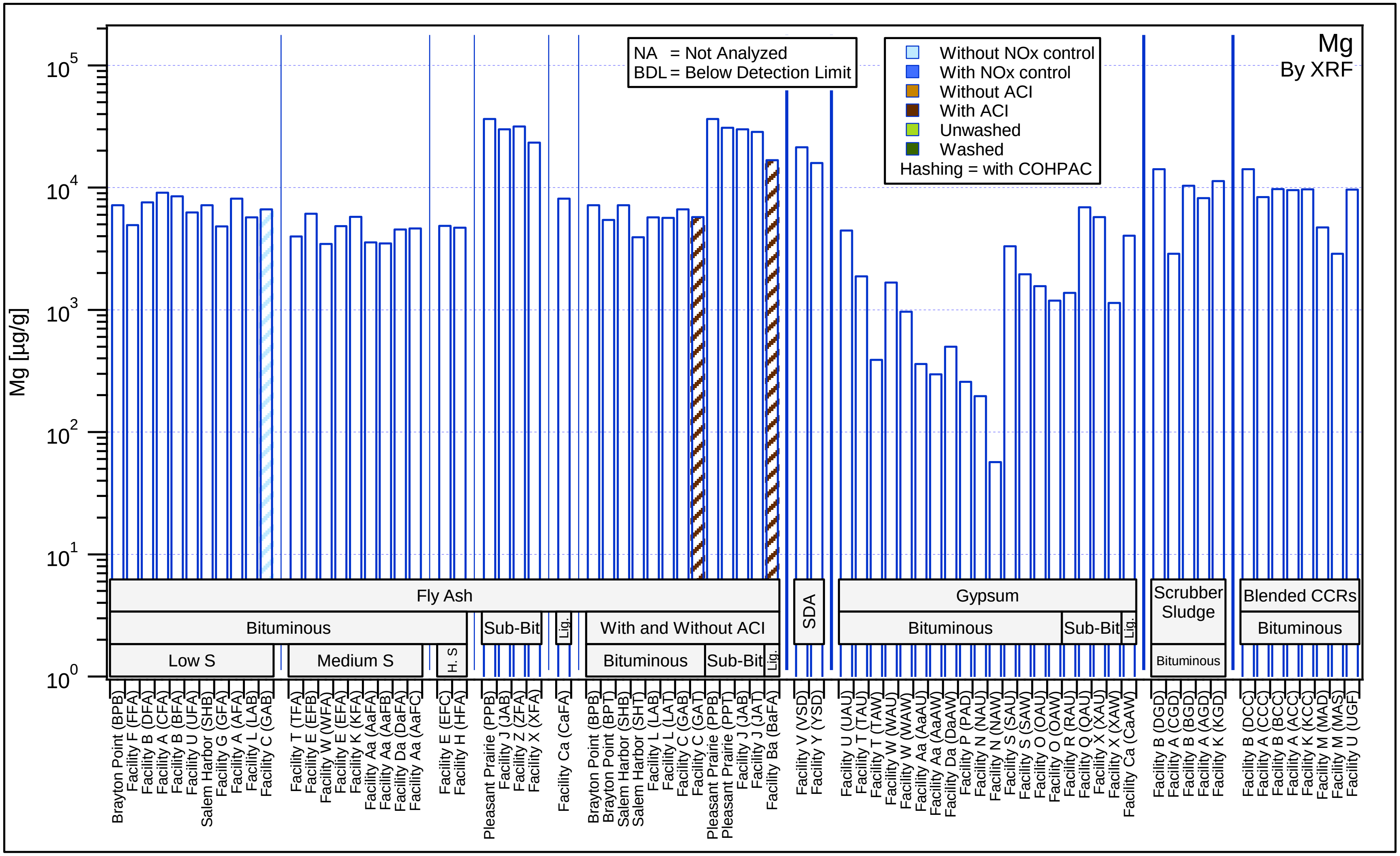

Figure 30. Magnesium. Comparison of total elemental content by XRF.

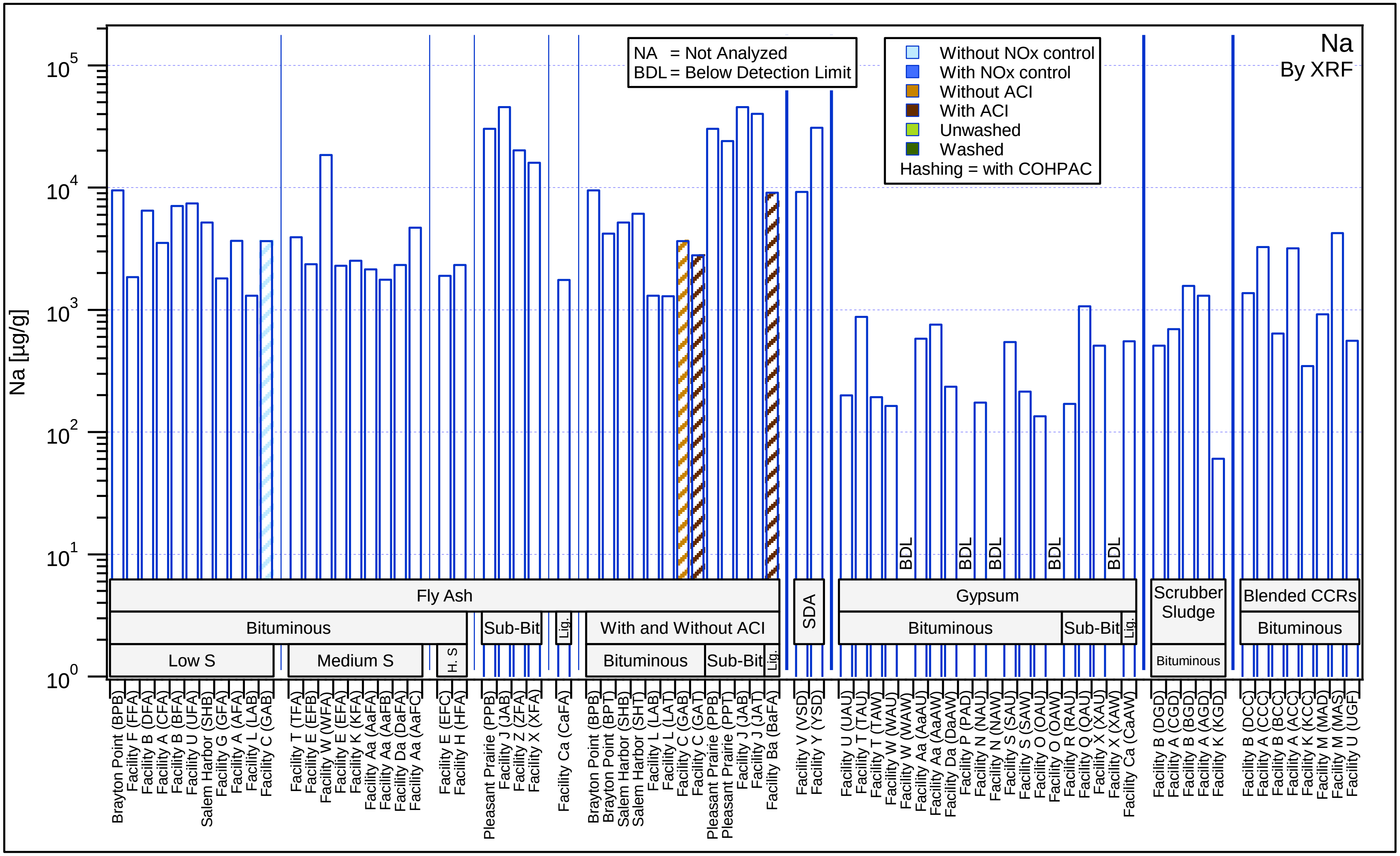

Figure 31. Sodium. Comparison of total elemental content by XRF.

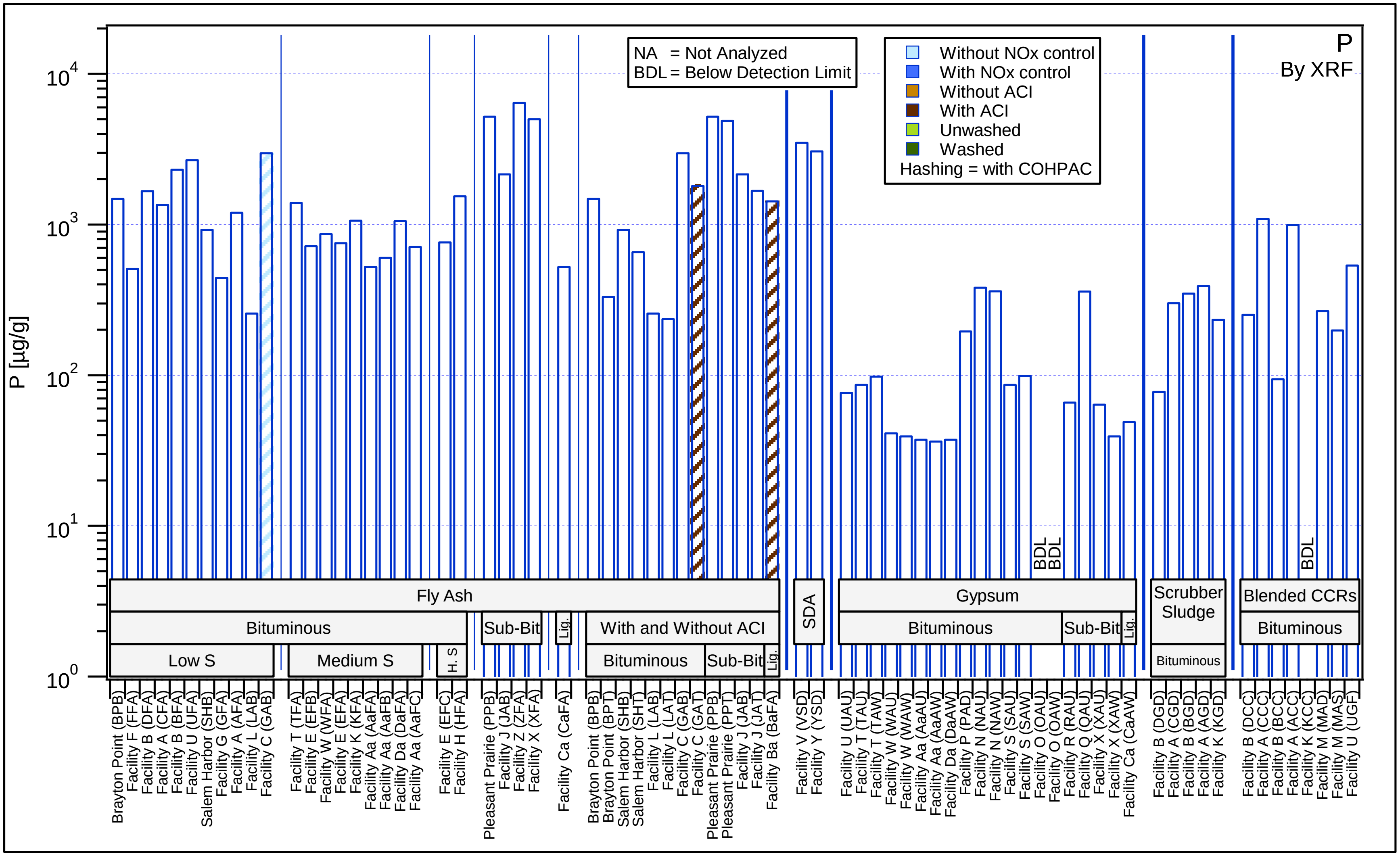

Figure 32. Phosphorous. Comparison of total elemental content by XRF.

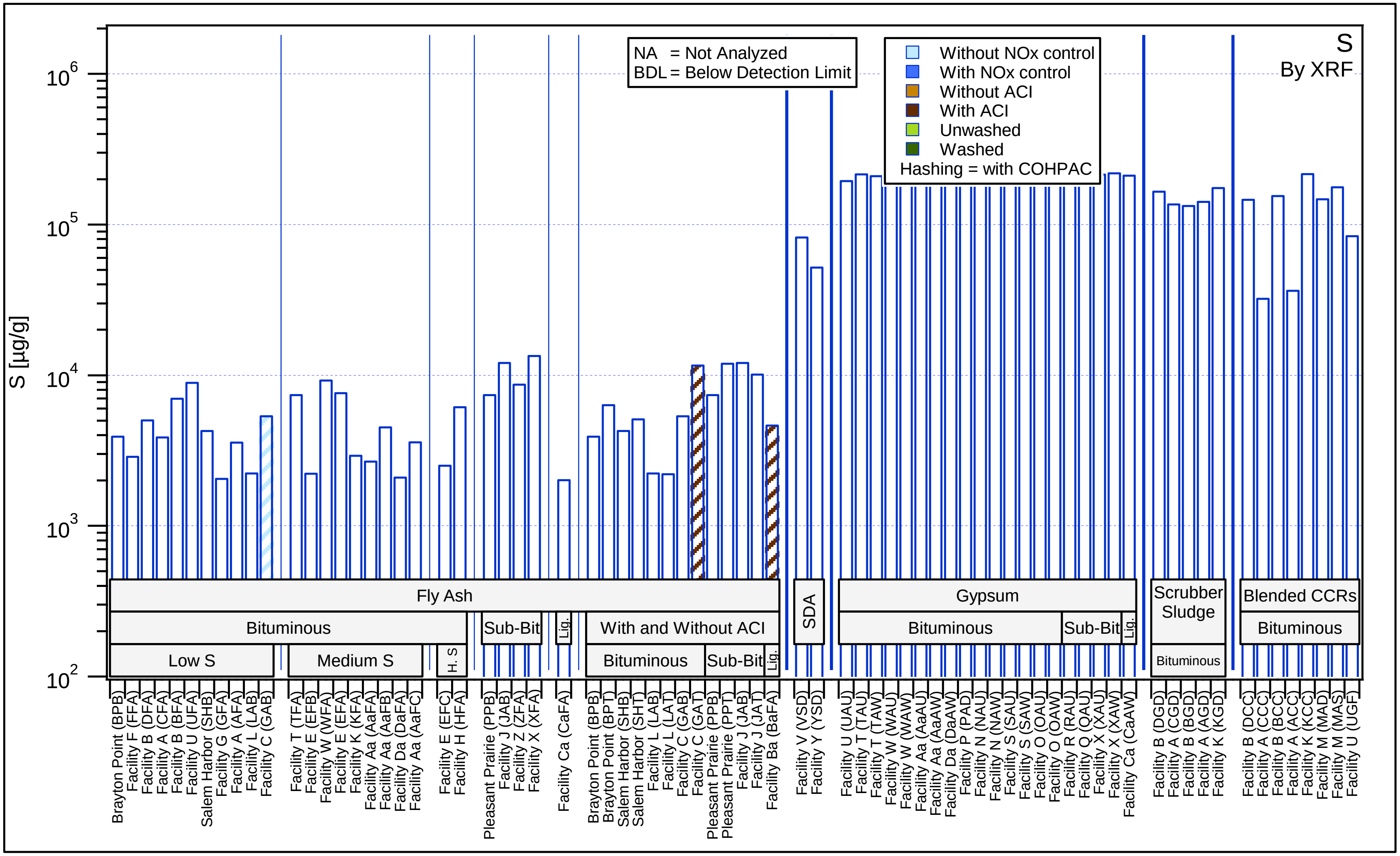

Figure 33. Sulfur. Comparison of total elemental content by XRF.

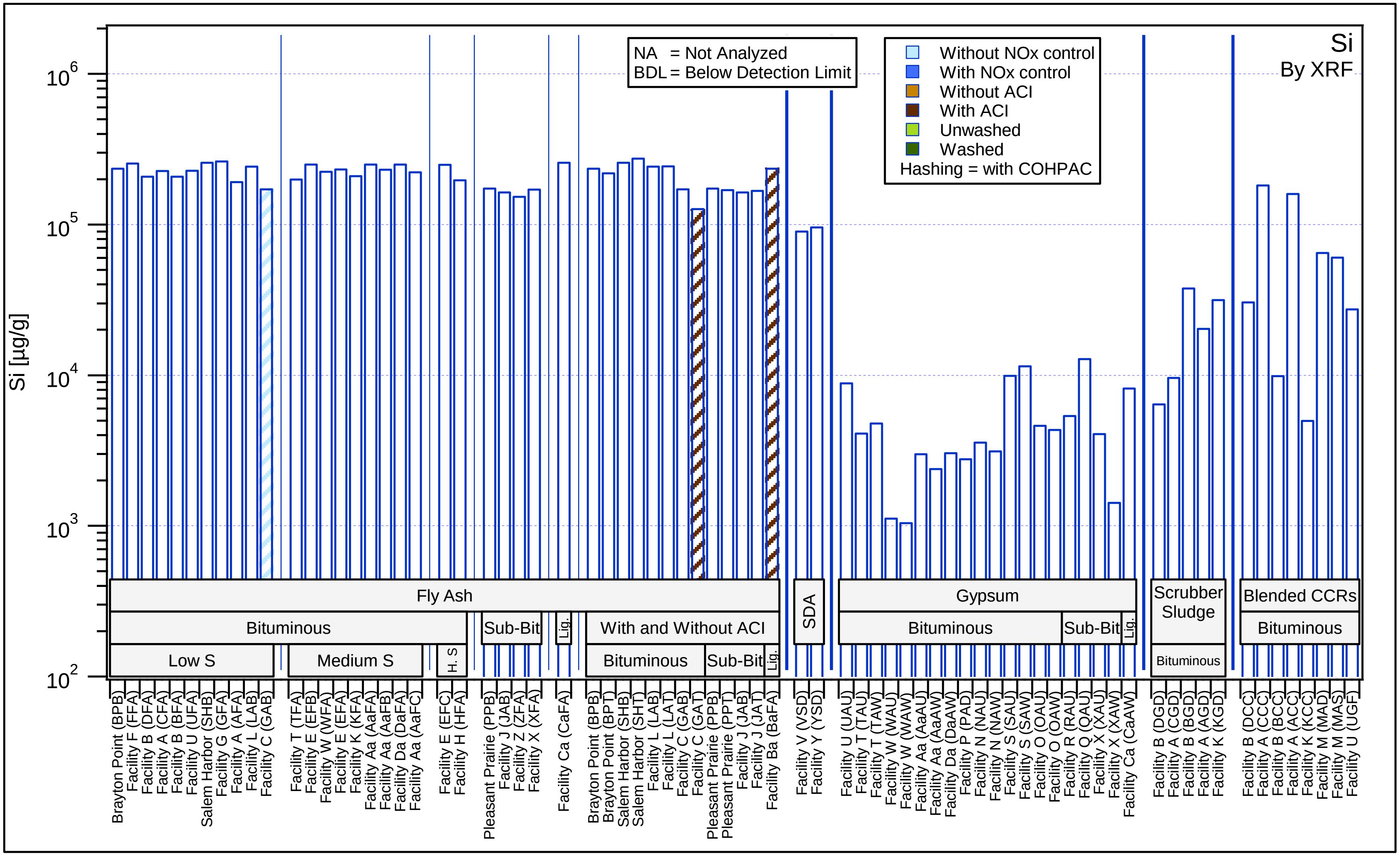

Figure 34. Silicon. Comparison of total elemental content by XRF.

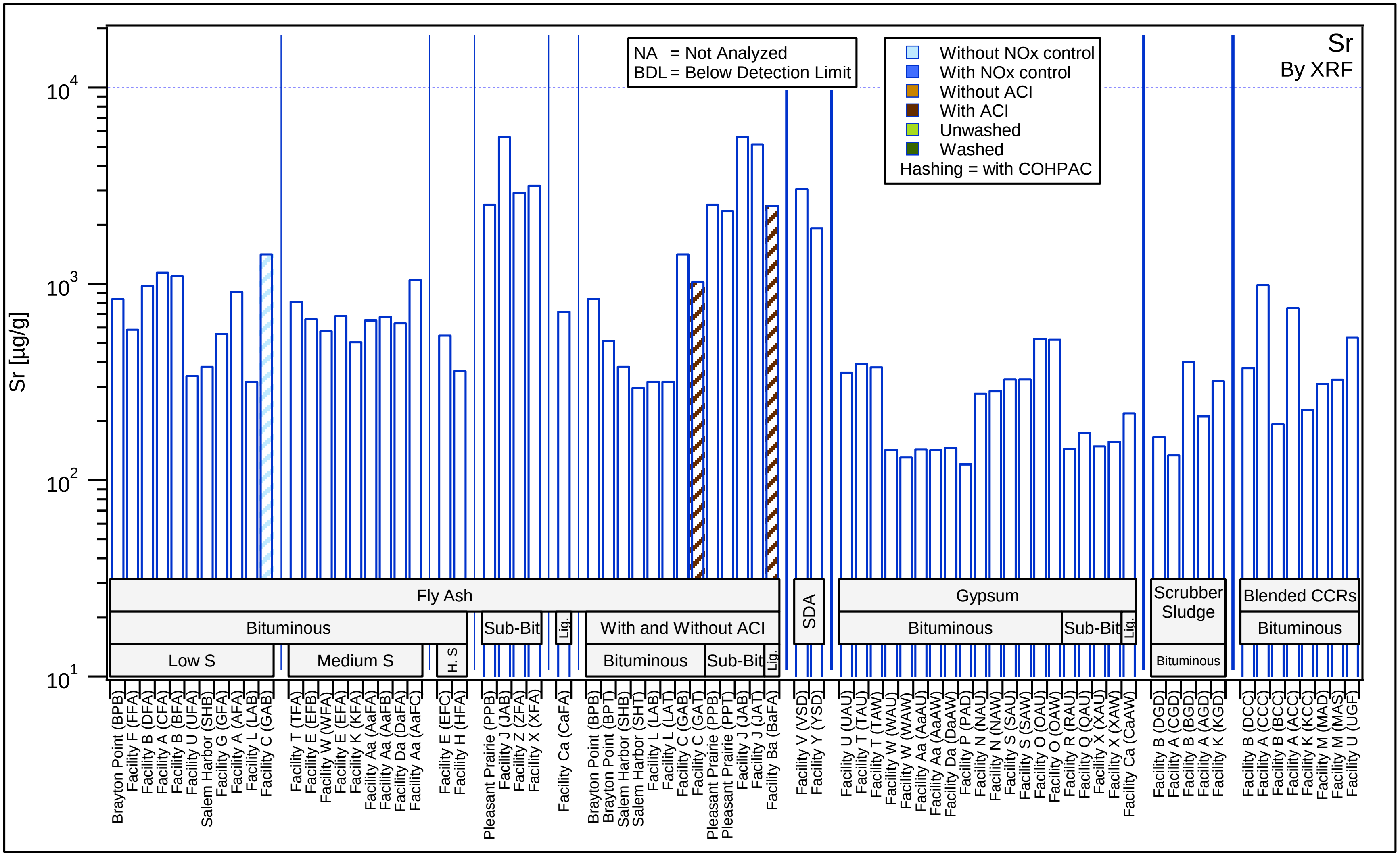

Figure 35. Strontium. Comparison of total elemental content by XRF.

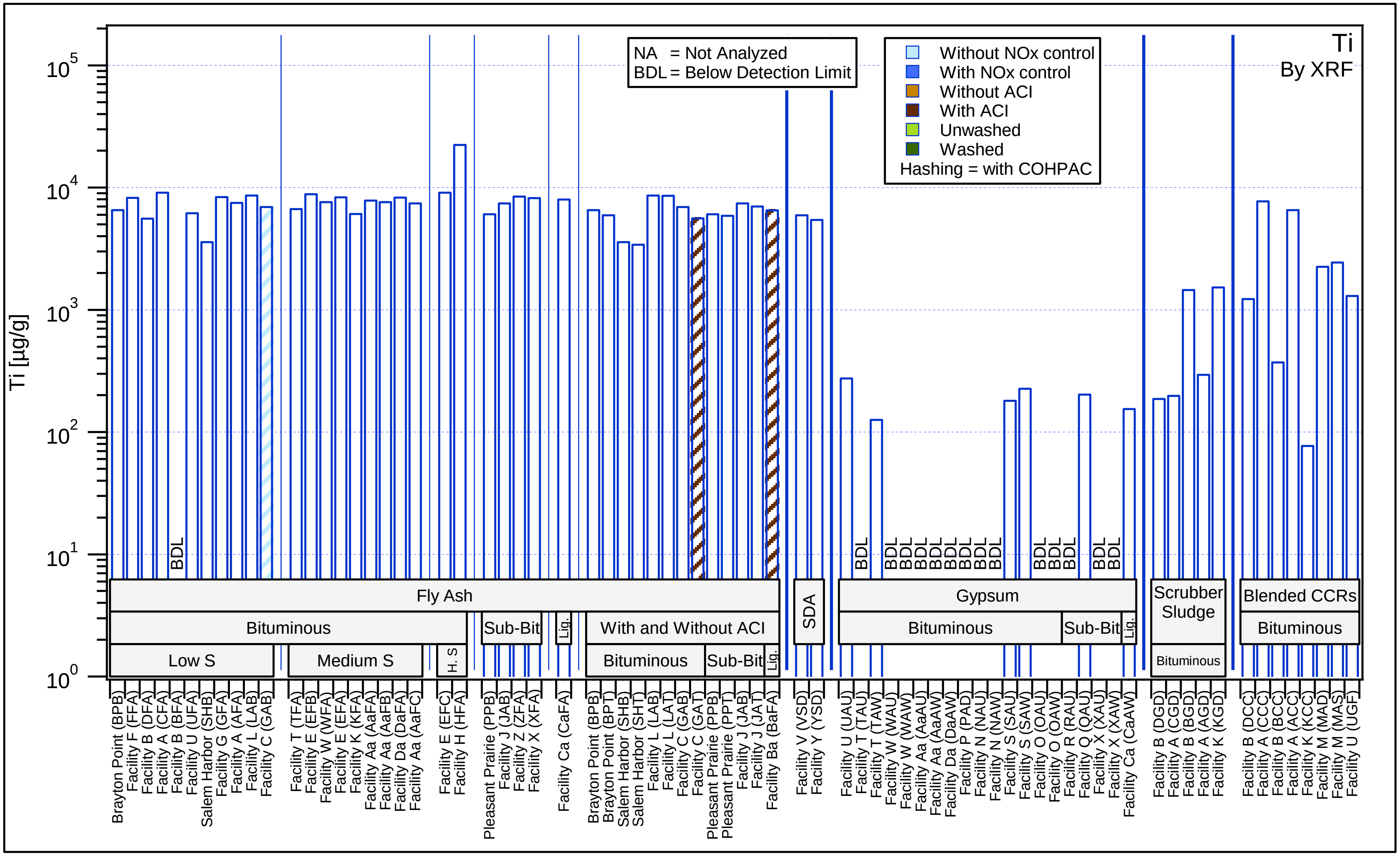

Figure 36. Thallium. Comparison of total elemental content by XRF.

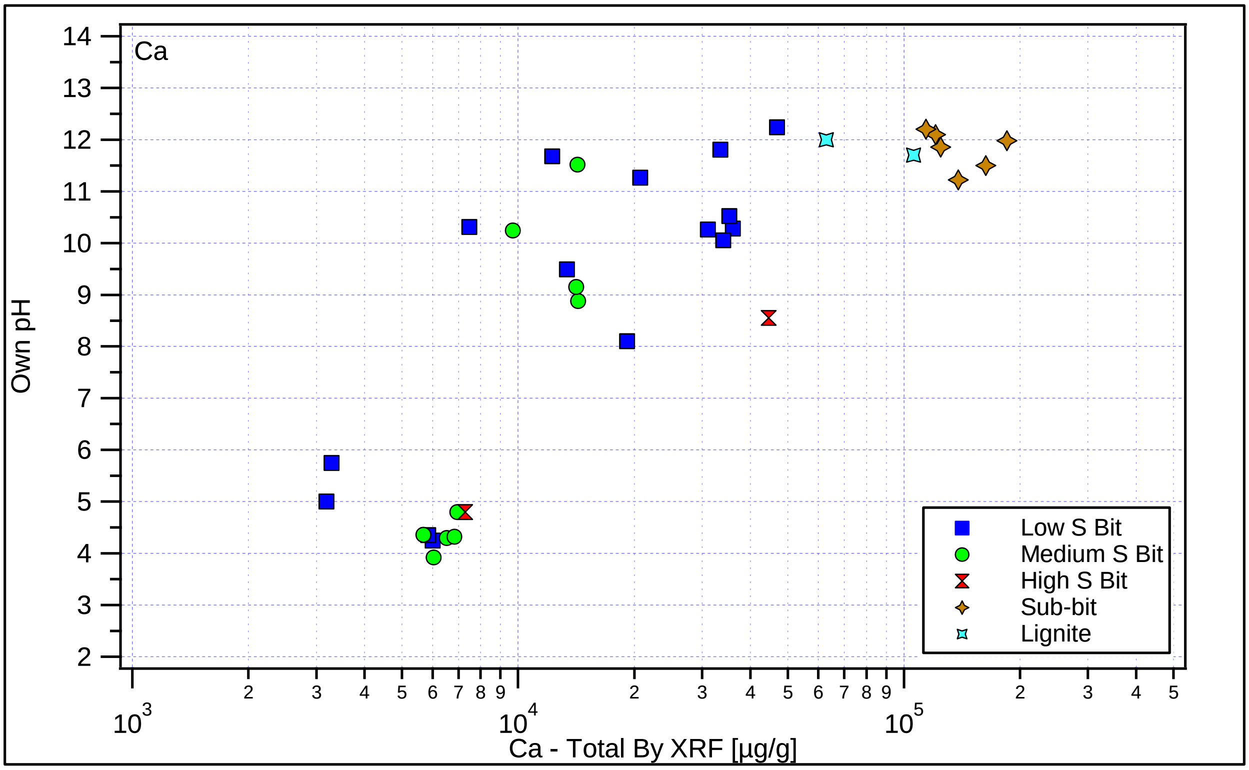

Figure 37. Total calcium content (by XRF) and own pH for fly ash samples.

3.2. LABORATORY LEACHING TEST RESULTS

Appendix F provides graphical presentation of the results of Solubility and Release as a Function of pH (SR002.1) and Solubility and Release as a Function of LS (SR003.1) for the 13 constituents of interest in this report. Results are grouped by facility type and within each facility comparisons are made by CCR type (fly ash without Hg sorbent injection, fly ash without and with Hg sorbent injection pairs, spray dryer, gypsum, scrubber sludge, blended CCRs, and filter cake) and constituent of interest. Appendix G provides graphical presentation of the pH titration curves from test method SR002.1.

Discussed below are:

1. Typical characteristic results for pH and each of the 13 constituents of interest (Section 3.2.1);
2. Comparison of the ranges of observed constituent leaching concentrations from laboratory testing (minimum concentrations, maximum concentrations, and concentrations at the materials' own pH – Section 3.2.2);
3. Comparison of the constituent maximum leaching concentrations and concentrations at the materials' own pH from laboratory testing grouped by material type with measurements reported elsewhere on field leachate and pore water samples for CCR disposal sites and the database used in the EPA Risk Report (EPA, 2007b) (Section 3.2.3); and,
4. pH at the maximum concentration value versus the materials' own pH (Section 3.2.4).

Complete data also have been developed for other constituents (e.g., other ions, DOC, etc.) to facilitate evaluation of geochemical speciation of constituents of concern and provide more thorough evaluation of leaching under alternative management scenarios in the future if warranted.

For each CCR evaluated, results of the leaching tests provide the following information:

- Leachate concentrations for the constituents of interest as a function of pH over the range of reported field management conditions (from test method SR002.1);
- pH titration curves (from test method SR002.1). This information is useful in characterizing the CCR and assessing how it will respond to environmental stresses and material aging (e.g., carbon dioxide uptake, acid precipitation, co-disposal, mixing with other materials); and,
- Leachate concentrations for the constituents of interest and pH as a function of LS ratio when contacted with distilled water (from test method SR003.1). This information provides insight into the initial leachate concentrations expected during land disposal and effects of pH and ionic strength at low LS ratio. Often these concentrations can be either greater than or less than concentrations observed at higher LS ratio (i.e., LS=10 mL/g as used in SR002.1) because of ionic strength and co-constituent concentration effects.

The MCL, DWEL, or AL (for lead) as available is used as a reference value for the constituent of interest. However, laboratory leaching test results presented here are estimates of concentrations potentially leaching from landfills, not the concentrations at potential points of exposure. Any assessment of the environmental impact of these releases needs to consider the dilution and attenuation of these constituents in ground water, and the plausibility of drinking water well contamination resulting from the release. Dilution and attenuation factors for metals (DAFs) have been estimated to be potentially as low as 2 to 10 on a national basis or as high as 8,000 at a particular site with hydrogeology that indicated low transport potential[41]. Therefore, comparison of the laboratory leach test results with thresholds greater than the MCL and developed for specific scenarios may be appropriate.

3.2.1. Typical Characteristic Leaching Behavior as a Function of pH

Comparisons of the leaching behavior as a function of pH for each of the 13 elements of interest are presented in Section 3.2.1.1 for fly ashes without Hg sorbent injection (as a baseline measure), Section 3.2.1.2 for fly ashes without and with Hg sorbent injection pairs, Section 3.2.1.3 for unwashed and washed gypsum, Section 3.2.1.4 for scrubber sludges, Section 3.2.1.5 for spray dryer absorber residues, and Section 3.2.1.6 for blended CCRs (mixed fly ash and scrubber sludge/mixed fly ash and gypsum). These comparisons illustrate on an empirical basis some of the differences in leaching behavior for different CCRs that result from the combination of the coal type combusted and air pollution control configuration used, including particulate control devices (cold-side ESP, hot-side ESP, or fabric filter), NO_x control (none or by passed, SNCR or SCR), and without and with Hg sorbent injection.

These figures illustrate that for a particular constituent, the chemistry controlling release or aqueous-solid equilibrium may be similar within a material type (i.e., mercury behavior for fly ash or scrubber sludge) or across material types (i.e., the same behavior for aluminum in fly ash and blended CCRs) but that there are not necessarily generalized behaviors present for each constituent that are consistent across all samples within a material type or between material types. The most robust groupings of leaching behavior will result from the development of geochemical speciation models of the materials that account for the underlying solid phase speciation (e.g., solid phases, adsorption behavior) and modifying solution characteristics (e.g., dissolved organic matter, pH, ionic strength, co-dissolved constituents). Development of the needed geochemical speciation models, and associated leaching behavior groupings as a function of coal rank, combustion facility design, and CCR type, will be the subject of a subsequent report (Report 4). The resulting models and groupings, in turn, are expected to allow for more detailed constituent release predictions based on limited testing for a broader set of facilities.

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[41] See 60 FR 66372, Dec. 21, 1995, for a discussion of model parameters leading to low DAFs, particularly the assumption of a continuous source landfill. Implied DAFs for the metals of interest here can be found at 60 FR 66432-66438 in Table C-2. Site specific high-end DAFs are discussed in 65 FR 55703, September 14, 2000.

3.2.1.1. Fly Ash without Hg Sorbent Injection

Figure 38 through Figure 40 present comparisons of leaching behavior as a function of pH for fly ash without Hg sorbent injection for each of the 13 elements of interest. Results are organized by coal type: bituminous, low sulfur coal (Figure 38); bituminous, medium and high sulfur coal (Figure 39); and sub-bituminous, sub-bituminous/bituminous mix, and lignite coal (Figure 40).

Figure 41 shows the main characteristic leaching behaviors observed for each element of interest for the different coal types and air pollution control configurations. Figure 42 presents the leaching behavior of calcium, magnesium, iron, strontium, and sulfur, expected to control or have an effect on the chemistry of the materials. Figure 43 illustrates the effect of NO_x controls (none or by-passed, SNCR or SCR) for facilities burning Eastern Bituminous coal and using CS-ESP for particulate control. Figure 44 illustrates the effect of fabric filters versus CS-ESP with and without SNCR for facilities burning Eastern Bituminous coal. Chromium speciation in selected fly ash samples and eluates is shown in Figure 45.

Main characteristics leaching behavior (Figure 41 and Figure 42)

The discussion of the results provided below is solely empirical and intends to show the range of leaching characteristics as a function of pH that were encountered for the fly ash without Hg sorbent injection. Details of speciation are beyond the scope of this report and require development of geochemical speciation models of the materials, which will be part of a subsequent report.

Aluminum (Al). The behavior of Al was generally amphoteric with a broad minimum between $4 < pH < 8.5$ and minima observed at different levels depending upon the ash type. The concentration of the minimum is typically influenced by the amount of DOC complexing aluminum in solution (increased complexation increases dissolved aluminum). Several samples, e.g. UFA, exhibited dramatically decreased leaching at pH > 11.

Arsenic (As). Six different leaching behaviors were observed for As. Sample LAB provides an example of a typical amphoteric behavior with minimum leaching occurring at a pH~5.2. Sample UFA is an example of typical oxyanionic behavior with increasing As concentration as pH decreased from *ca*. 10.5 to less than 3. Sample GAB shows an example where As concentration peaked at pH~8, which was, in this case, most likely a consequence of the presence of the COHPAC. Sample ZFA shows an example where As release was below the MDL for all pHs and was representative of the sub-bituminous and sub-bit/bituminous mix coal, reflecting the relatively high total content of calcium and magnesium of this coal type compared to the other coal types. Sample AaFC also showed amphoteric behavior but was distinctly different from that of sample LAB. Sample AFA also showed oxyanionic behavior but at a lower concentration level than sample UAF. As concentrations were at or above the MCL value for most pHs, except for the sub-bituminous coal, e.g. ZFA, for which arsenic concentrations were below the MDL across the full pH range examined.

In general, As leaching behavior had been reported to be influenced by precipitation/co-precipitation with group II elements (Mg, Ca, Ba, and Sr) and precipitation/adsorption onto iron oxide (Drahota et al., 2009; Mohan et al., 2007). Figure 42 presents the characteristic leaching behavior of these constituents, which shows significant differences between ash types. Sample ZFA had overall the greatest concentrations of group II elements while sample LAB had the lowest concentrations of group II elements. As a general observation, the bituminous coal fly ashes having a low own pH and corresponding to eluate calcium concentrations of less than 120 mg/L, tended to exhibit amphoteric behavior. Detailed mechanistic evaluation is, however, beyond the scope of this report and will be addressed in Report 4.

Boron (B). Most samples showed relatively constant boron concentrations for pH < 10.5 with a few samples, e.g. AFA, showing a decrease in B eluate concentration with increasing pH for pH > 8. In general, samples with decreasing concentration for pH>8 were those with higher own pH and eluate calcium concentration greater than 120 mg/L. B is highly soluble at neutral to acidic pHs and as a result observed B concentrations were most likely controlled by the total B content of the material.

Barium (Ba). All samples showed a similar leaching behavior of Ba with the exceptions of samples ZFA and XFA for which a much greater release of barium was observed, in agreement with a much greater Ba content for these samples (as much as 12 times greater than for the other samples). All own pH results were less than the MCL except for the sub-bituminous and lignite coal samples.

Cadmium (Cd). Typical behavior of increasing eluate concentration with decreasing pH for pH<5 was observed for Cd for most cases except for sample AFA that showed increasing eluate concentration with decreasing pH for pH < 8.

Cobalt (Co). Cobalt leaching behavior was similar for all samples tested with minimum values observed for pH > 11, an increase in eluate concentration with decreasing pH for pH < 11, and a maximum concentration reached for pH less than 5.

Chromium (Cr). Three different leaching behaviors were observed for Cr: (i) amphoteric behavior (e.g., UFA and AaFC), (ii) relatively constant concentration for pH>5 with an increase in concentration for pH < 5 (e.g., AFA and GAB) [Both have fabric filter (one fabric filter and one COHPAC)], and (iii) concentration peaking at 8 < pH < 10 with low concentrations at both low and high pH values (e.g., ZFA, typical for all sub-bituminous coal and sub-bit/bituminous mix samples). The amphoteric behavior was typical for all bituminous coal samples with the exceptions of the samples where SCR or SNCR resulted in elevated ammonia concentrations (e.g., BFA) and the samples where a fabric filter (e.g., CFA) or COHPAC (GAB) was used.

Mercury (Hg). Three different leaching behaviors were observed for Hg: (i) an increasing concentration peaking at pH~8 (e.g., AFA), most likely indicative of ammonium complexation from the use of SNCR (Wang et al., 2007), (ii) an increasing concentration with decreasing pH for pH < 5 with a peak concentration at pH~3.8 and a relatively constant concentration for pH > 5.5 (e.g., GAB, most likely, in this case, a consequence from the use of HS ESP with COHPAC), and (iii) concentrations below the MDL for most pHs (e.g., ZFA and UFA).

Molybdenum (Mo). All bituminous coal and lignite samples, except when SCR or SNCR resulted in elevated ammonia (e.g., AFA), showed relatively constant concentrations with a decrease at pH < 7 (e.g., GAB and LAB) or pH < 4 (UFA) followed by an increase. As with Hg, sample AFA exhibited a Mo concentration peaking at pH~8, most likely indicative of ammonium complexation from the use of SNCR in conjunction with fabric filter. As with Cr, all sub-bit/bituminous mixes showed an increased Mo concentration peaking at pH~8 (e.g., ZAF).

Lead (Pb). Minimal lead leaching was observed. In all cases, lead leaching was below the MDL between pH 4 and 12. For some samples, e.g. AaFC, typical amphoteric behavior was observed with increased concentrations for pHs above 12 and below 4.

Antimony (Sb). Several leaching behaviors were observed for Sb: (i) a decreasing concentration with decreasing pH (e.g., LAB), (ii) an increasing concentration with decreasing pH (e.g., UAF), (iii) concentrations below the MDL over the entire pH range (e.g., ZFA), (iv) a concentration peaking at pH~8 (e.g., AFA), most likely indicative of ammonium complexation from the use of SNCR, and (v) concentrations peaking at 7 < pH < 10 (e.g., GAB)

Selenium (Se). Four different leaching behaviors were observed for Se. Sample LAB provides an example of typical amphoteric behavior with minimum leaching occurring at 5<pH<6. Sample GAB illustrates an example of decreasing leaching with decreasing pH while sample ZAF is an example of increasing leaching with decreasing pH. Sample AFA shows an example of increasing concentration peaking at pH~8, most likely indicative of ammonium complexation from the use of SNCR. In most cases, Se concentrations were above the MCL.

Thallium (Tl). Two different leaching behaviors were observed for Tl: (i) increasing concentration with decreasing pH at pH < 12 (e.g., UAF and AaFC), pH < 9 (e.g., AFA), or pH < 7 (e.g, LAB and ZFA) and (ii) relatively constant concentration with an increase at pH < 7 (e.g., GAB).

Effect of coal type (Figure 38, Figure 39, and Figure 40)

In general, the bituminous coal samples and the lignite sample (CaFA) behaved similarly with respect to leaching while the sub-bituminous coal and sub-bit/bituminous mix exhibited a significantly different behavior for most elements of interest. A greater release of group II elements (Mg, Ca, Ba, and Sr) was generally observed for the sub-bituminous coal and sub-bit/bituminous mix samples compared to the bituminous coal and lignite samples, in agreement with an overall greater total content of these elements for the sub-bituminous coal and sub-bit/bituminous mix.

Effect of NO_x control (SNCR vs. SCR, Figure 43)

The effect of NO_x control (none or by passed, SNCR or SCR) was examined for the facilities burning Eastern Bituminous coal and using CS-ESP for particulate control. No significant effect on the leaching behavior could be attributed to the presence of SCR or SNCR except one where a pairwise comparison (with and without NO_x control at the same facility) was possible. For Facility B, an increase in Cr and Co with SCR was observed (BFA *vs*. DFA), when NO_x control was in use. This observation and the Cr leaching observed across the set of facilities is likely the result of complex phenomena associated with gas conditioning (addition of ammonia or sulfuric acid) to improve particulate capture, such as for coals with low sulfur and high calcium, and ammonium residual from NO_x control.

Effect of fabric filter vs. CS-ESP (Figure 44)

The effect of fabric filter *vs*. CS-ESP with and without SNCR was examined for the facilities burning Eastern Bituminous coal. An effect was seen only on Cr, Hg, Co, and Mo concentrations with an increase in the release in some cases by a factor much greater than 10 (e.g., Cr from CFA vs. FFA, DFA, TFA, and EFB). The effect of ammonia complexation from the use of SNCR was seen with an increase in Hg and Mo concentrations peaking at pH~8 (AFA).

Chromium speciation in selected fly ash samples and eluates (Figure 45)

Chromium leaching as a function of pH (SR002.1) was analyzed for all samples. Leaching results for samples from selected facilities are provided in Figure 45 to illustrate (i) comparative results from the sample facility operated without and with NO_x controls and bituminous coal (Facility A, SCR-BP and SCR on [samples CFA and AFA, respectively] and Facility B, SNCR-BP and SNCR on [samples DFA and BFA, respectively]), and (ii) for a facility with relatively high chromium leaching but not having NO_x controls and burning sub-bituminous coal (Facility J, sample JAB). Initial review of these results suggested that fly ash samples obtained from facilities with NO_x controls (i.e., SNCR or SCR) resulted in higher chromium concentrations in the leachates as a consequence of the NOx controls. Leaching results as a function of pH also indicated concentration profiles indicative of Cr(VI) leaching. Selected fly ash samples were leached using the SR002.1 procedure at subset of desired endpoint pH values, with the resulting eluates analyzed directly to differentiate between Cr(III) and Cr(VI) in solution. Results of solution phase chromium speciation are provided in a tabular format in Appendix H, and plotted along with the initial SR002.1 results in Figure 45. Chromium speciation in the solid phase of fly ash samples was also confirmed using X-ray absorption fine structure spectroscopy (XAFS; Appendix H). Results of these analyses indicate:

1. Comparison of leaching of the same samples from facilities without and with NO_x controls indicated higher chromium concentrations in eluates when NO_x controls were in use. However, direct comparisons are limited to two facilities and a similar range of leaching results was observed for other facilities that both did and did not have post-combustion NO_x controls.
2. For all of the cases except one examined, the chromium in eluates at pH > 7 was determined to nearly 100 percent Cr(VI), within the uncertainty of the analytical method.
3. The amount of chromium leached under the test conditions and pH > 5 is a small fraction (< 1% up to <10 %) of the total chromium present in the solid phase.
4. The amount of the chromium present in the solid phase as Cr(VI) is on the same order of magnitude as the amount of Cr(VI) leached at neutral to alkaline pH but precise quantification by XAFS is uncertain.

It is hypothesized that residual ammonia injected as part of NO_x controls or to facilitate particulate capture by ESPs may play a role in solubilizing Cr(VI) in the fly ash. If this is the case, it would explain why samples BFA and AFA had relatively less chromium leaching when analyzed after several months of storage in comparison to testing recently sampled fly ash. The expected cause would be loss of ammonia during sample storage. However, although this mechanism is consistent with operations of air pollution control devices (EPRI, 2008) and residual ammonia observed, ammonia content was not measured in CCR samples for this study.

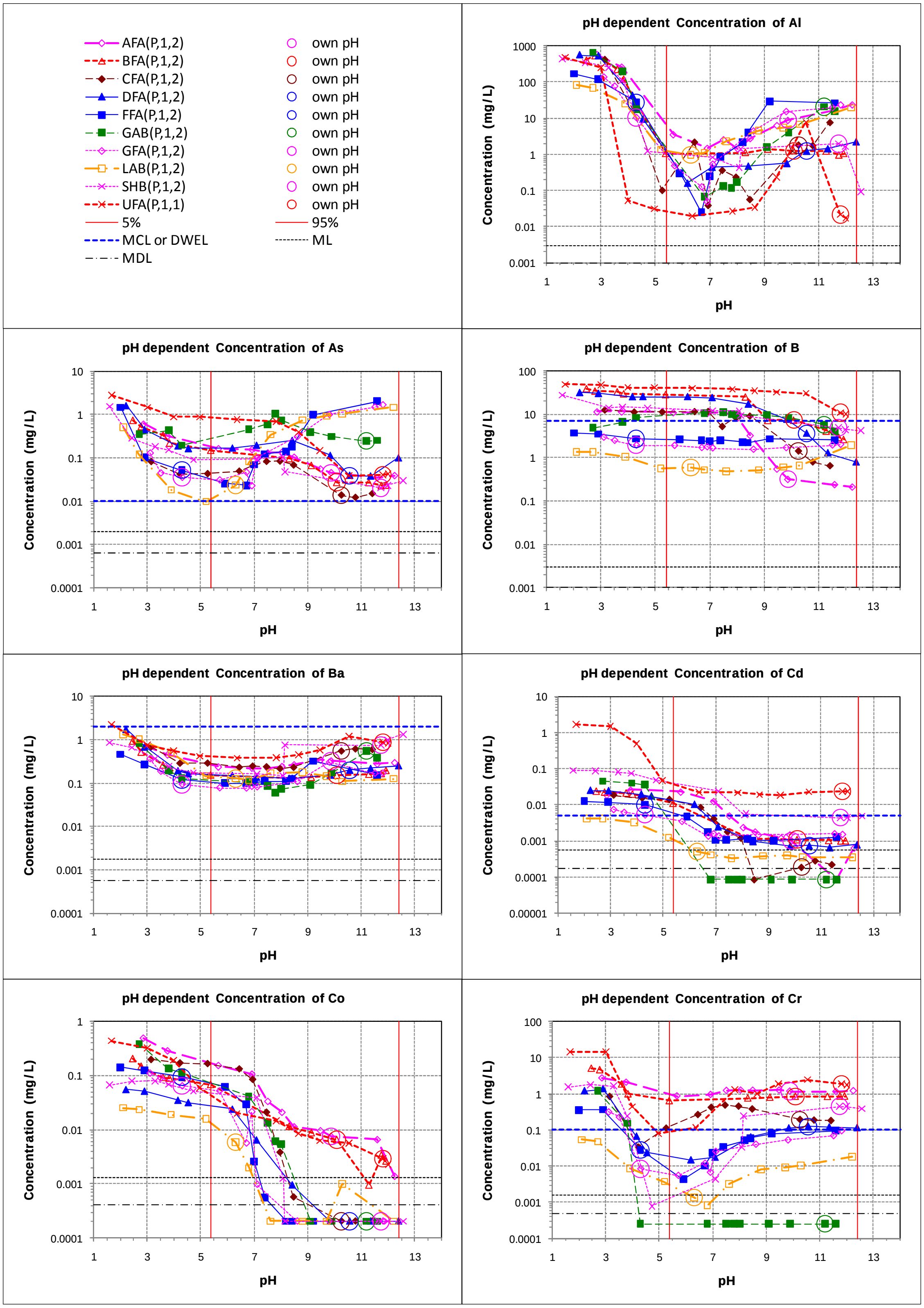


Figure 38. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous low sulfur coal]. Facility A (AFA, CFA), Facility B (BFA, DFA), Facility C (GAB), Facility G (GFA), Facility L (LAB), Salem Harbor (SHB).

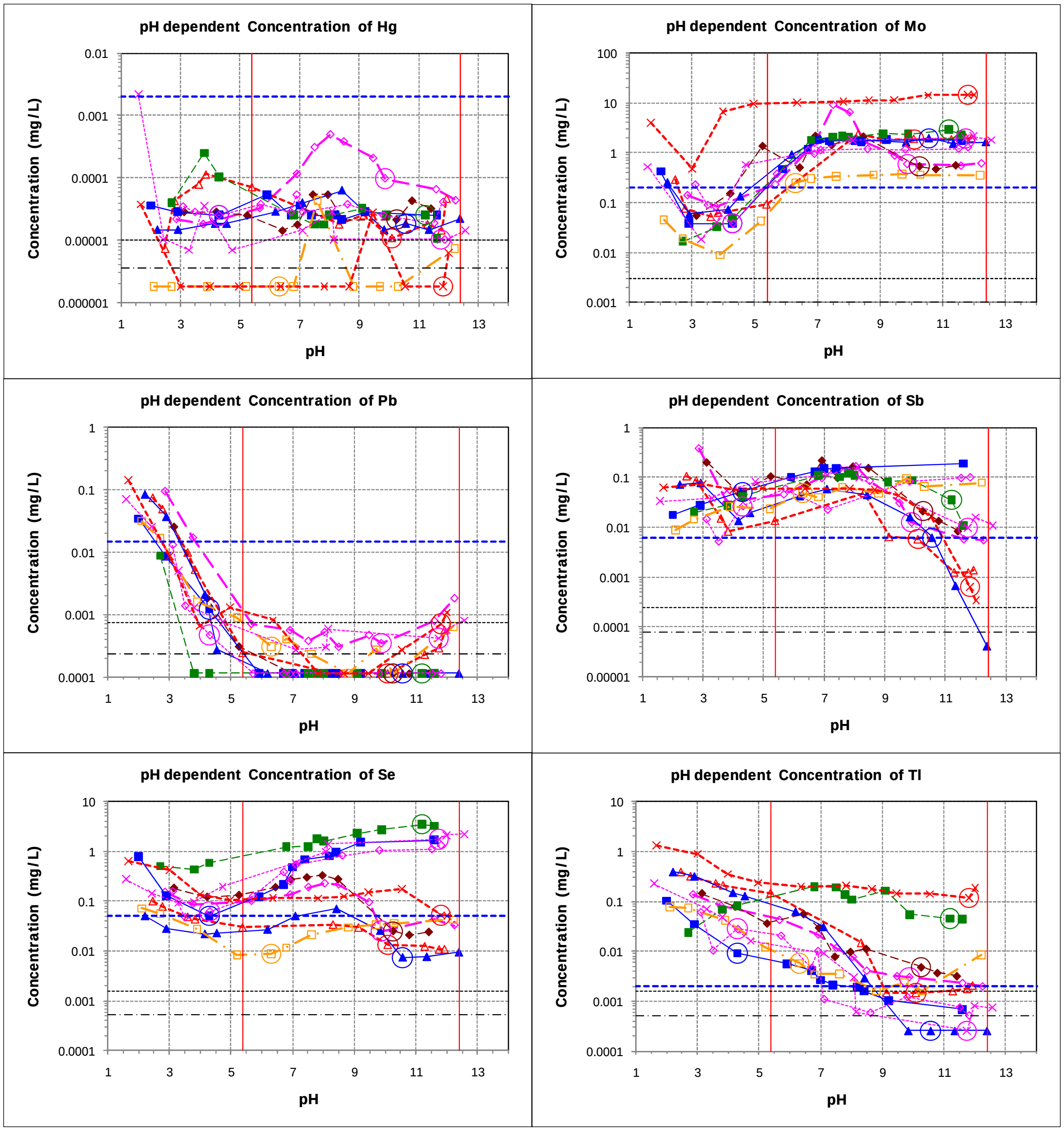


Figure 38 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous low sulfur coal]. Facility A (AFA, CFA), Facility B (BFA, DFA), Facility C (GAB), Facility G (GFA), Facility L (LAB), Salem Harbor (SHB).

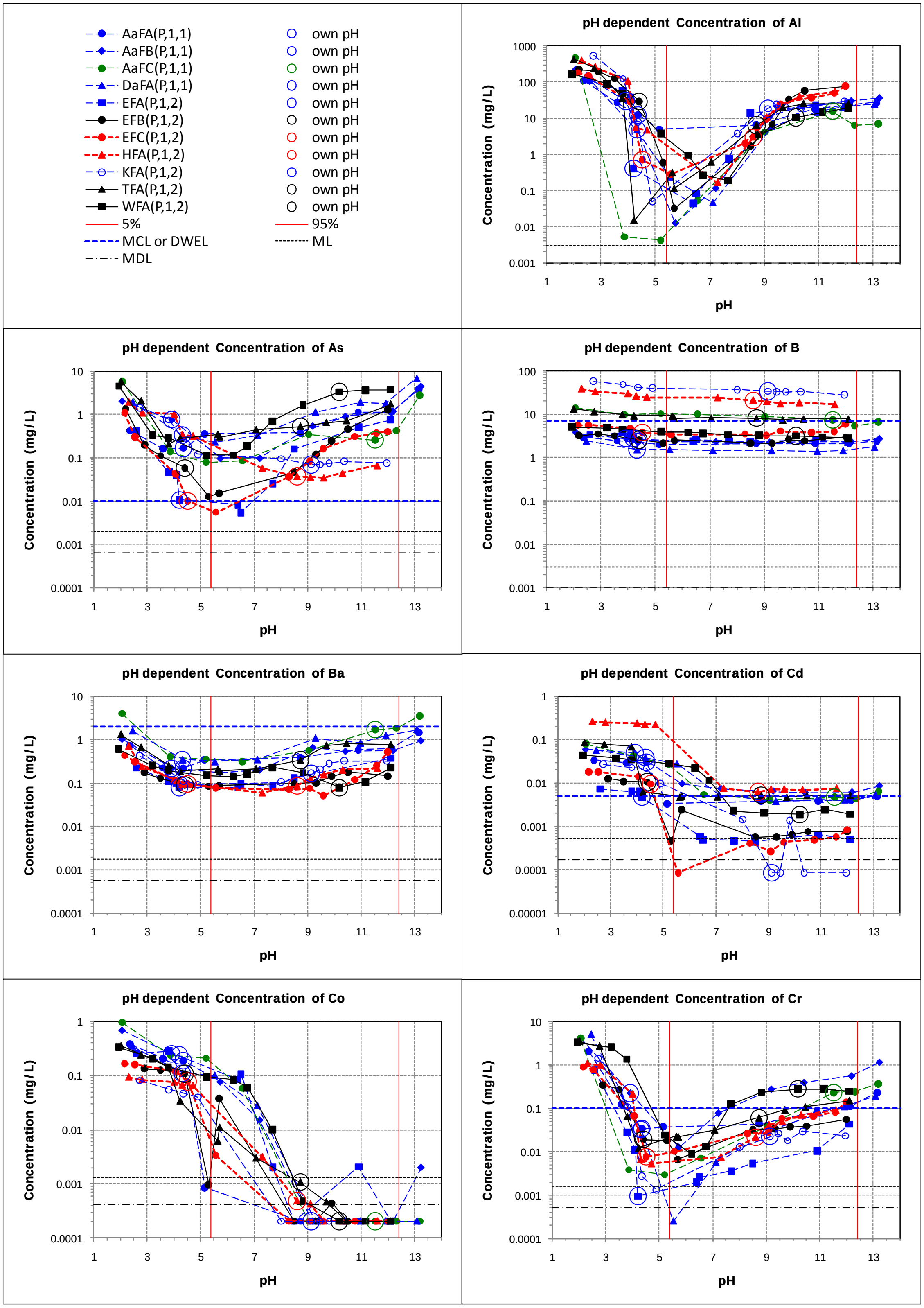


Figure 39. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous medium and high sulfur coal]. Facility E (EFA, EFB), Facility K (KFA), Facility T (TFA), Facility W (WFA), Facility Aa (AaFA, AaFB, AaFC), Facility Da (DaFA).

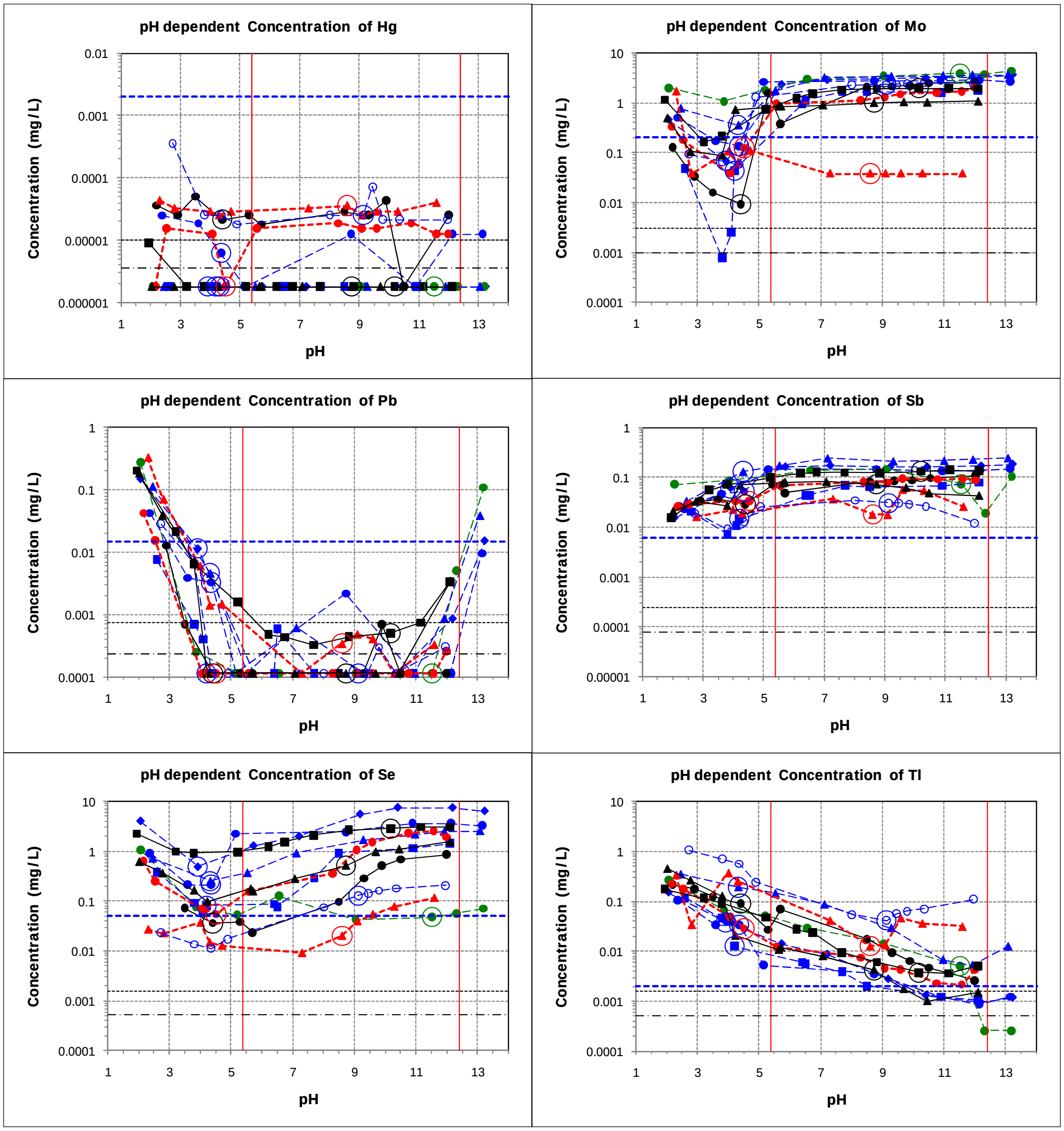


Figure 39 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous medium and high sulfur coal]. Facility E (EFA, EFB), Facility K (KFA), Facility T (TFA), Facility W (WFA), Facility Aa (AaFA, AaFB, AaFC), Facility Da (DaFA).

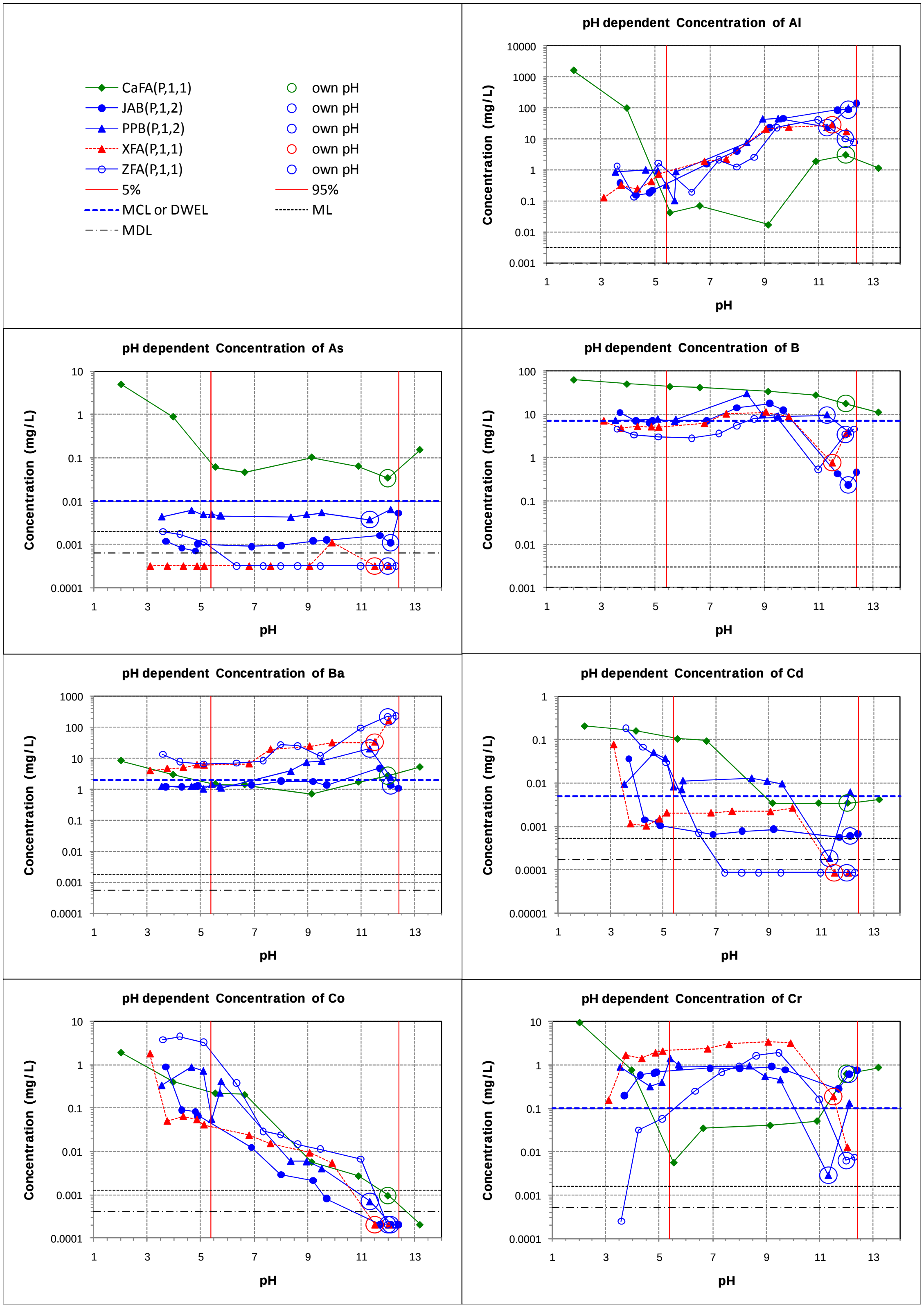


Figure 40. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [sub-bituminous and lignite coal]. Sub-bituminous: Facility J (JAB), Facility X (XFA), Facility Z (ZFA), Pleasant Prairie (PPB). Lignite: Facility Ca (CaFA).

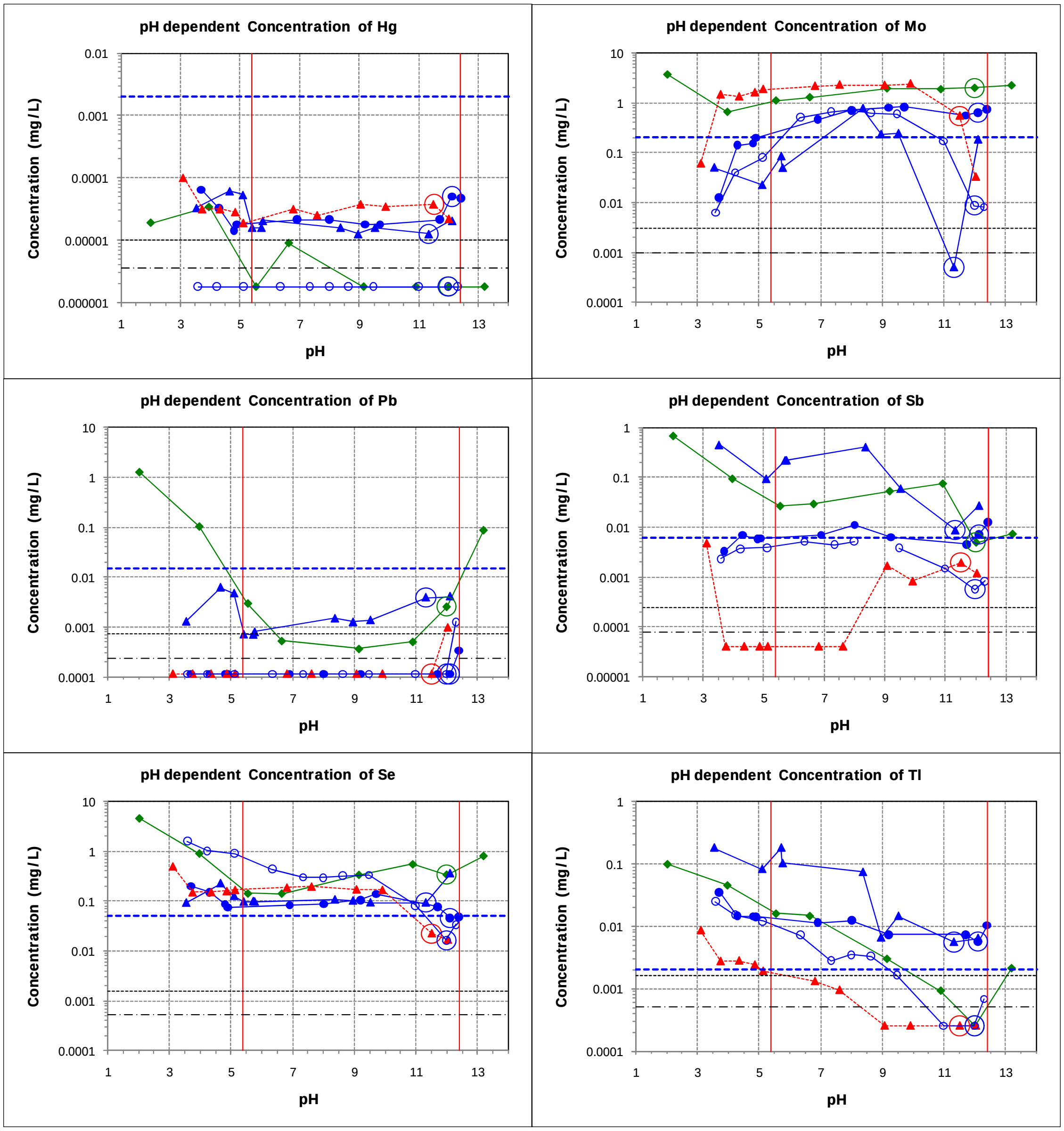


Figure 40 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [sub-bituminous and lignite coal]. Sub-bituminous: Facility J (JAB), Facility X (XFA), Facility Z (ZFA), Pleasant Prairie (PPB). Lignite: Facility Ca (CaFA).

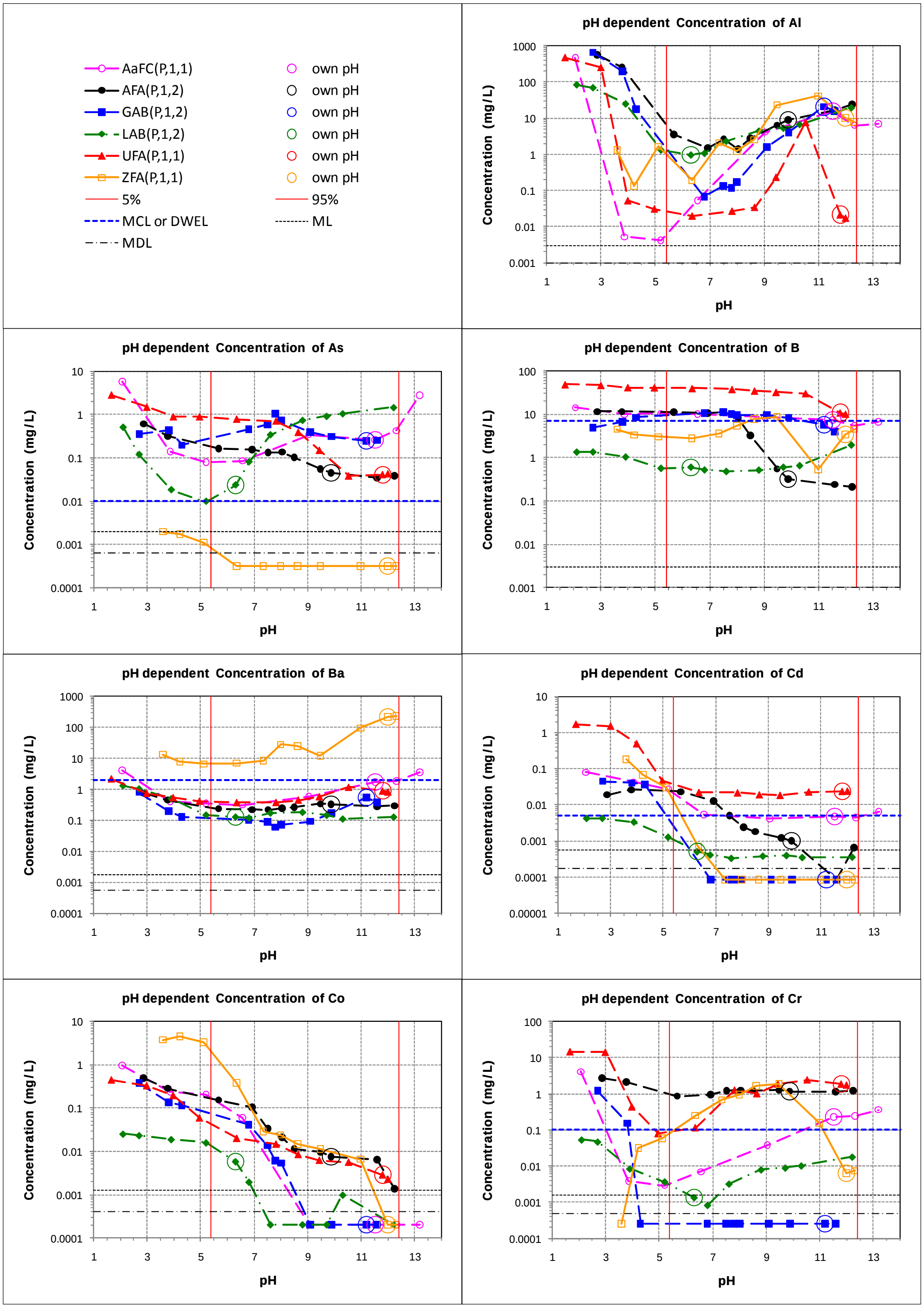


Figure 41. pH dependent leaching results. Selected results to illustrate characteristic leaching behavior.

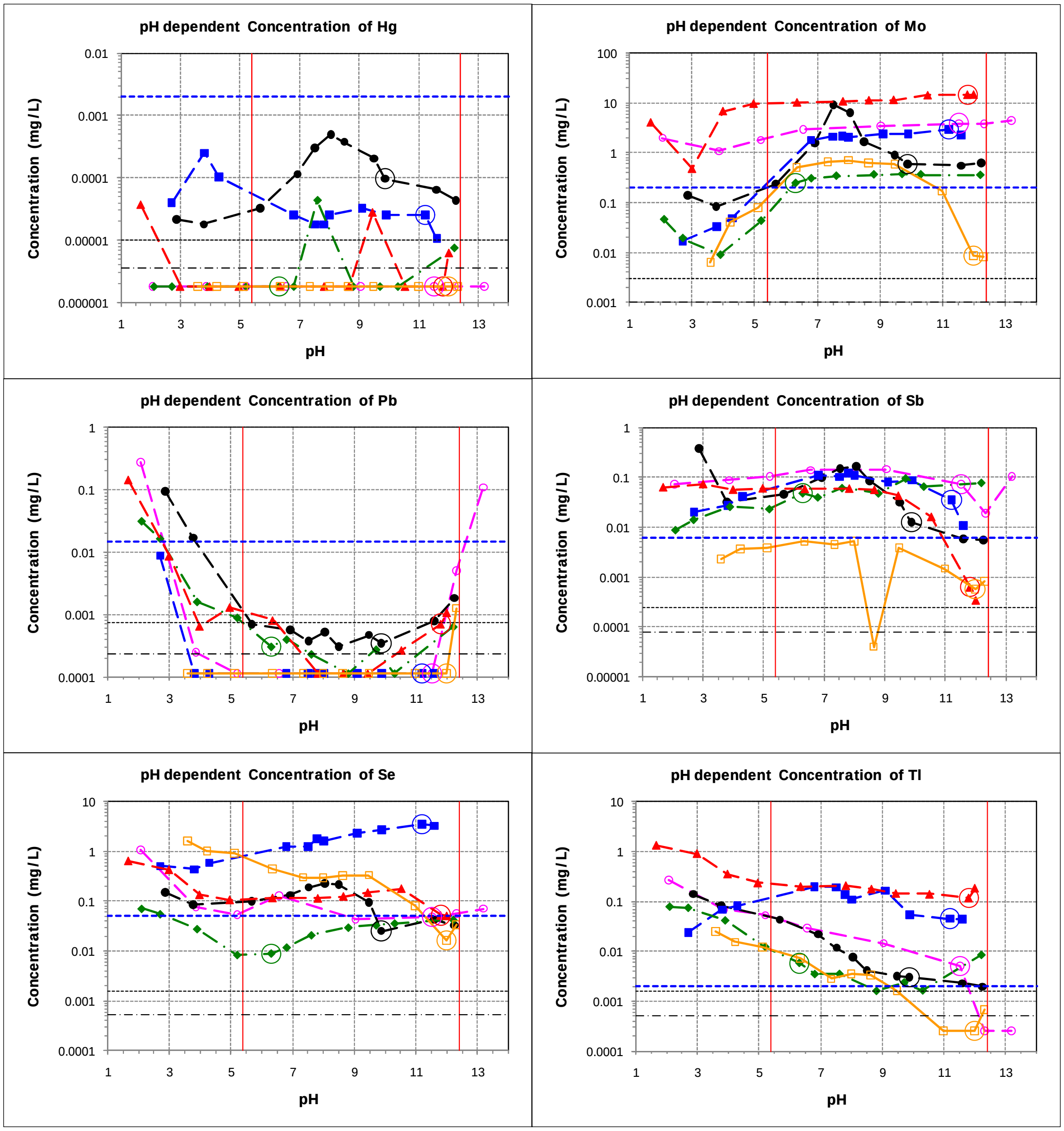


Figure 41 (continued). pH dependent leaching results. Selected results to illustrate characteristic leaching behavior.

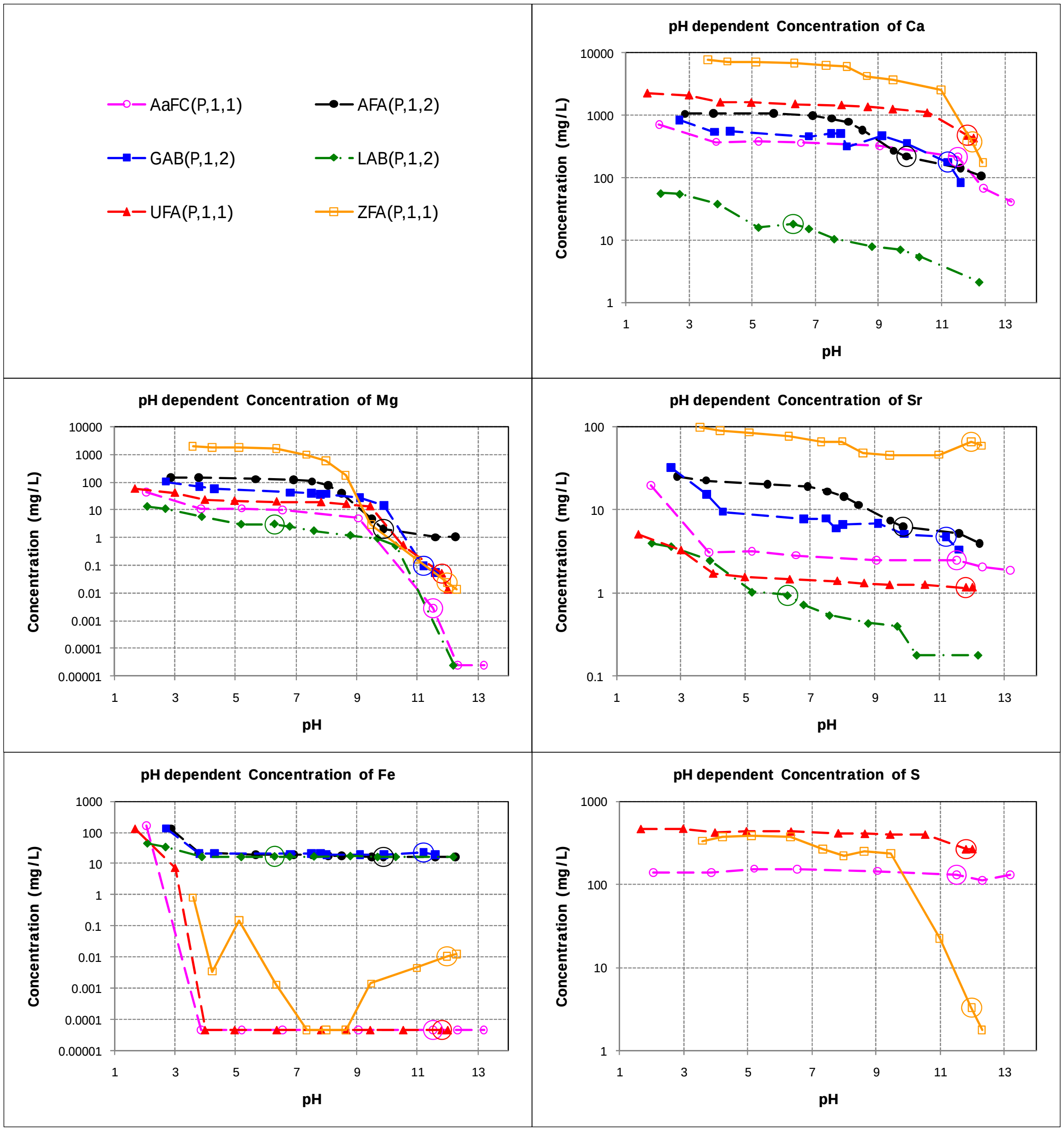


Figure 42. pH dependent leaching results. Selected results to illustrate characteristic leaching behavior of calcium, magnesium, strontium, iron, and sulfur.

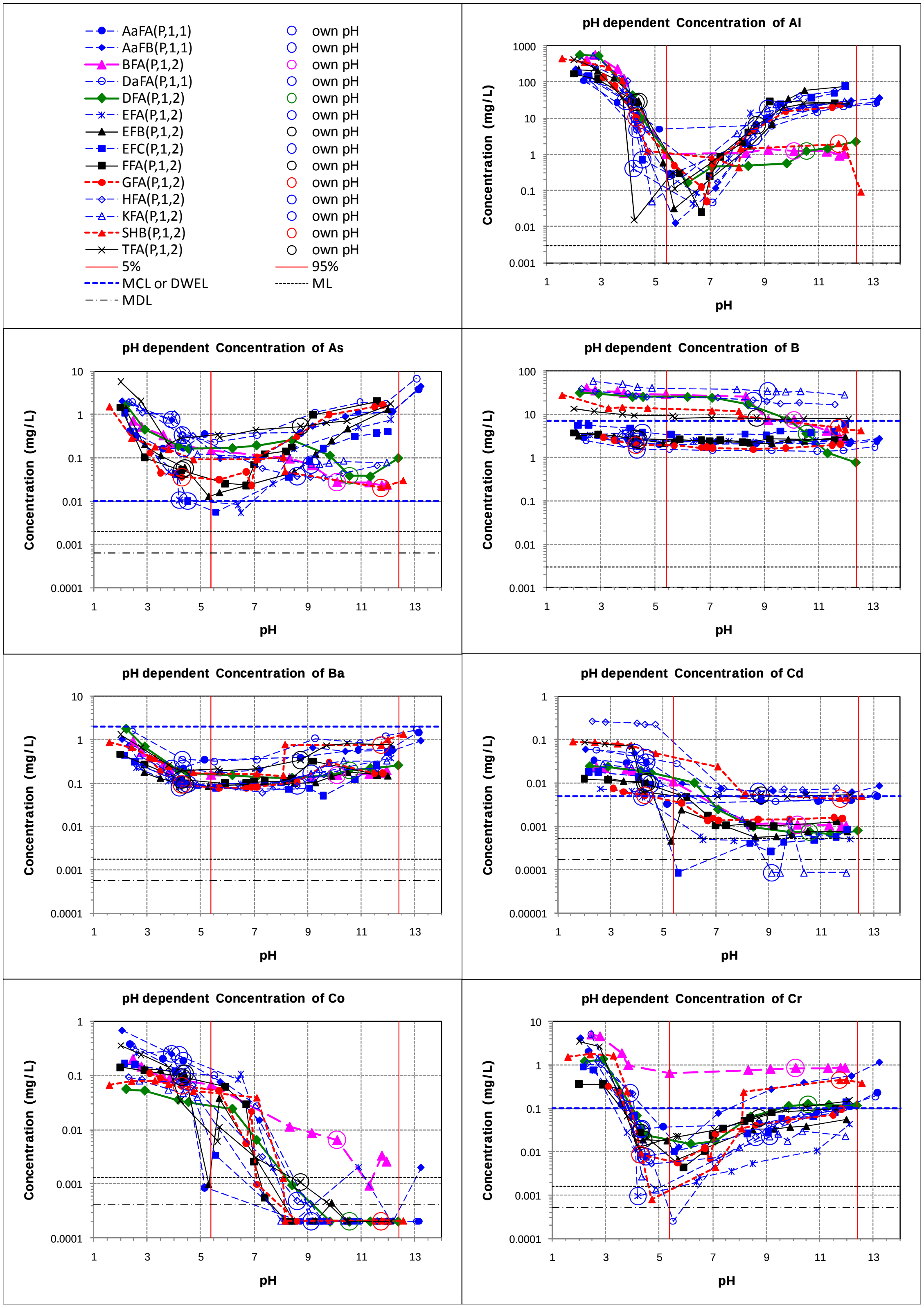


Figure 43. Effect of NO_x controls - none (or by-passed; samples DFA, EFB, FFA, TFA), SNCR (samples GFA, SHB) or SCR (all other samples) for facilities burning Eastern Bituminous coal and using CS-ESP for particulate control.

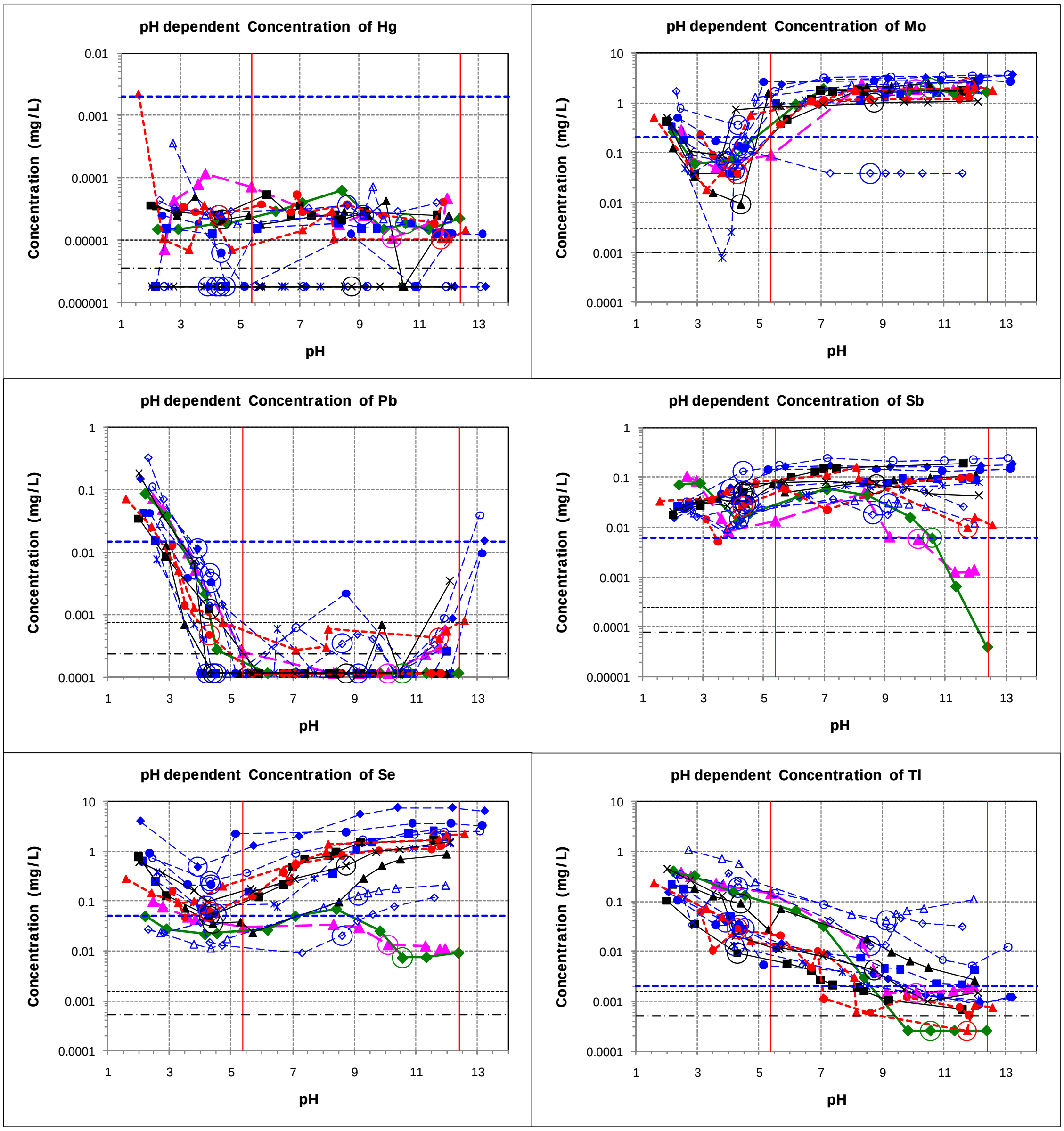


Figure 43 (continued). Effect of NO_x controls - none (or by-passed; samples DFA, EFB, FFA, TFA), SNCR (samples GFA, SHB) or SCR (all other samples) for facilities burning Eastern Bituminous coal and using CS-ESP for particulate control.

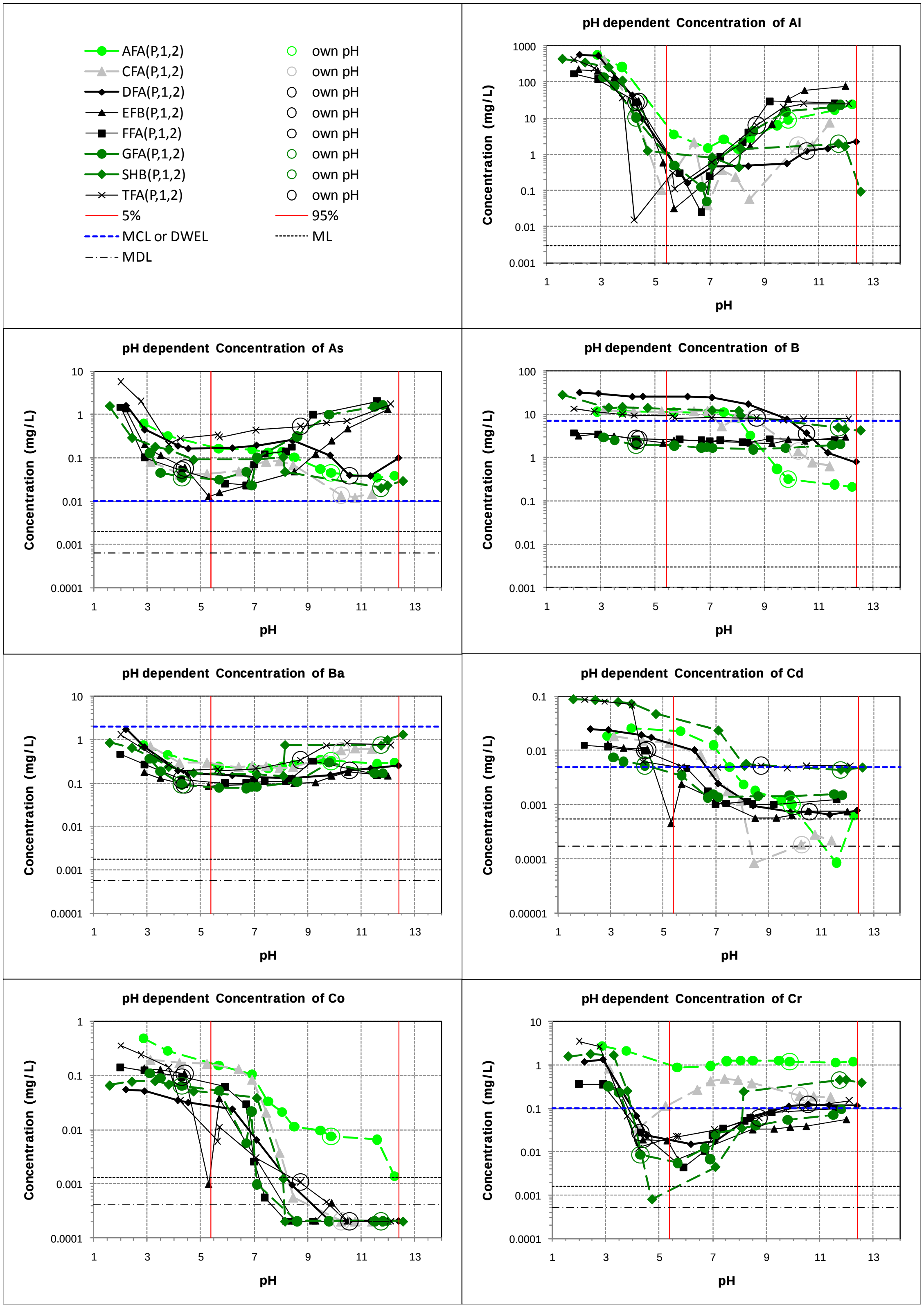


Figure 44. Effect of fabric filter vs. CS-ESP (fabric filter without NO_x control, sample CFA; with SNCR, sample AFA; CS-ESP without NO_x control, samples DFA, EFB, FFA, TFA; with SNCR, samples GFA, SHB) for facilities burning Eastern Bituminous coal.

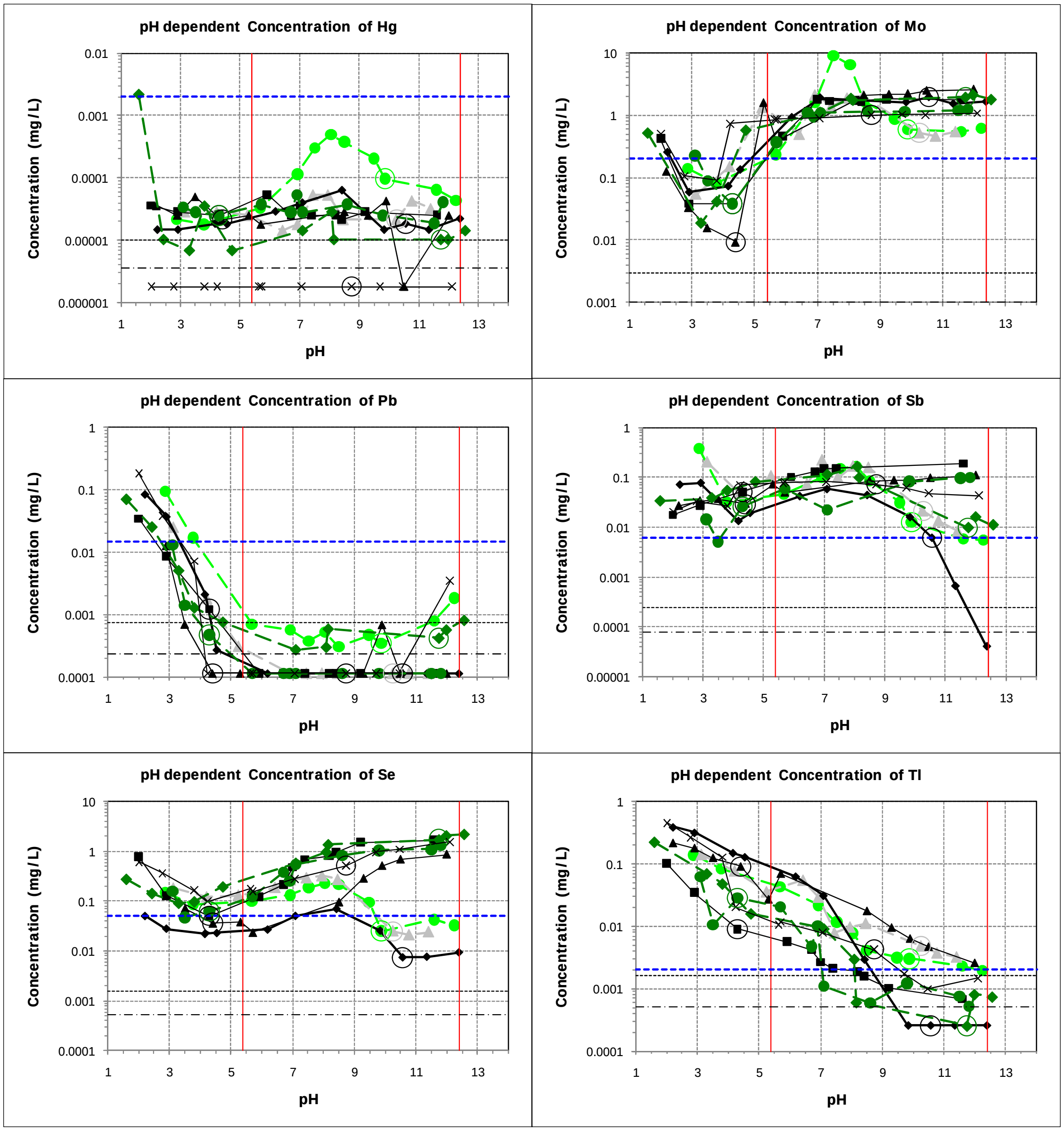


Figure 44 (continued). Effect of fabric filter vs. CS-ESP (fabric filter without NO_x control, sample CFA; with SNCR, sample AFA; CS-ESP without NO_x control, samples DFA, EFB, FFA, TFA; with SNCR, samples GFA, SHB) for facilities burning Eastern Bituminous coal.

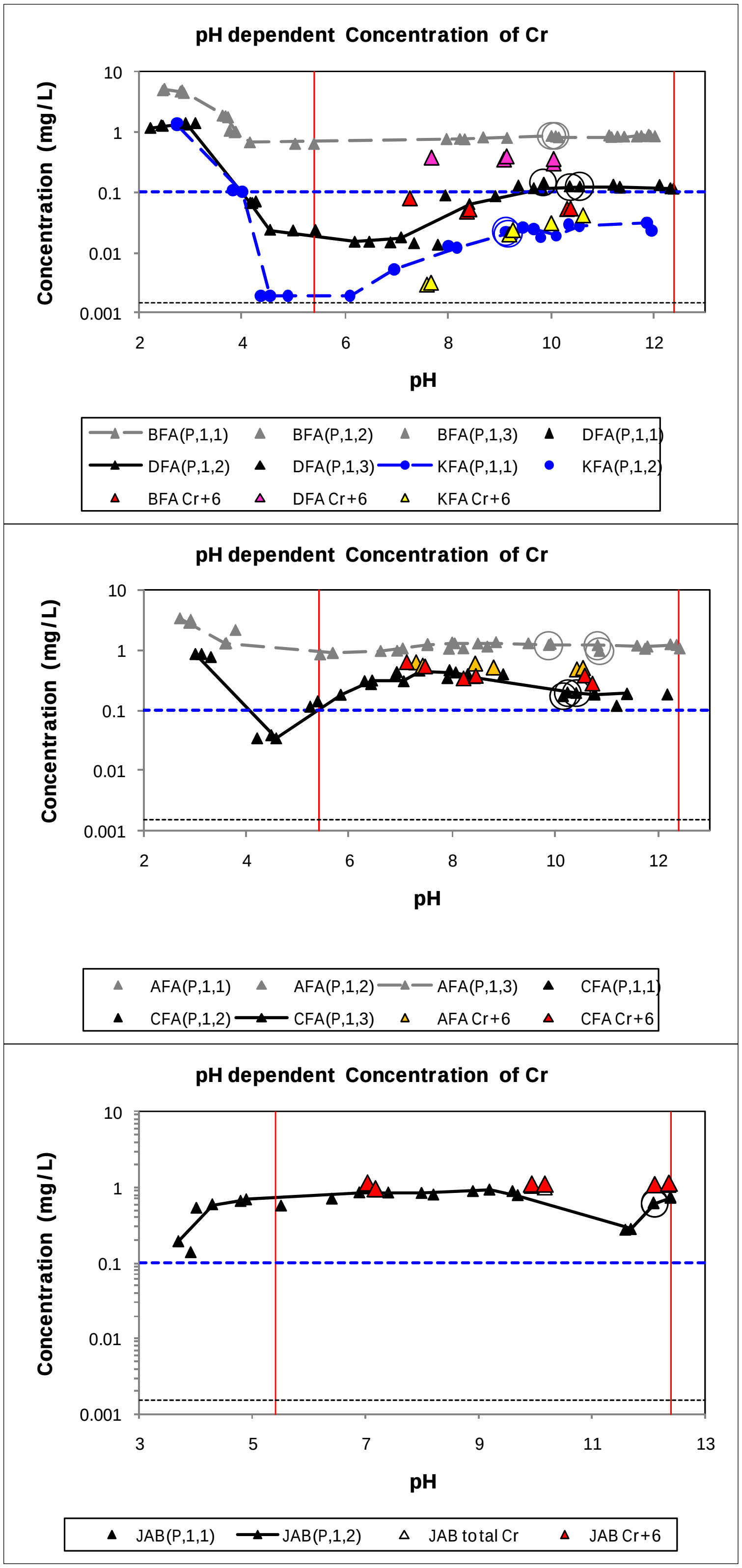


Figure 45. Chromium speciation results. Bituminous coal: Facility B with SCR (BFA), with SCR-BP (DFA); Facility K with SCR (KFA); Facility A with SNCR (AFA), with SNCR-BP (CFA). Sub-bituminous coal: Facility J with SCR (JAB).

3.2.1.2. Fly ash without and with Hg Sorbent Injection Pairs

Figure 46 presents comparisons of leaching behavior as a function of pH for fly ash without and with Hg sorbent injection pairs for each of the 13 elements of interest. For each facility, the baseline case and the treatment case (with Hg sorbent injection), either activated carbon injection or brominated activated carbon injection for facilities J and L, are compared. Also, note that Facilities C and Ba use COHPAC air pollution control configuration. Report 1 (Sanchez *et al.*, 2006) provided results for Hg, As, and Se. The discussion below expands the list to also include Al, B, Ba, Cd, Co, Cr, Mo, Pb, Sb, and Tl.

Considering the results provided in Appendix F and comparisons in Figure 46, the following observations were made.

Aluminum (Al). Al eluate concentrations as a function of pH showed typical amphoteric behavior. For Brayton Point and Facility C, the cases with ACI showed overall an increase in Al concentrations compared to the same facility without. For Facilities J and L, no significant change was observed, while a corresponding decrease was seen for Pleasant Prairie.

Arsenic (As). There was not a consistent pattern with respect to the effect of ACI on the range of laboratory eluate concentrations. For Salem Harbor and slightly for Pleasant Prairie facilities, the cases with ACI had an increase in the upper bound of eluate concentrations compared to the same facility without ACI. For Brayton Point and Facilities C and J, a corresponding decrease was observed.

Very low eluate concentrations were observed for the Facility J without and with brominated PAC, even though the total arsenic content was comparable to several of the other cases. Conversely, relatively high eluate concentrations were observed for Facility L without and with brominated PAC, even though the total arsenic concentration was low compared to the other cases. Thus, the presence of other constituents in the CCRs or the formation conditions appears to have a strong influence on the release of arsenic.

The range of arsenic concentrations observed in the laboratory eluates is consistent with the range of values reported for field leachates from landfills and impoundments. For some cases, both laboratory (Salem Harbor, Facility C, Facility L) and field concentrations exceeded the MCL by greater than a factor of 10. The expected range of arsenic concentrations under field conditions is less than 10 µg/L to approximately 1000 µg/L.

Arsenic leachate concentrations typically are strongly a function of pH over the entire pH range examined and within the pH range observed for field conditions. For some cases (for example, see Facility J, Appendix F), measured concentrations of arsenic are strongly a function of LS ratio at the material's natural pH, with much greater concentrations observed at low LS ratio. Therefore, testing at a single extraction final pH or LS ratio would not provide sufficient information to characterize the range of expected leachate concentrations under field conditions. Furthermore, for some of the CCRs a shift from the CCR's natural pH within the range of anticipated conditions (e.g., Facility L, Brayton Point with ACI, Salem Harbor baseline, Facility C baseline) can result substantial increases in leachate concentrations. Therefore, co-disposal of these CCRs with other materials should be carefully evaluated.

For several cases [Brayton Point, Salem Harbor, Facility C (without ACI), Facility L], arsenic concentrations in laboratory eluates appear to be controlled by solid phase solubility, while adsorption processes appear to play a more important role for other cases [Pleasant Prairie, Facility C (with ACI), Facility J].

Boron (B). No significant effect of ACI on B eluate concentrations as a function of pH was observed, except for Brayton Point that showed an increase in B concentrations for $8 < pH < 12$ with ACI. Facility L showed the lowest B eluate concentrations with and without ACI (by a factor greater than 10). Most samples showed a relatively constant B concentrations over the entire pH range, except for the samples from Facility J showing an increase with decreasing pH for $9.5 < pH < 12$.

Barium (Ba). No significant effect of ACI on Ba eluate concentrations as a function of pH was seen, except for Pleasant Prairie for which a decrease in Ba concentrations was observed with ACI for $6 < pH < 11.5$ and Brayton Point for which a decrease was seen over the entire pH range examined. Sample BaFA (lignite, ACI + COHPAC) had the greatest Ba release for $pH < 7$ and $pH > 12$ (above the MCL).

Cadmium (Cd). For Salem Harbor, the case with ACI had an increase in Cd eluate concentrations for $pH > 4.5$ compared to the same facility without ACI. For Brayton Point a decrease in Cd concentrations was observed with ACI for $pH < 7$. No significant effect of ACI was seen for the other facilities tested.

Cobalt (Co). Sample BaFA (lignite, ACI + COHPAC) showed the greatest Co eluate concentrations for all pHs examined. No significant effect of ACI on Co eluate concentrations was observed, except for Brayton Point that showed a decrease in Co concentration with ACI.

Chromium (Cr). For most cases a decrease in Cr eluate concentrations was observed for the cases with ACI compared to the same facility without ACI. Facility C showed, however, an increase in Cr concentrations for $pH > 7$ for the case with ACI.

Mercury (Hg). Although the use of activated carbon injection substantially increases the total Hg content in the fly ashes, the range of laboratory leaching eluate concentrations in the baseline cases and cases with sorbent injection are either unchanged or the maximum leaching concentration is reduced as a consequence of activated carbon injection. The exceptions are Facility C and Facility L, which have an increased maximum eluate concentration for the case with sorbent injection.

The expected range of Hg leachate concentrations based on these results is from < 0.004 (below MDL) to 0.2 µg/L over the range of pH conditions expected in coal ash landfill leachate.

The range of Hg concentrations observed from laboratory eluates is consistent with the range reported for field leachates from landfills in the EPRI database.

All concentrations observed in laboratory leach test eluates from fly ash over $5.4 \leq pH \leq 12.4$ were at least an order of magnitude less than the MCL.

For all cases of laboratory eluates, Hg concentrations in eluates from fly ash were consistent without any significant effect of total mercury content, pH, or LS ratio observed. Mercury leaching appears to be controlled by adsorption from the aqueous phase with strong interaction between adsorbed mercury molecules, indicating that use of a linear partition coefficient (K_d) approach to model source term mercury leaching would not be appropriate. Variability observed in concentrations observed within individual cases is likely the result of sampling and CCR heterogeneity at the particle scale (i.e., resulting from mercury adsorption specifically onto carbon surfaces and relatively more or less carbon particles in a specific subsample used for extraction).

Molybdenum (Mo). For all cases, there was no significant effect of ACI on Mo eluate concentrations as a function of pH.

Lead (Pb). Minimal Pb leaching was overall observed. In most cases, Pb leaching was at or below the MDL for 4 < pH < 12. For Facility J, the case with ACI showed an increase in Pb eluate concentrations for 4 < pH < 10 compared to the same facility without.

Antimony (Sb). There was no significant effect of ACI on Sb eluate concentrations, except for Salem Harbor that showed an increase in Sb concentrations with ACI over the entire pH range and Brayton Point for which an increase in Sb concentrations for pH > 8 and a decrease for pH < 7.5 was observed with ACI.

Selenium (Se). The range of selenium concentration in laboratory leach test eluates is not correlated with total selenium content in the CCRs. For example, Brayton Point with ACI had much greater total selenium content than the other cases except Facility C with ACI, but had only the fifth highest selenium concentration under the laboratory leaching conditions. Conversely, Facility C baseline had one of the lowest selenium total content (less than MDL) but had second greatest selenium concentration under the laboratory leaching conditions.

The range of selenium concentrations observed in laboratory leach test eluates for Facility C are much greater than the concentrations observed for other cases and for field conditions. This is a COHPAC facility and field leachate composition data for CCRs from this type of facility were not available in the EPA or EPRI databases. For all other facilities, the range of concentrations observed from laboratory testing is consistent with the range reported in the EPRI database for landfills. The concentration range reported in the EPA database for CCR landfills has a much lower upper bound than reported in the EPRI database.

The concentration range for laboratory eluates and field observations exceeded the MCL for all cases except Facility L. For 5 out of 12 of the cases used for laboratory evaluation, and for some field observations, the MCL is exceeded by more than a factor of 10.

Selenium concentrations in laboratory leach test eluates typically are strongly a function of pH over the entire pH range examined and within the pH range observed for field conditions (for example, see leaching test results for Brayton Point, Salem Harbor, Facility C). For some cases (for example, see Brayton Point, Salem Harbor, and Facility J in Appendix F), measured concentrations of selenium are strongly a function of LS ratio at the material’s natural pH, with much greater concentrations observed at low LS ratio. Therefore, testing at a single extraction final pH or LS ratio would not provide sufficient information to characterize the range of expected leachate concentrations under field conditions.

For several cases (Brayton Point, Salem Harbor, Facility C, Facility L) selenium concentrations in laboratory eluates appears to be controlled by solid phase solubility, while adsorption processes appear to play a more important role for other cases (Pleasant Prairie and Facility J).

Thallium (Tl). For Pleasant Prairie, the case with ACI resulted in an increase in Tl concentrations over the entire pH range compared to the same facility without ACI. For Facility J, a decrease in Tl eluate concentrations with ACI was observed for all pHs examined. For Brayton Point, the case with ACI showed an increase in Tl concentrations for pH > 10 and a decrease for pH < 9.

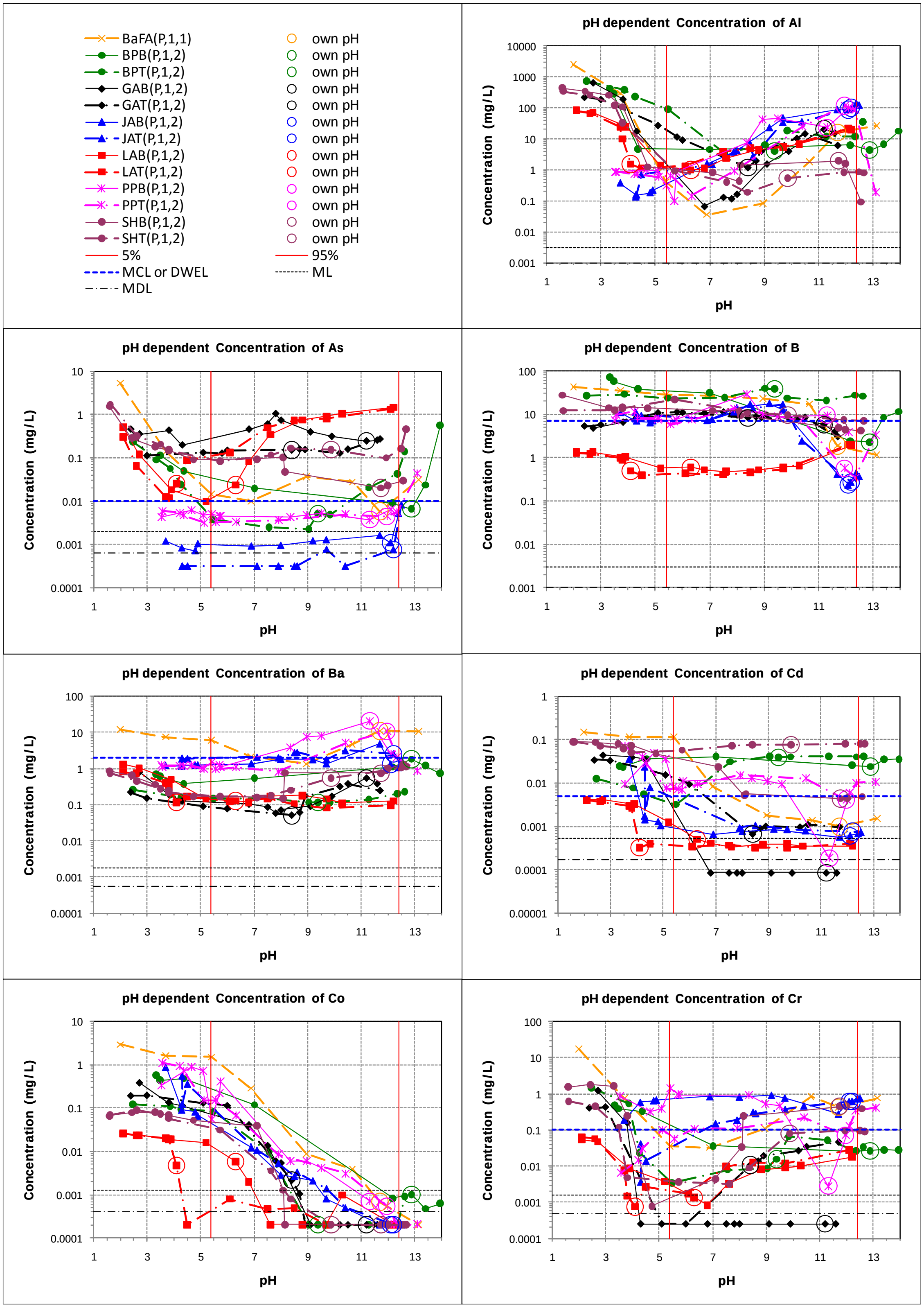


Figure 46. pH dependent leaching results. Fly ash samples from facility pairs with and without mercury sorbent injection. Sample codes ending __B (BPB) indicate without sorbent injection; Sample codes ending __T (BPT) indicate with sorbent injection for the corresponding facility.

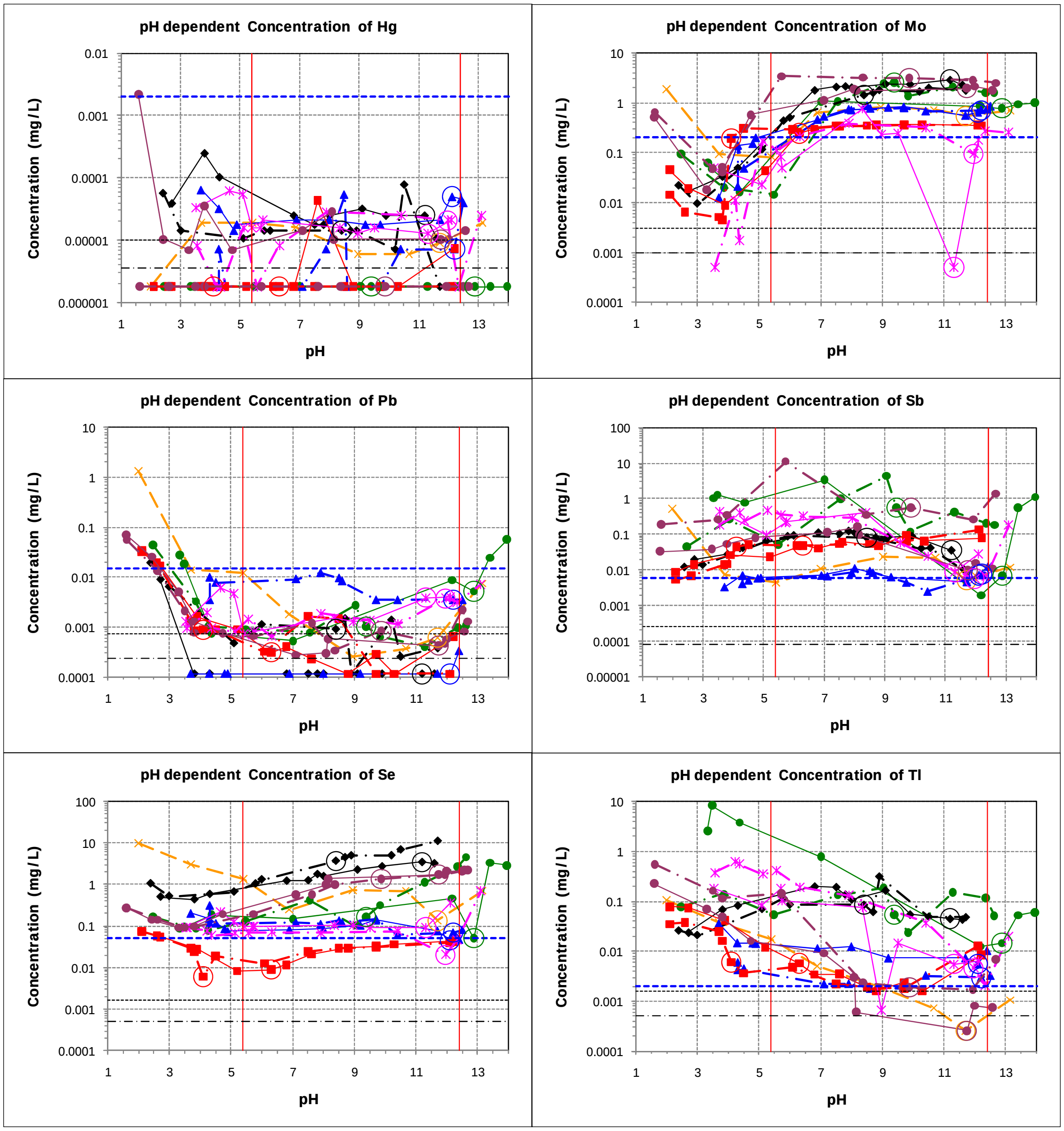


Figure 46 (continued). pH dependent leaching results. Fly ash samples from facility pairs with and without mercury sorbent injection. Fly ash samples from facility pairs with and without mercury sorbent injection. Sample codes ending __B (BPB) indicate without sorbent injection; Sample codes ending __T (BPT) indicate with sorbent injection for the corresponding facility.

3.2.1.3. Gypsum, Unwashed and Washed

The effect of the washing step on the leaching behavior of gypsum as a function of pH for each of the 13 elements of interest is illustrated in Figure 47, Figure 48, and Figure 49. Typically, washing resulted in at least an order of magnitude reduction in the observed leached concentrations for the soluble species (e.g., B, Tl) and the oxyanions (e.g., Se). B and Tl release from both unwashed and washed gypsum were generally relatively constant as a function of pH for most facilities. Se release was either relatively constant as a function of pH (Facilities O, P) or amphoteric (Facilities N, Q).

The washing step resulted, however, in greater leaching concentrations of Hg ($7 < pH < 10$) and Cr ($4 < pH < 12$) for Facility X. Also, the washed gypsum sample from lignite (CaAW) showed a greater release for Pb and Se compared to washed and unwashed gypsum samples from facilities using high sulfur bituminous or sub-bituminous coal.

The unwashed sample from Facility W (WAU) showed greater concentrations of As, Pb, and Tl, which was most likely a consequence of the Trona injection used for SO_3 control by this facility.

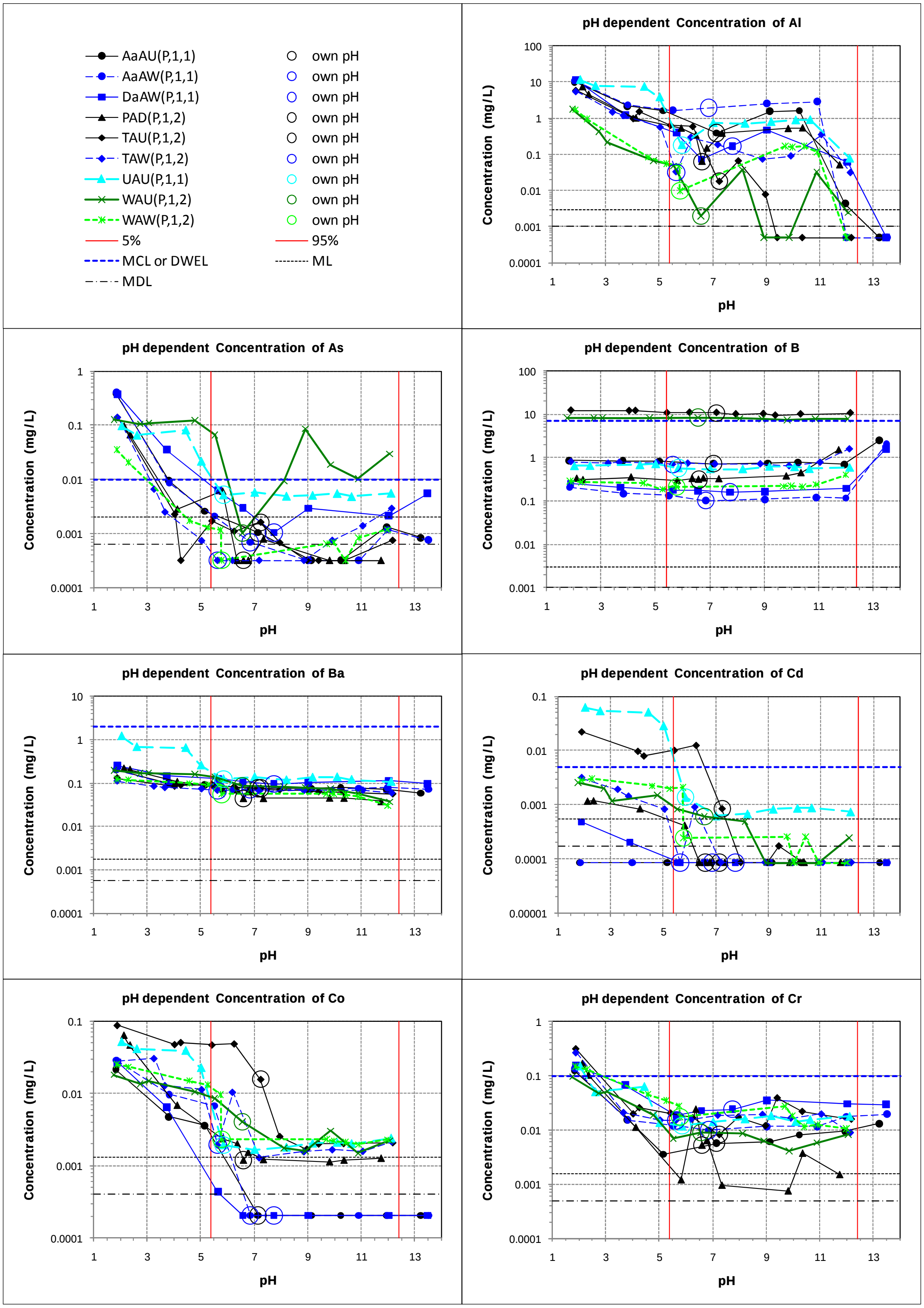


Figure 47. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using low and medium sulfur bituminous coals.

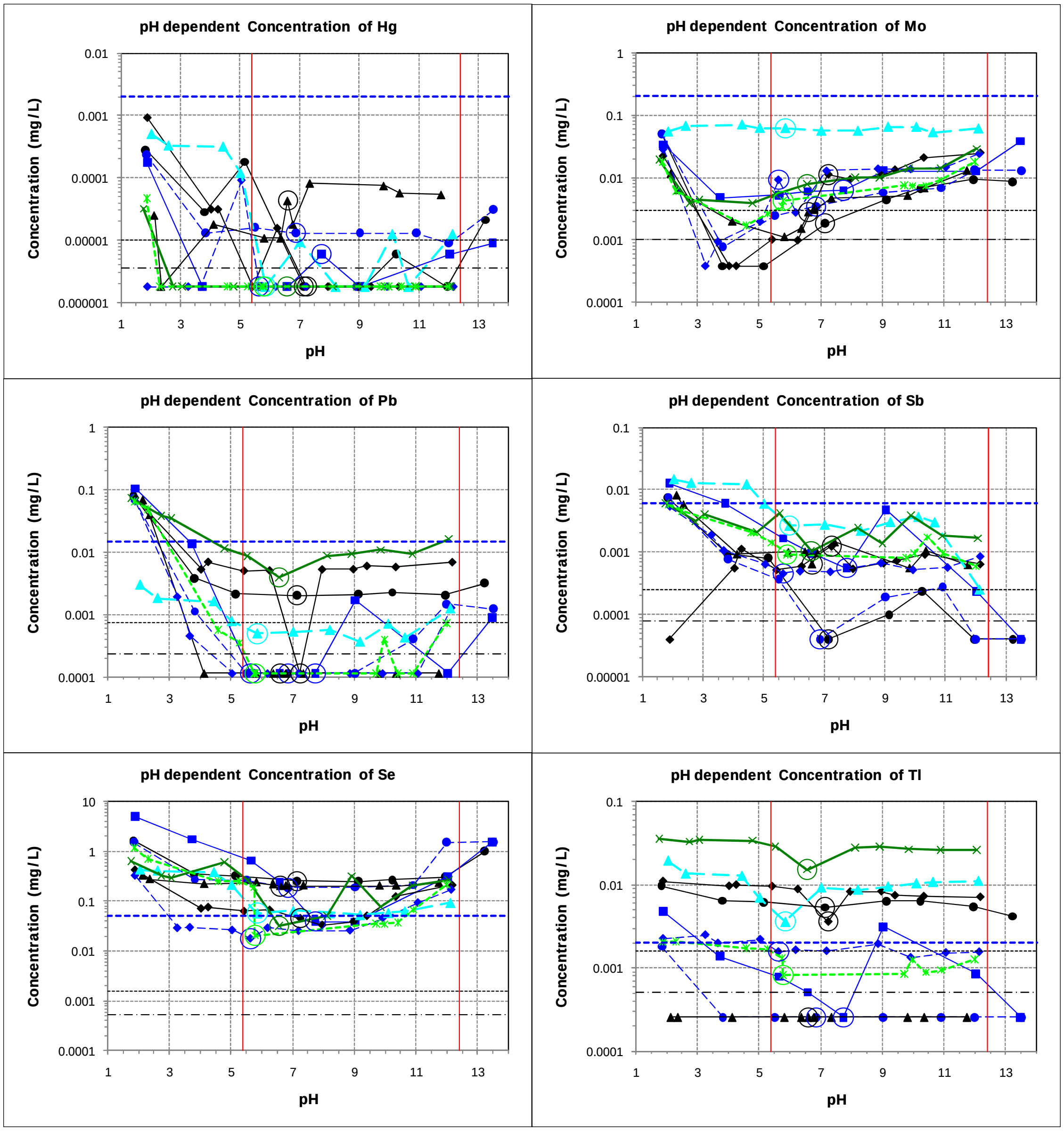


Figure 47 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using low and medium sulfur bituminous coals.

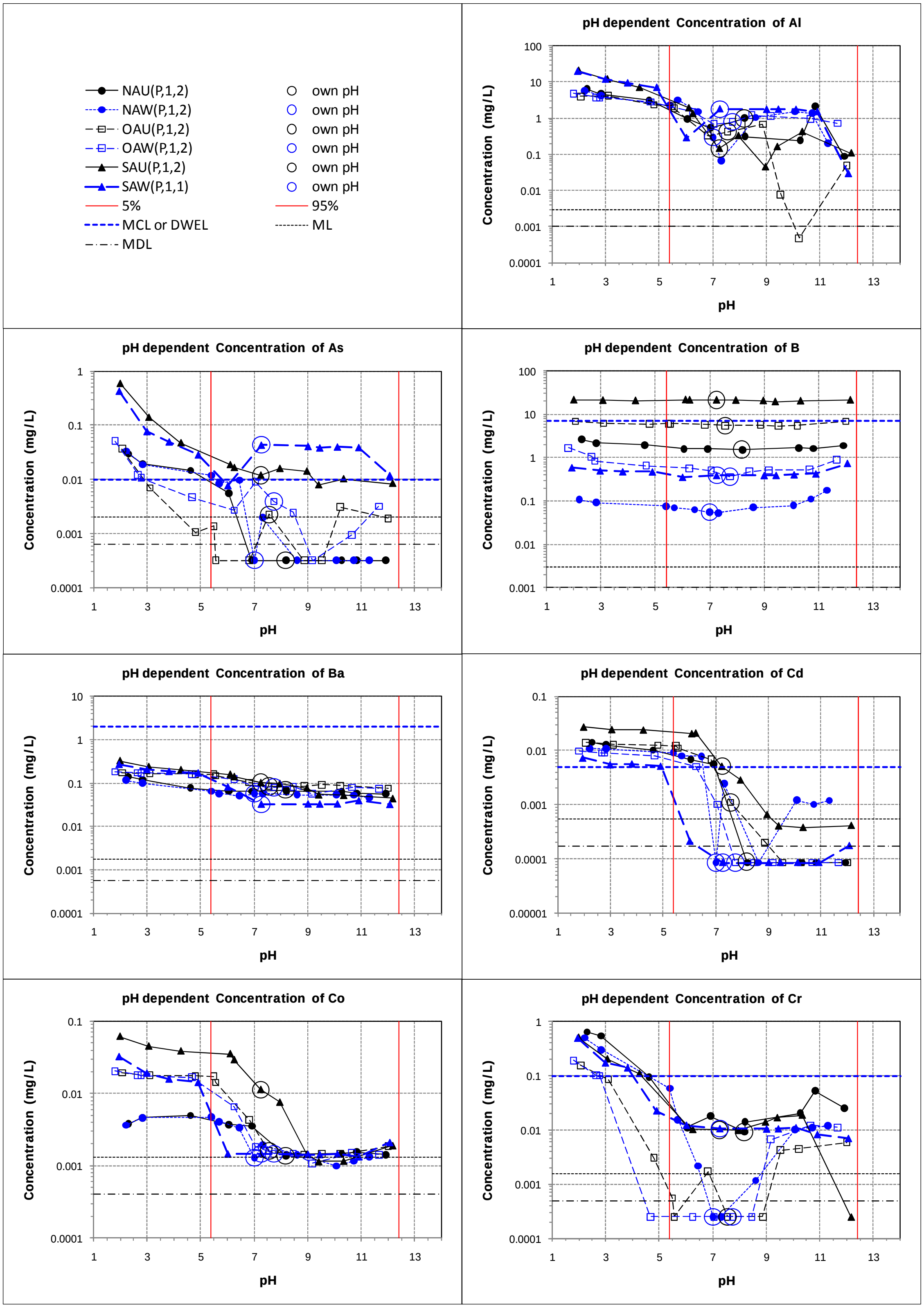


Figure 48. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using high sulfur bituminous coal.

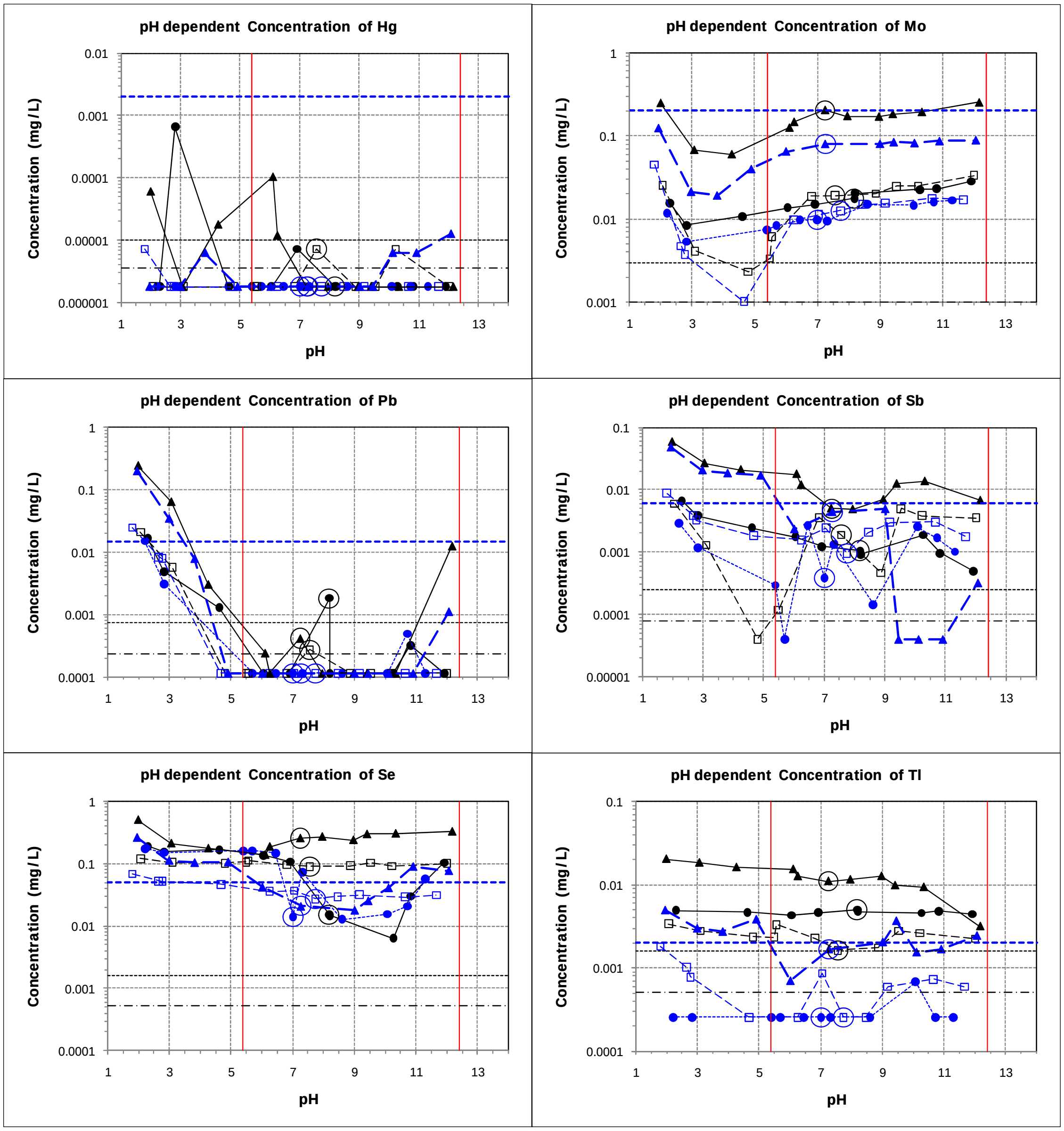


Figure 48 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using high sulfur bituminous coal.

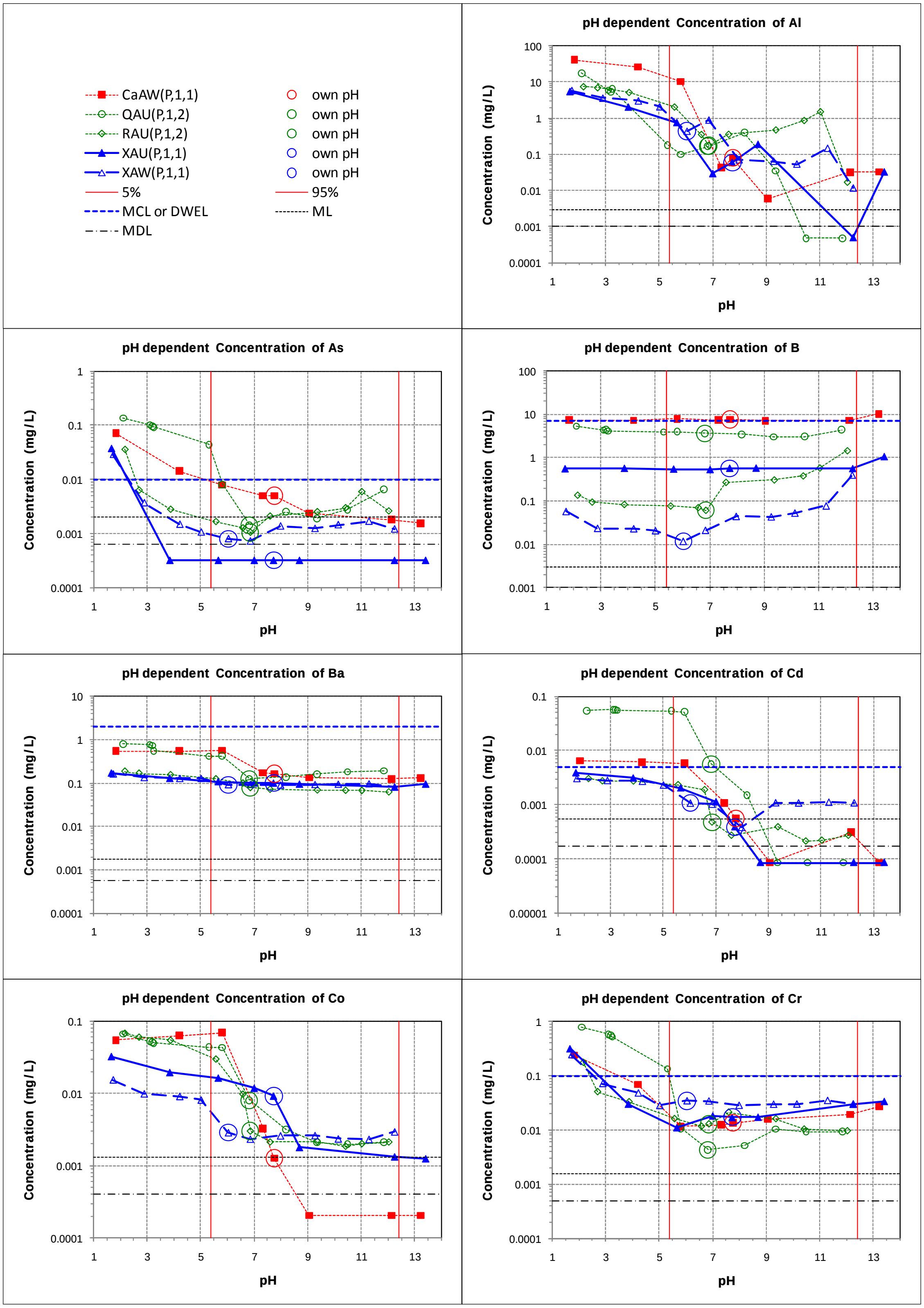


Figure 49. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using sub-bituminous and lignite bituminous coals.

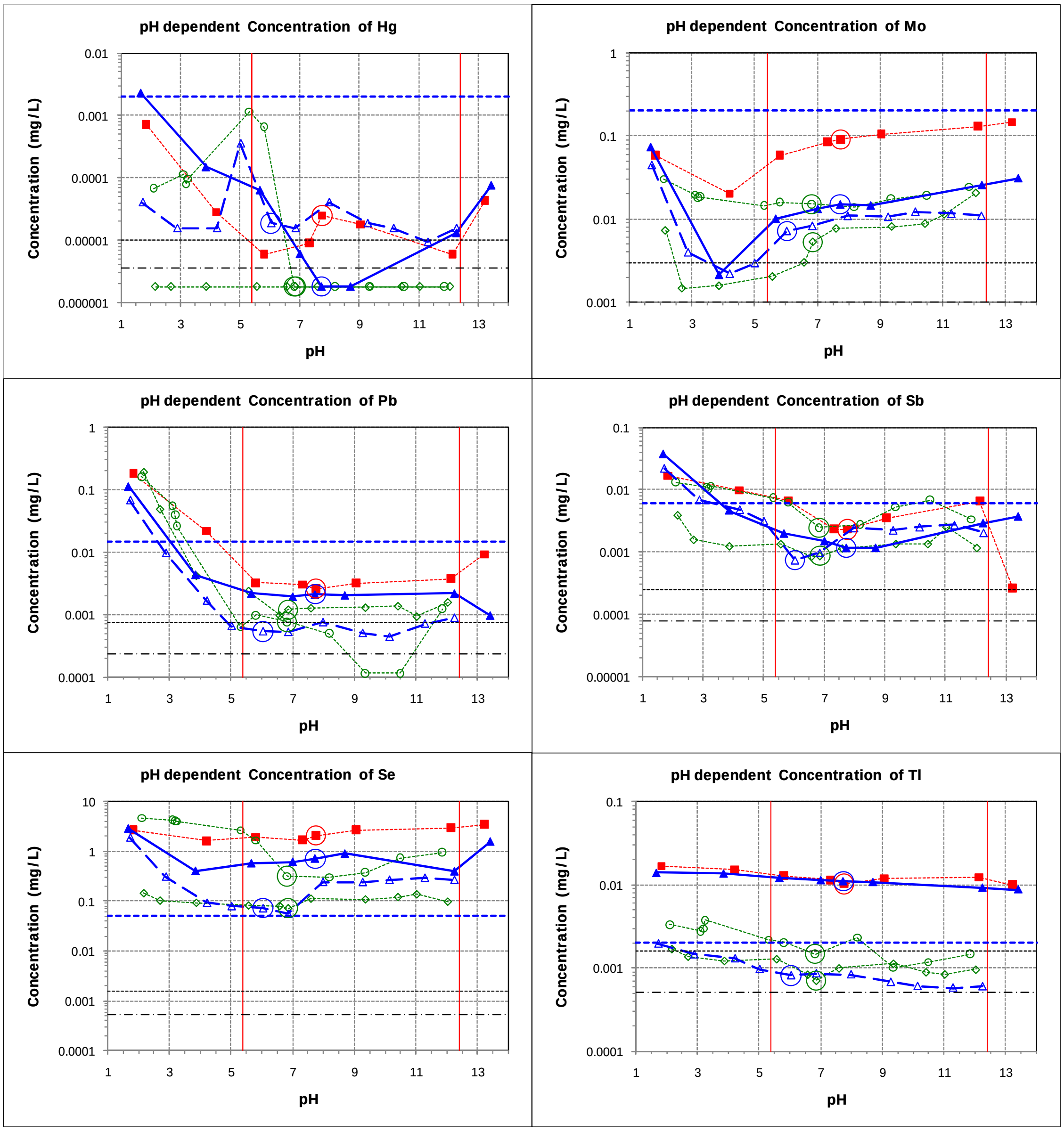


Figure 49 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using sub-bituminous and lignite bituminous coals.

3.2.1.4. Scrubber Sludge

Figure 50 presents results of the leaching behavior as a function of pH for the scrubber sludge samples. The effect of SNCR in combination with a fabric filter (AGD *vs*. CGD) was manifested by (i) a significant increase in the leaching concentrations of Cr over the entire pH range examined, (ii) a slight reduction in Hg, and (iii) an increase in Tl. An effect of SCR (BGD *vs*. DGD) was seen for As (slight increase with SCR), Ba (increase with SCR), Co (increase with SCR), and Cr (significant increase with SCR). Sample KGD exhibited the highest leaching concentrations for Ba, Cd, Co, Mo, Se, and Tl.

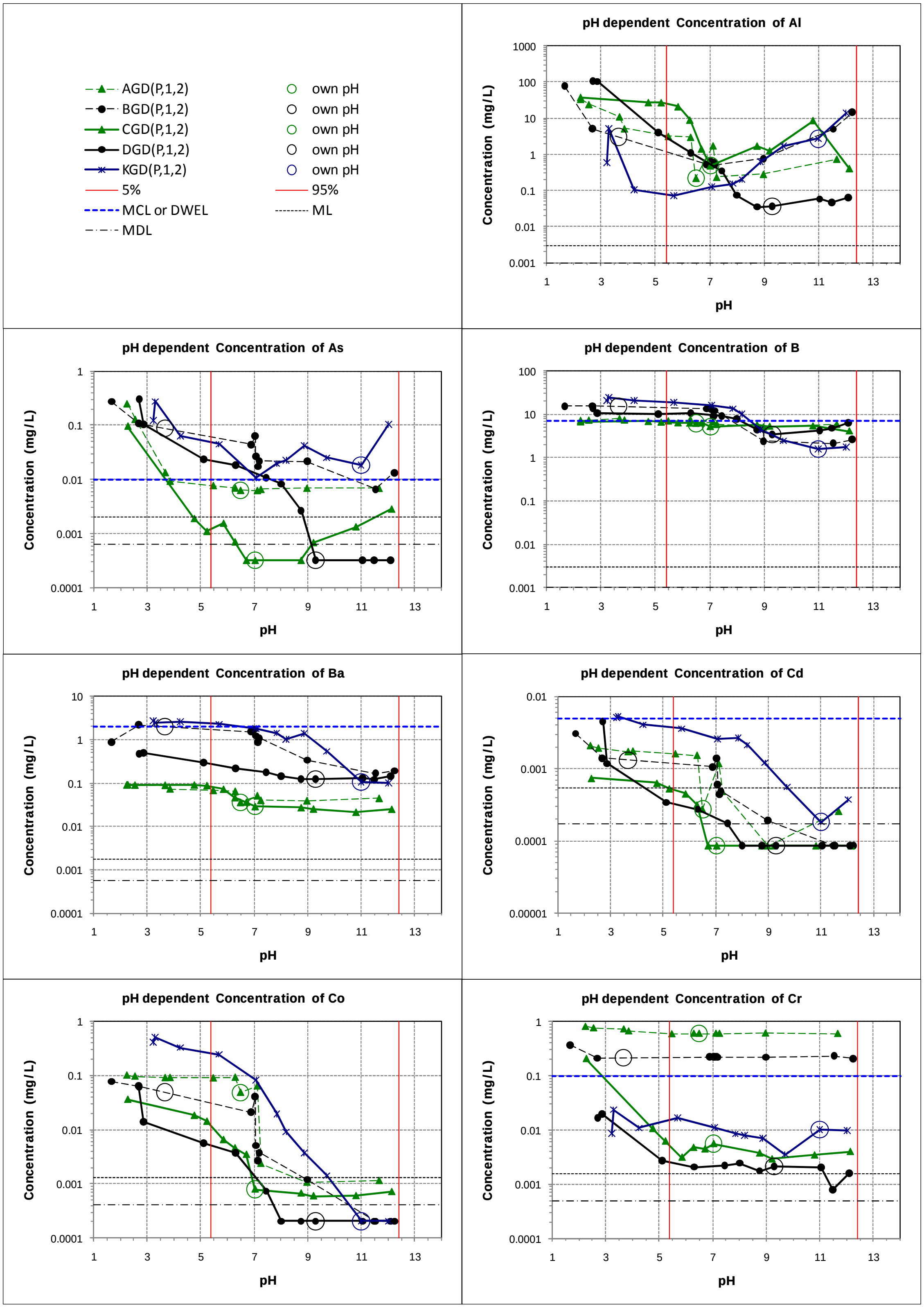


Figure 50. pH dependent leaching results. Scrubber sludges. Facility A (AGD, CGD), Facility B (BGD, DGD), Facility K (KGD). Samples DGD and KGD with SCR, Samples BGD with SNCR. Samples CGD and DGD without post-combustion NO_x controls.

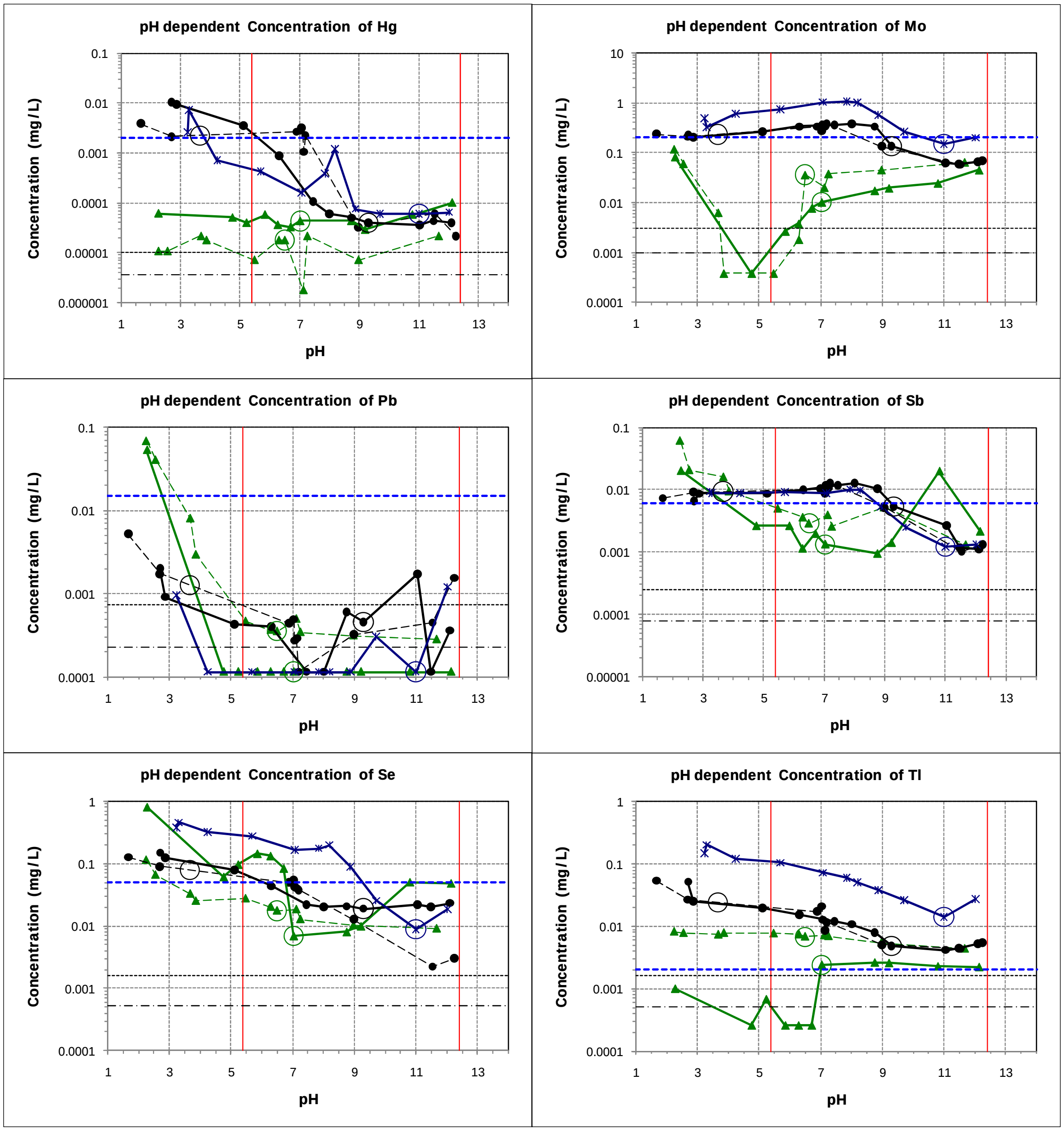


Figure 50 (continued). pH dependent leaching results. Scrubber sludges. Facility A (AGD, CGD), Facility B (BGD, DGD), Facility K (KGD). Samples DGD and KGD with SCR, Samples BGD with SNCR. Samples CGD and DGD without post-combustion NO_x controls.

3.2.1.5. Spray Dryer Absorber Residues

Figure 51 presents results of leaching behavior as a function of pH for spray dryer residue samples. Sample VSD showed a greater release of Al (9 < pH < 12), Ba (8 < pH < 12), Cr (pH < 6), and Tl (pH < 6) and a lower release of Co and Pb (4 < pH < 12) than sample YSD, though the two samples are from the same coal type and air pollution control configurations. The observed differences between the two samples could be due to differences in the lime used.

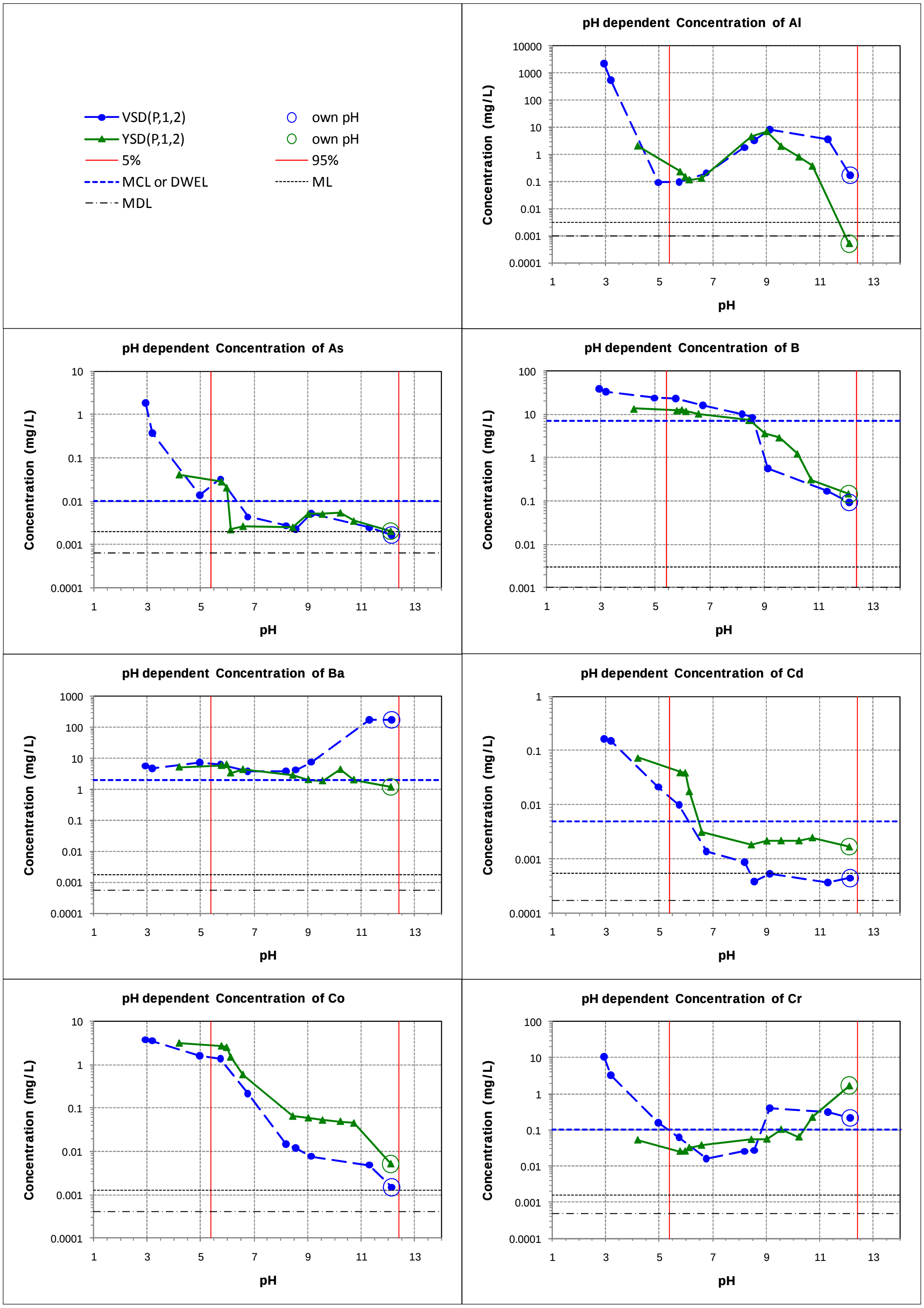


Figure 51. pH dependent leaching results. Spray dryer residue samples (sub-bituminous coal).

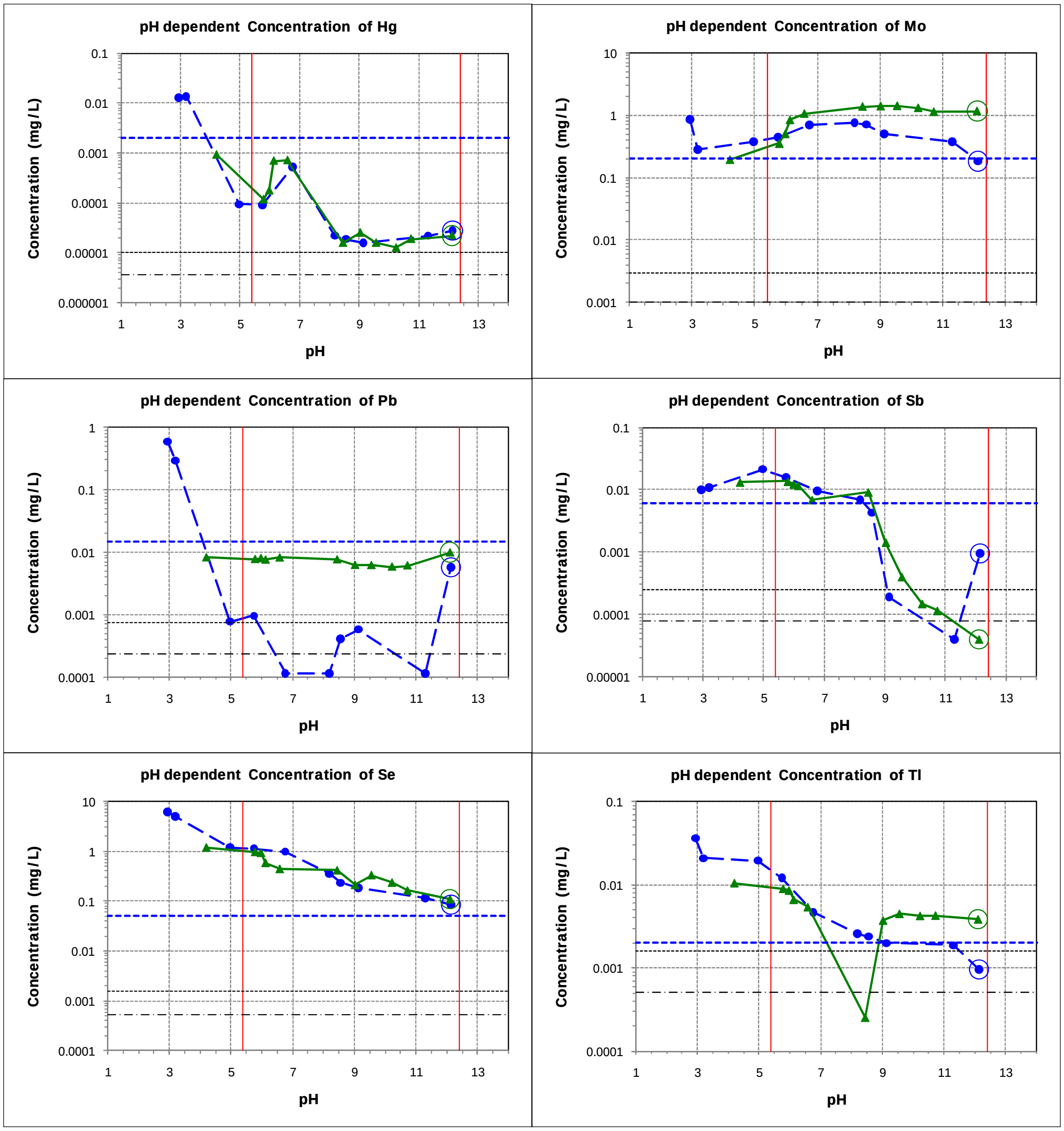


Figure 51 (continued). pH dependent leaching results. Spray dryer residue samples (sub-bituminous coal).

3.2.1.6. Blended CCRs (Mixed Fly Ash and Scrubber Sludge/Mixed Fly Ash and Gypsum)

The leaching behavior of the blended CCRs (mixed fly ash and scrubber sludge/mixed fly ash and gypsum) was mainly controlled by the behavior of the fly ash. This behavior is illustrated in Figure 52 (Facility A, SNCR-BP) that shows comparisons of pH dependent leaching results for fly ash (CFA), scrubber sludge (CGD), and blended fly ash and scrubber sludge (CCC). Results for the blended fly ash and gypsum can be found in Appendix F (UGF).

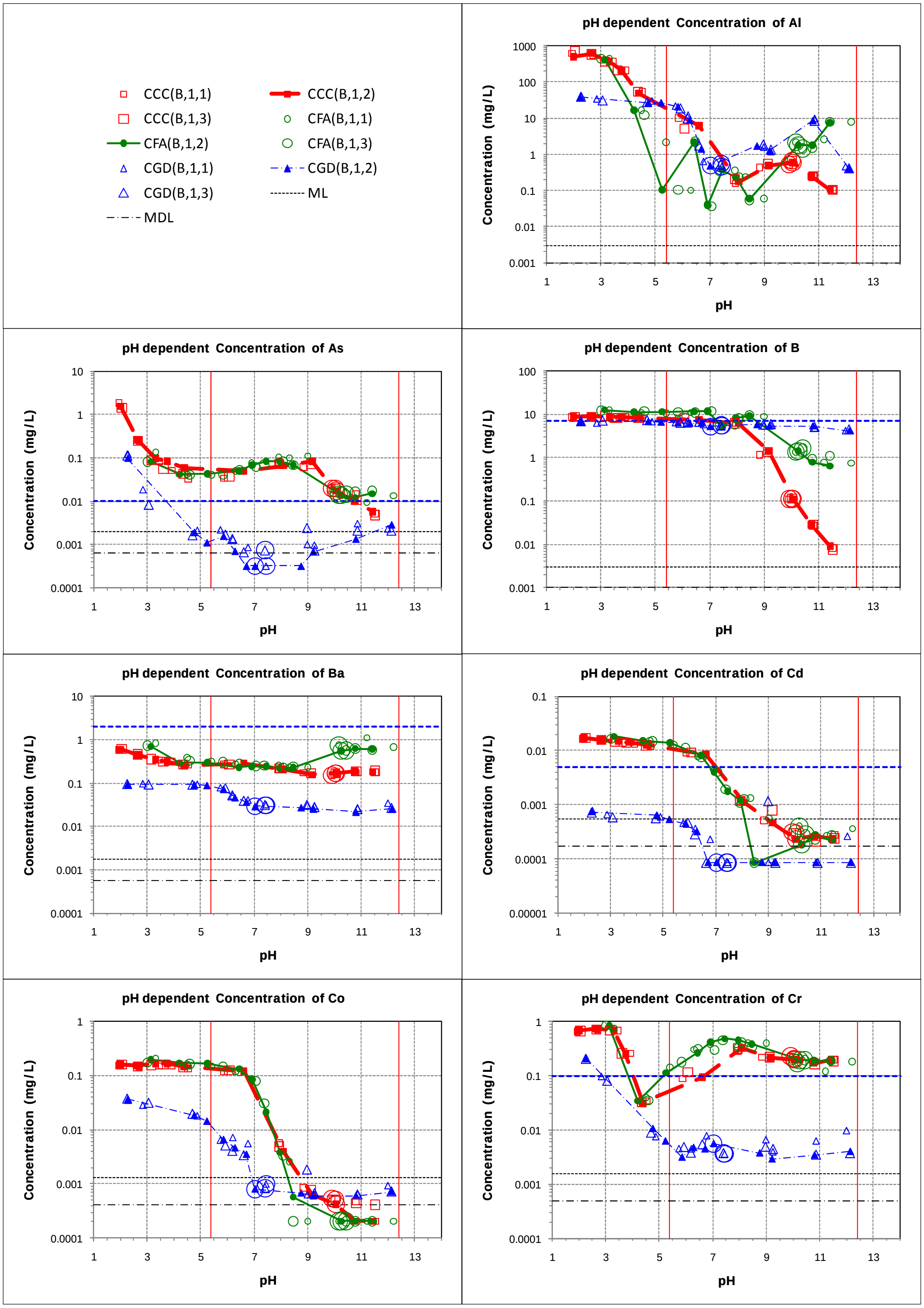


Figure 52. pH dependent leaching results. Facility A samples (low S east-bit., fabric filter, limestone, natural oxidation). SNCR-BP. Fly ash (CFA); scrubber sludge (CGD); blended fly ash and scrubber sludge (“as managed,” CCC).

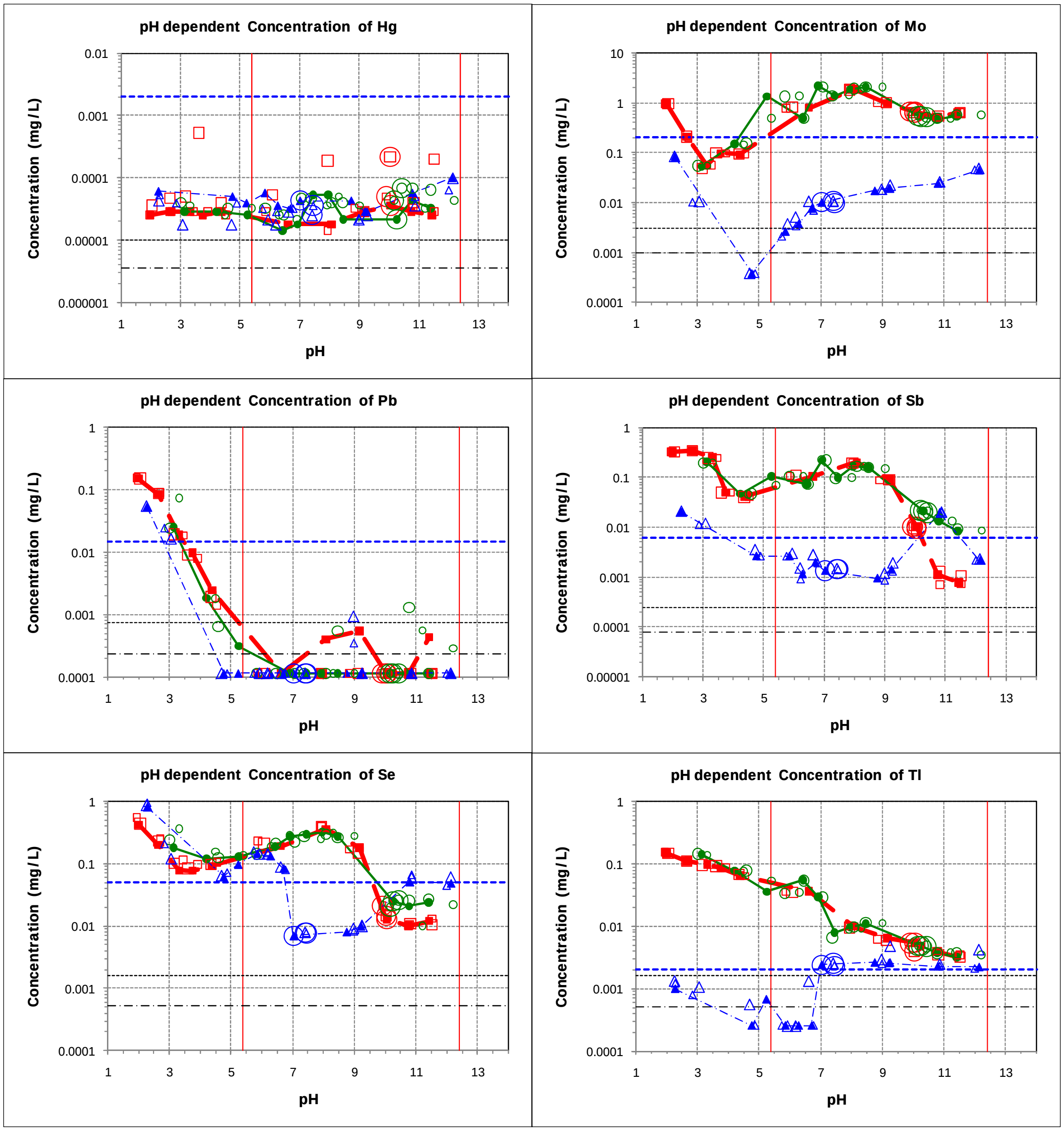


Figure 52 (continued). pH dependent leaching results. Facility A samples (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP. Fly ash (CFA); Scrubber sludge (CGD); Blended fly ash and scrubber sludge (“as managed,” CCC).

3.2.1.7. Waste Water Filter Cake

Figure 53 presents results of leaching behavior as a function of pH for waste water filter cake for each of the 13 elements of interest. These are samples with waste water treatment process associated with management of CCRs and are not a direct product of the air pollution control systems. Overall similar results were observed for all samples tested except for sample XFC that showed a greater release for Hg, Mo, Pb, and Se.

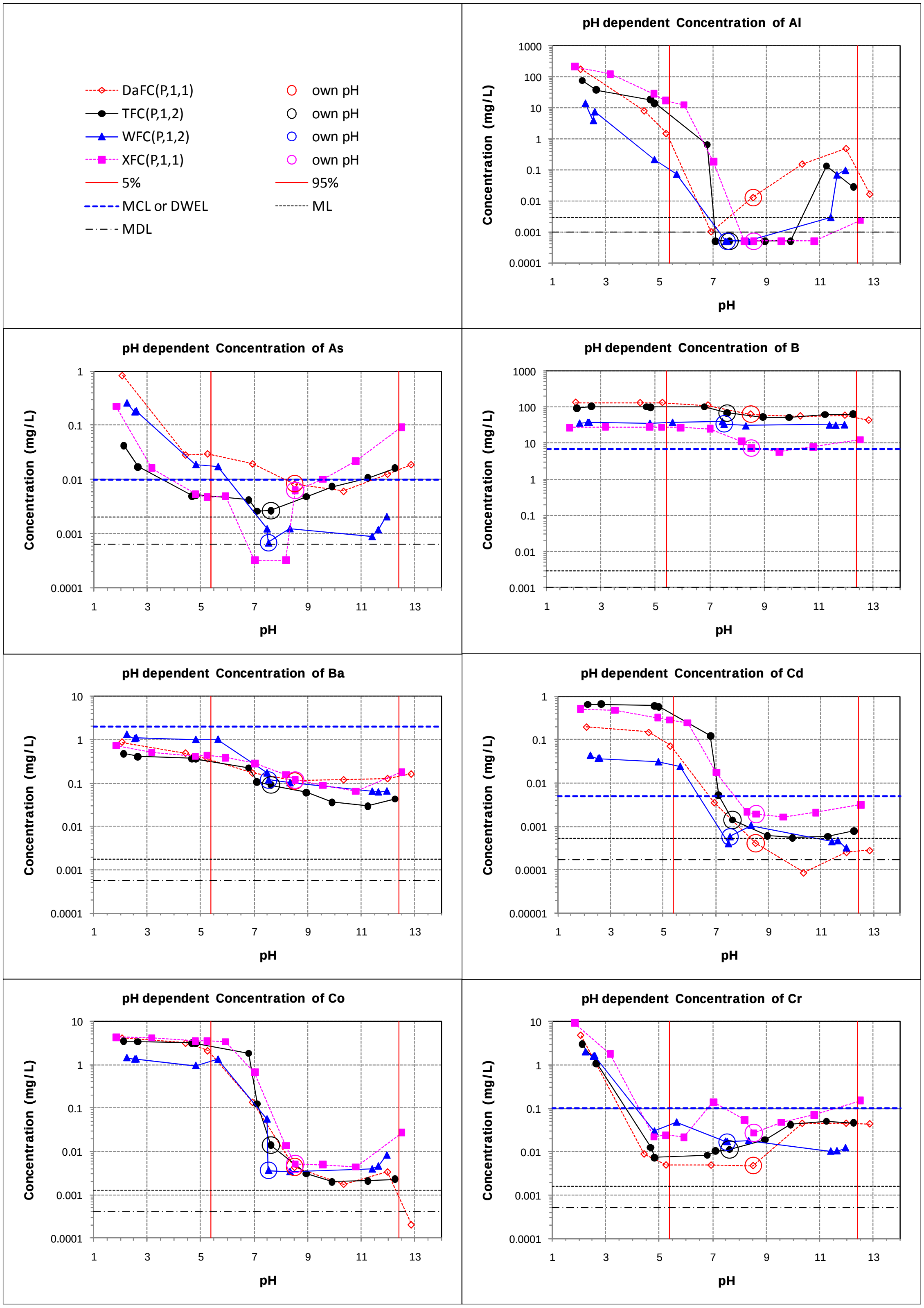


Figure 53. pH dependent leaching results. Filter cake samples.

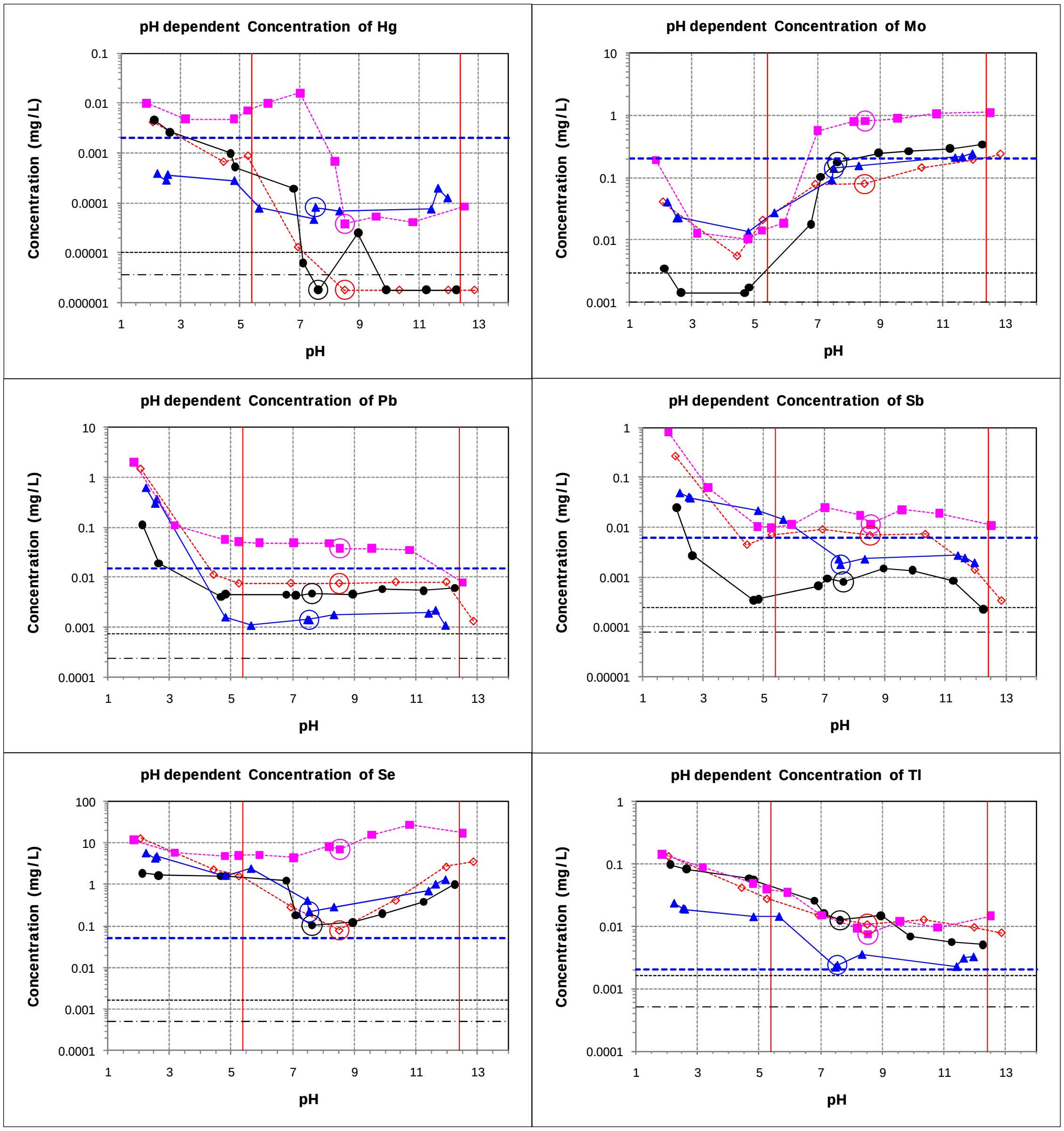


Figure 53 (continued). pH dependent leaching results. Filter cake samples.

3.2.2. Comparisons of the Ranges of Constituent Concentrations from Laboratory Testing (Minimum Concentrations, Maximum Concentrations, and Concentrations at the Materials' Own pH)

Figure 54 through Figure 66 present comparisons of the range of constituent concentrations observed in laboratory eluates from testing as a function of pH and LS (SR002.1 and SR003.1) over the pH range from 5.4 to 12.4 and LS ratios from 0.5 to 10. This pH range represents the 5th and 95th percentiles of pH observed in field samples from CCR landfills and surface impoundments, as discussed in Section 2.5.2. For laboratory leaching test eluates, the presented data represent the observed maximum and minimum concentrations within the pH range from 5.4 to 12.4 from both test methods (upper and lower whiskers) and the concentration at the materials' own pH (closed circles or asterisks), which may be outside the pH range criteria. Including results from testing as a function of LS allows consideration of potentially higher concentrations observed for initial releases that may occur at low LS ratios in the field. The TC and MCL, DWEL, or AL (as available) is included in each figure as a dashed horizontal line to provide a reference value. The concentration ranges indicated in the figures as results of this study are direct measurements of laboratory eluates of the CCRs and do not consider attenuation that may occur in the field. Tabular results are provided in Appendix I.

Important observations from these figures are summarized as follows.

Aluminum (Al). Gypsum generally had lower eluate concentration ranges than the other CCR types. No trend was readily discernable with respect to coal type or facility configuration.

Arsenic (As). Lower eluate concentration ranges were associated with fly ash produced from sub-bituminous coal than other coal types. Many of the values for eluates from fly ash exceeded the MCL but results only for one fly ash sample (WFA) exceeded the TC. Results for five of the gypsum samples exceeded the MCL. For scrubber sludges, results suggest that use of post-combustion NO_x controls may increase As leachability.

Boron (B). Washed gypsum samples all had lower eluate concentrations for B than unwashed gypsum samples, indicating the effectiveness of the washing process in reducing leachable B. All of the CCR types had a significant fraction of the samples that exceeded the DWEL.

Barium (Ba). The greatest Ba concentrations in eluates was from fly ash and SDA sample produced from sub-bituminous coal. All gypsum samples had barium eluate concentrations less than the MCL. Use of post-combustion NO_x controls appears to have reduced Ba leachability in blended CCRs.

Cadmium (Cd). All CCR types had a significant fraction of samples from which eluate concentrations exceeded the MCL. For many samples of all CCR types, the own pH concentration was less than the method detection limit.

Cobalt (Co). All CCR types had samples with cobalt eluate concentrations from less than the method detection limit up to three orders of magnitude greater. SDA residues had the greatest range in Co eluate concentrations.

Chromium (Cr). Use of post-combustion NO_x controls appeared to increase the eluate concentrations for fly ash, scrubber sludges, and blended CCRs when samples were collected from the same facility. All gypsum samples except one unwashed gypsum, had eluate concentrations less than the MCL. All other CCR types had multiple samples with eluates that exceeded the MCL.

Mercury (Hg). The greatest Hg concentrations in eluates were from scrubber sludges and blended CCRs, including all of those that exceeded the MCL.

Molybdenum (Mo). Higher eluate concentration ranges were associated with fly ash, SDA residues and blended CCRs (which include fly ash) than associated with gypsum and scrubber sludge samples. All CCR types had multiple samples with eluates that exceeded the DWEL.

Lead (Pb). Eluate concentrations were below the AL for eluates from all samples except for 8 samples. There was no clear trend with respect to coal type, facility configuration or CCR type.

Antimony (Sb). Higher eluate concentration ranges were associated with fly ash samples than with gypsum samples although there were exceptions to this trend. All CCR types had samples for which eluate concentrations exceeded the MCL.

Selenium (Se). All CCR types had similar ranges in Se eluate concentrations with several fly ash and gypsum samples having notably higher Se eluate concentrations without any clear dependence on coal type or facility configuration.

Thallium (Tl). Most CCR samples had eluate concentrations that exceeded the MCL with no apparent trend with respect to coal type or facility configuration.

pH. Figure 67 presents the pH ranges (minimum and maximum) of actual samples observed in SR002.1 and SR003.1 over the pH domain $5.4 \leq \text{pH} \leq 12.4$. The closed circles represent the material's own pH. When the closed circle is outside the range $5.4 \leq \text{pH} \leq 12.4$, this means that the material's own pH was more acidic than pH 5.4. Fly ash samples exhibited own pH values ranging from acidic ($4 \leq \text{pH} \leq 6$) to moderately alkaline ($8 \leq \text{pH} \leq 11$) to highly alkaline ($11 < \text{pH}$) with a high degree of correlation with total calcium content. The own pH range for gypsum samples was between 5.5 and 8, while the range was much larger for scrubber sludges and blended CCRs.

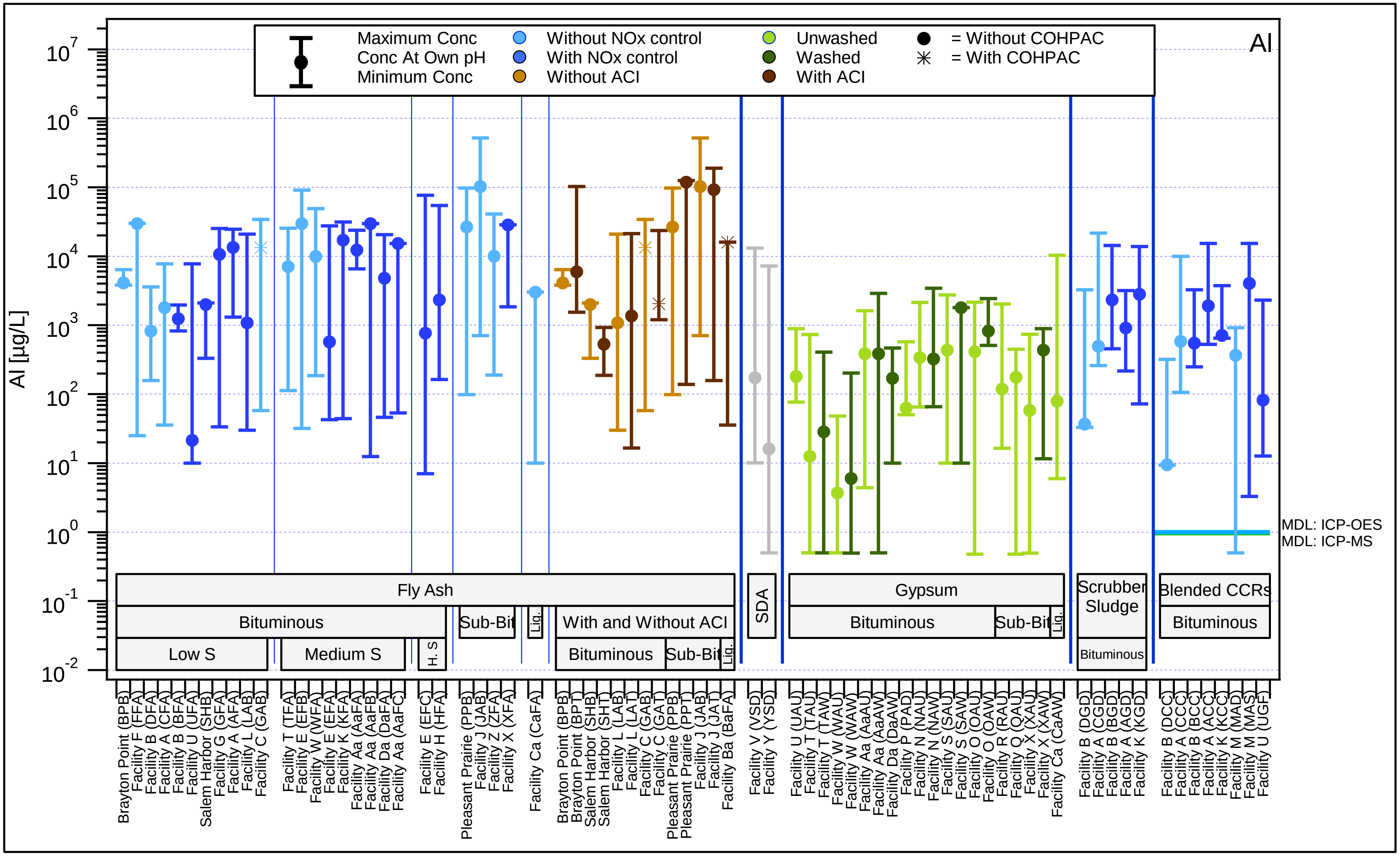


Figure 54. Aluminum. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

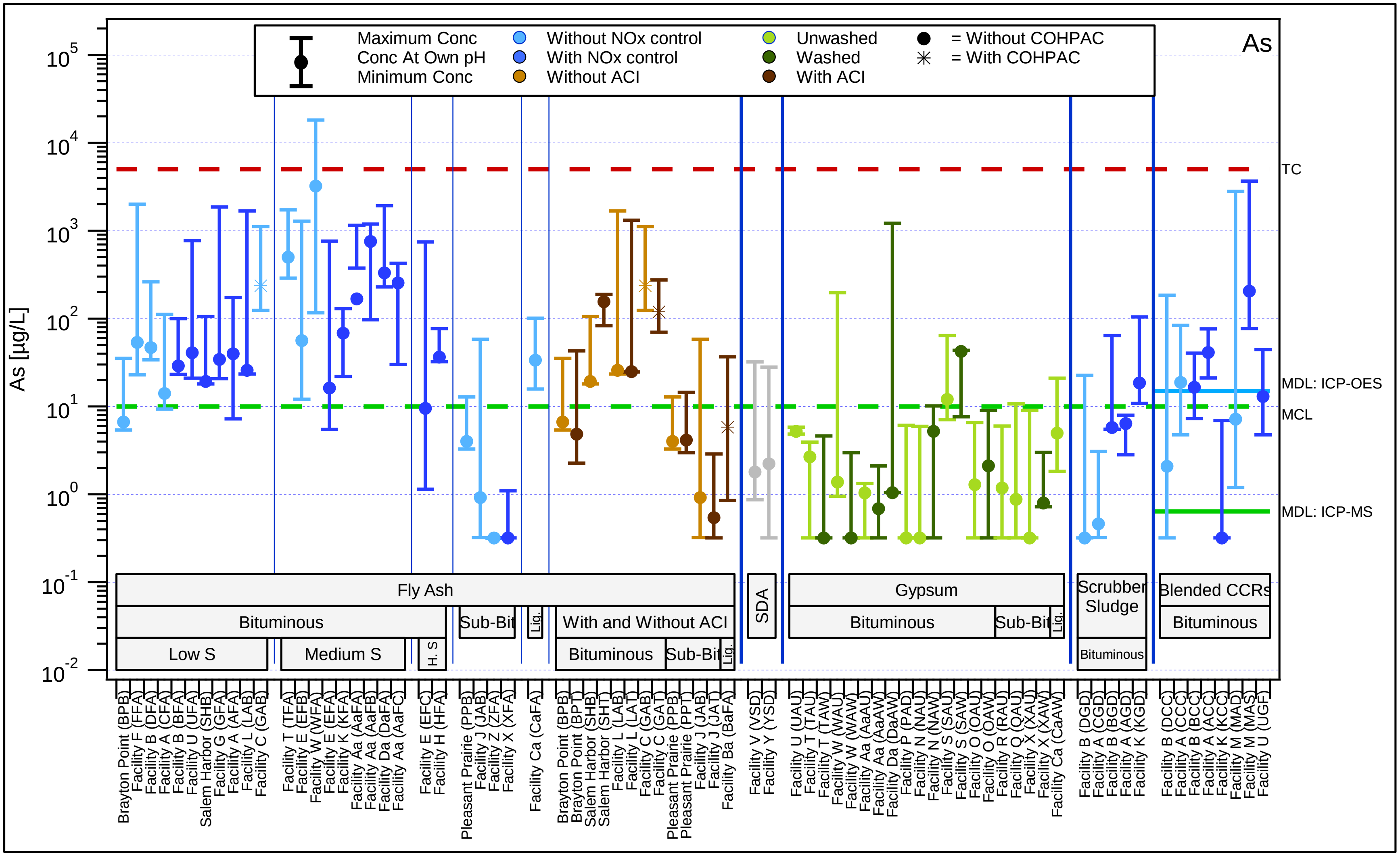


Figure 55. Arsenic. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

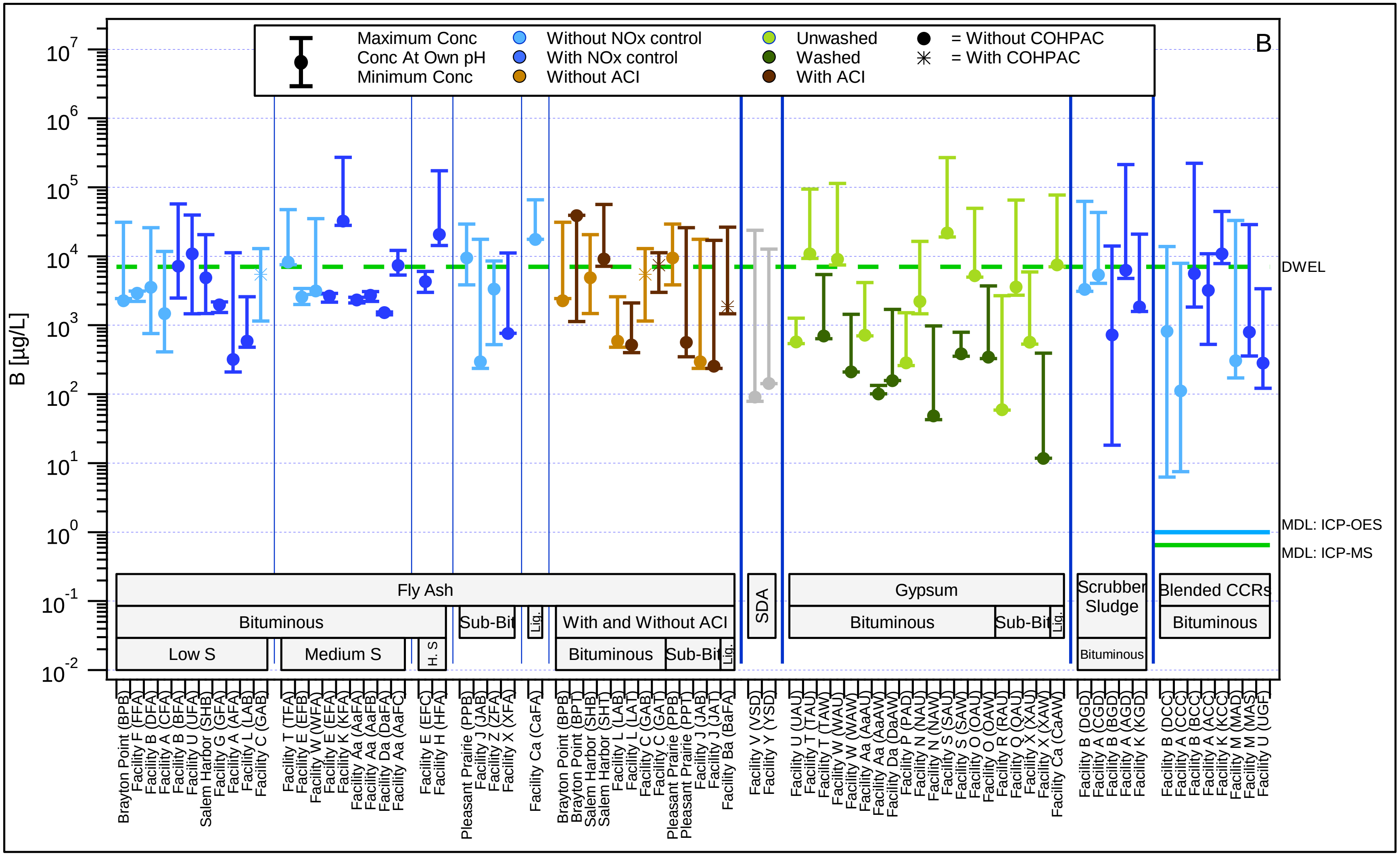


Figure 56. Boron. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤pH≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

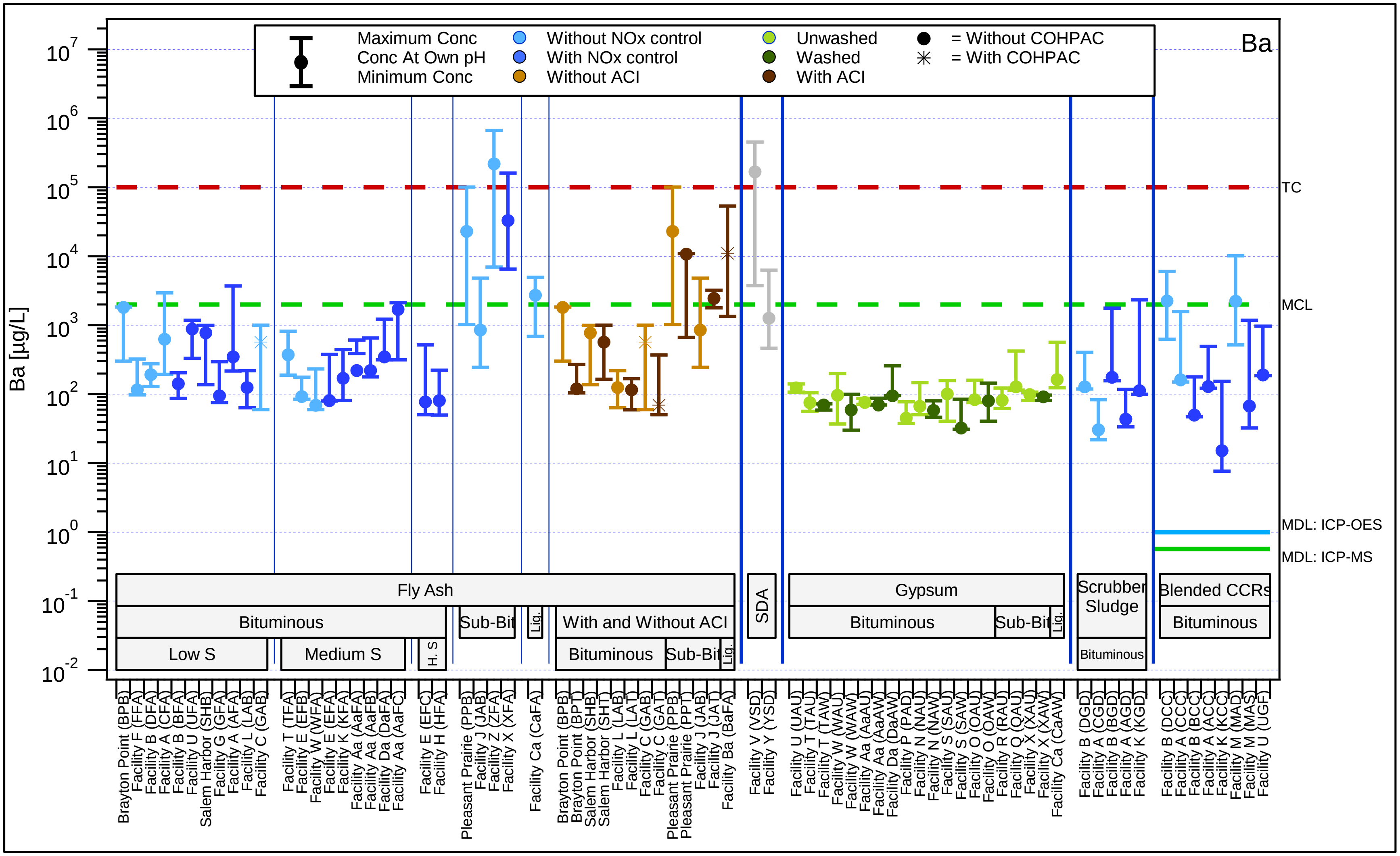


Figure 57. Barium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

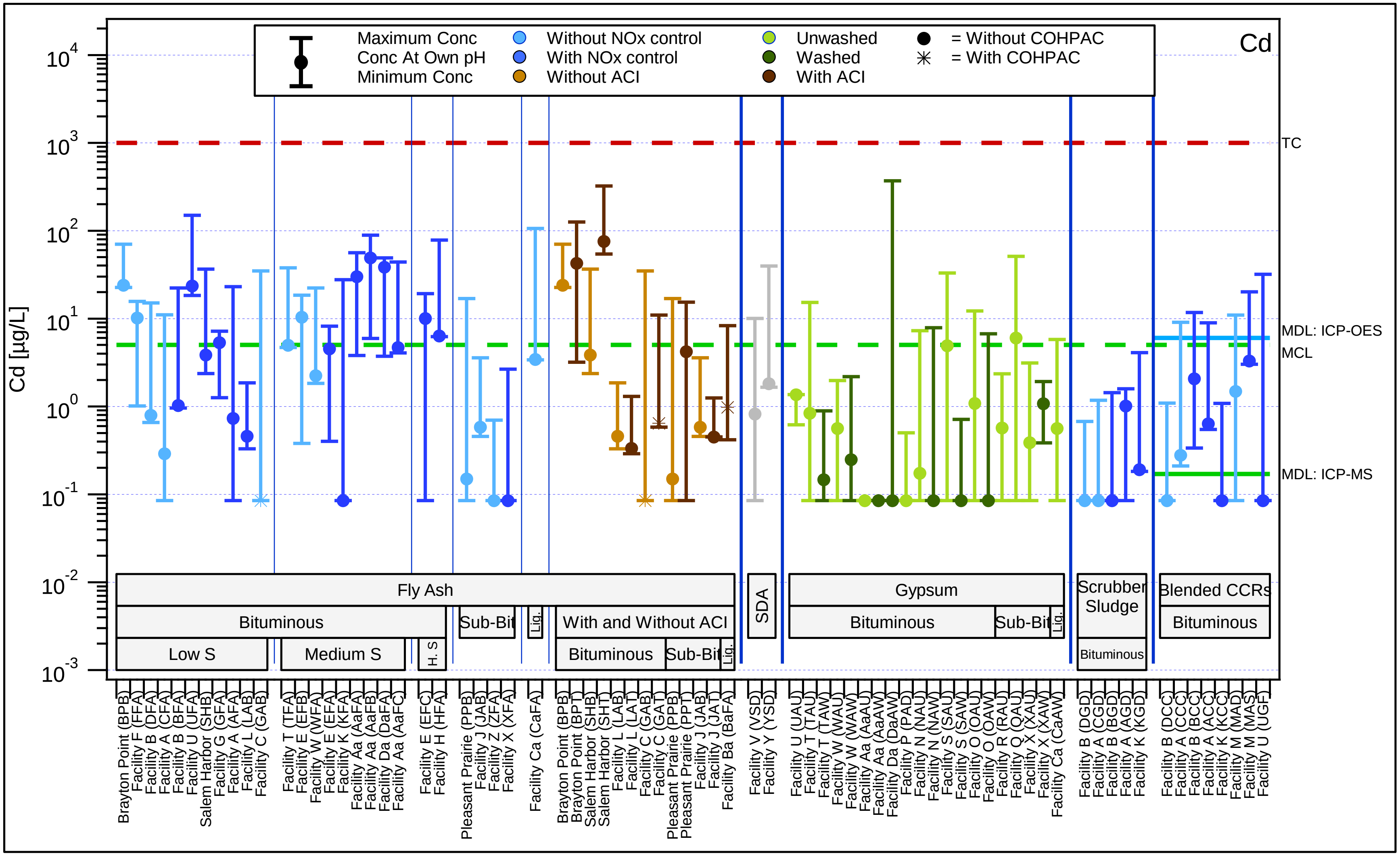


Figure 58. Cadmium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

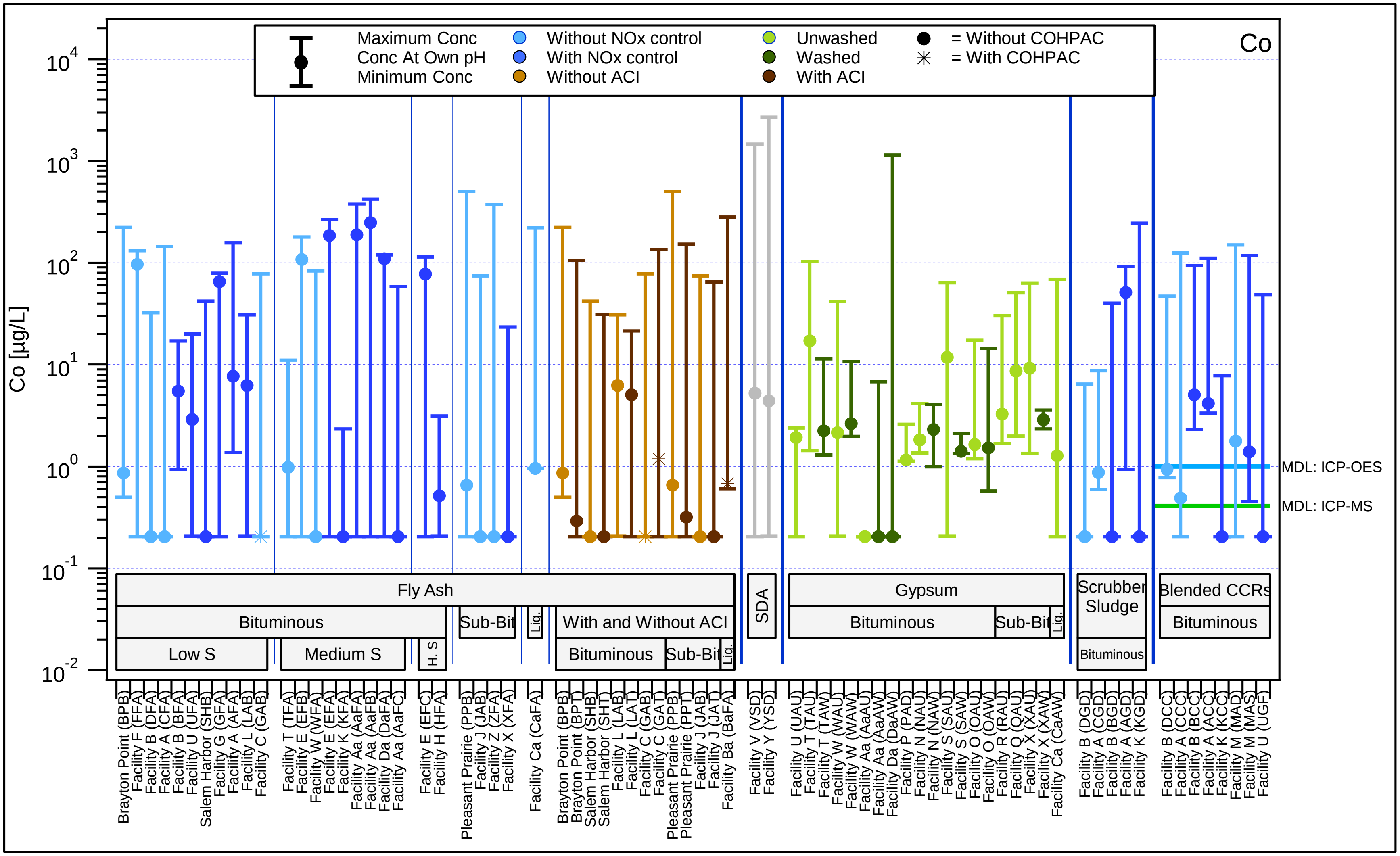


Figure 59. Cobalt. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

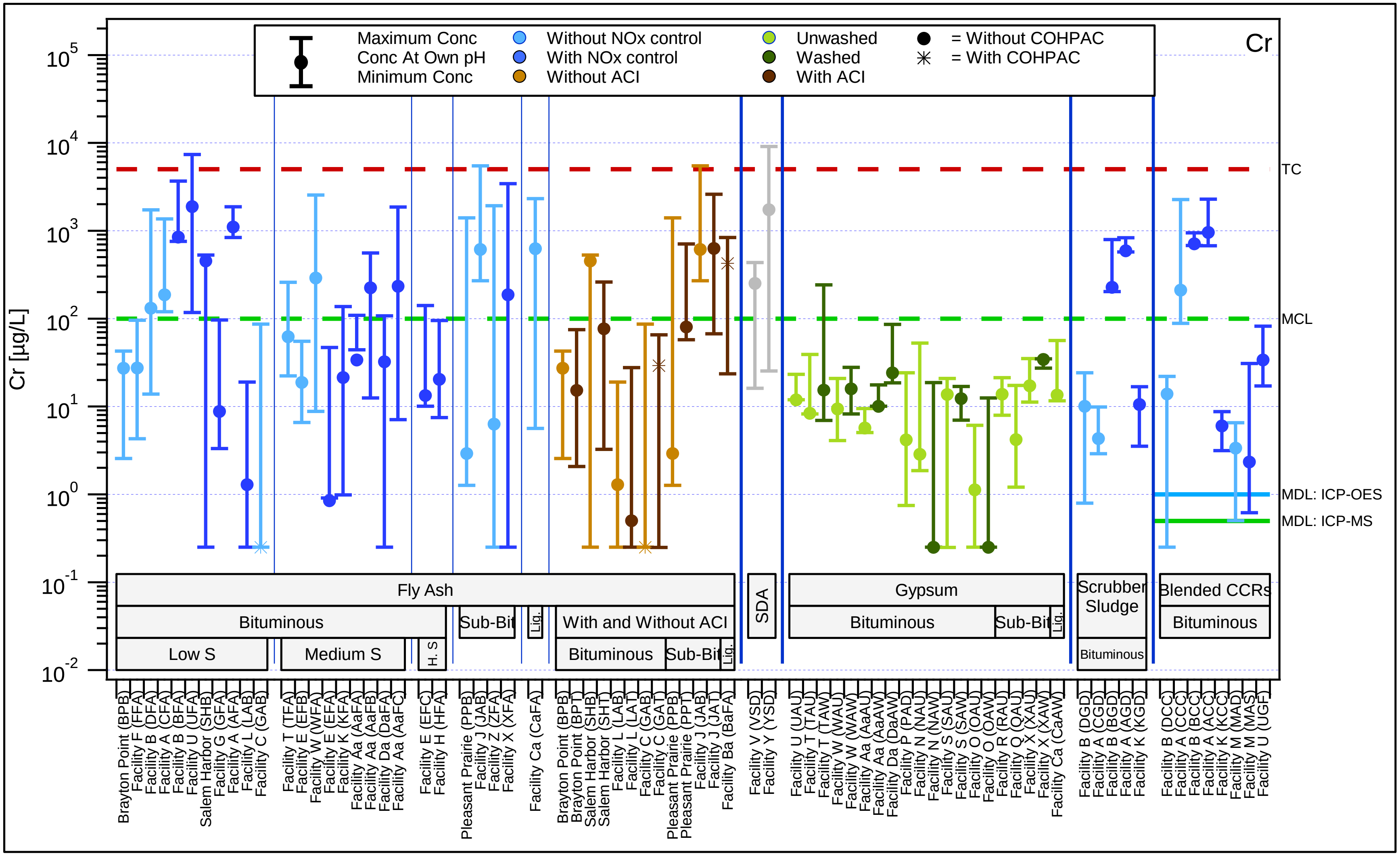


Figure 60. Chromium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

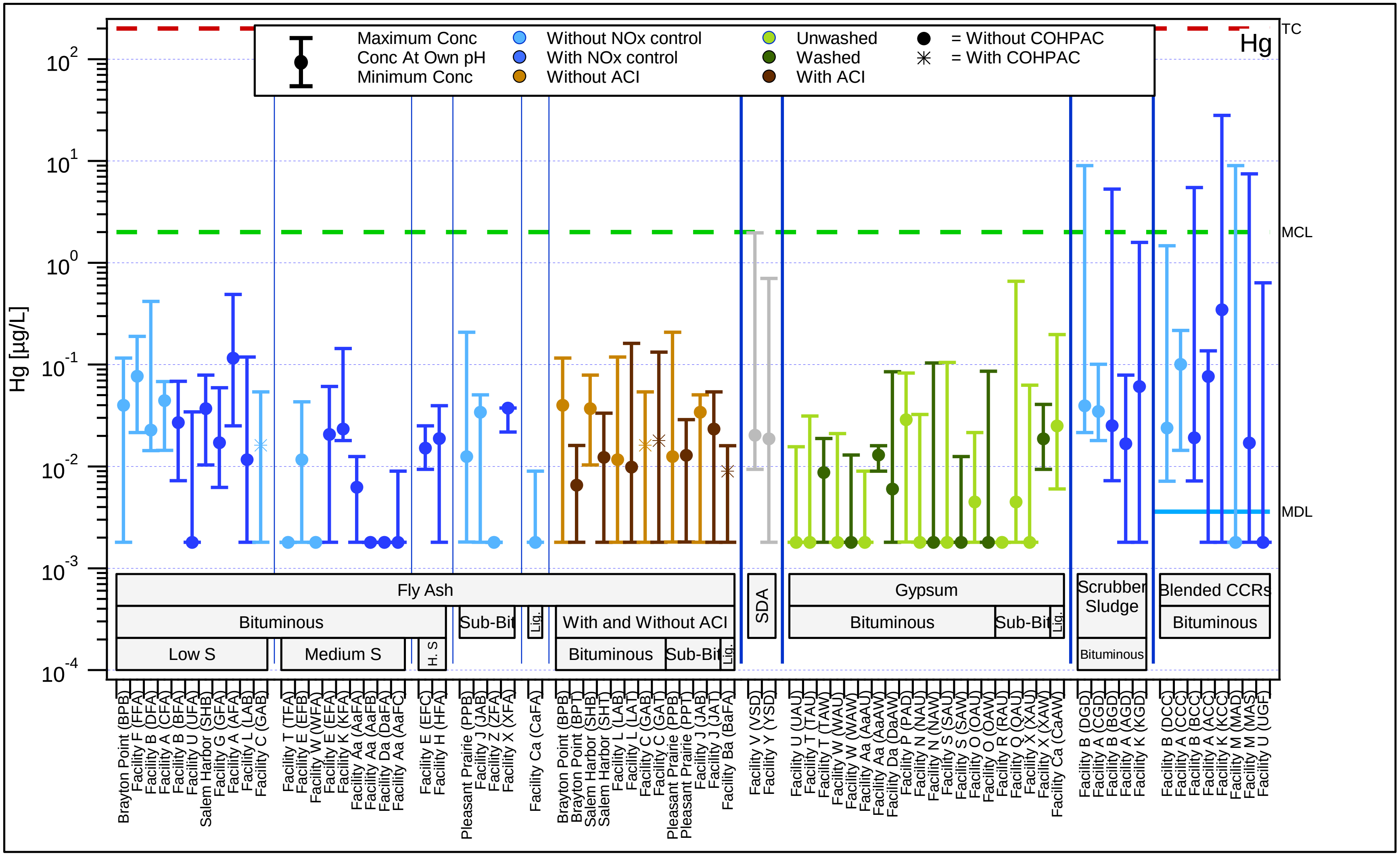


Figure 61. Mercury. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

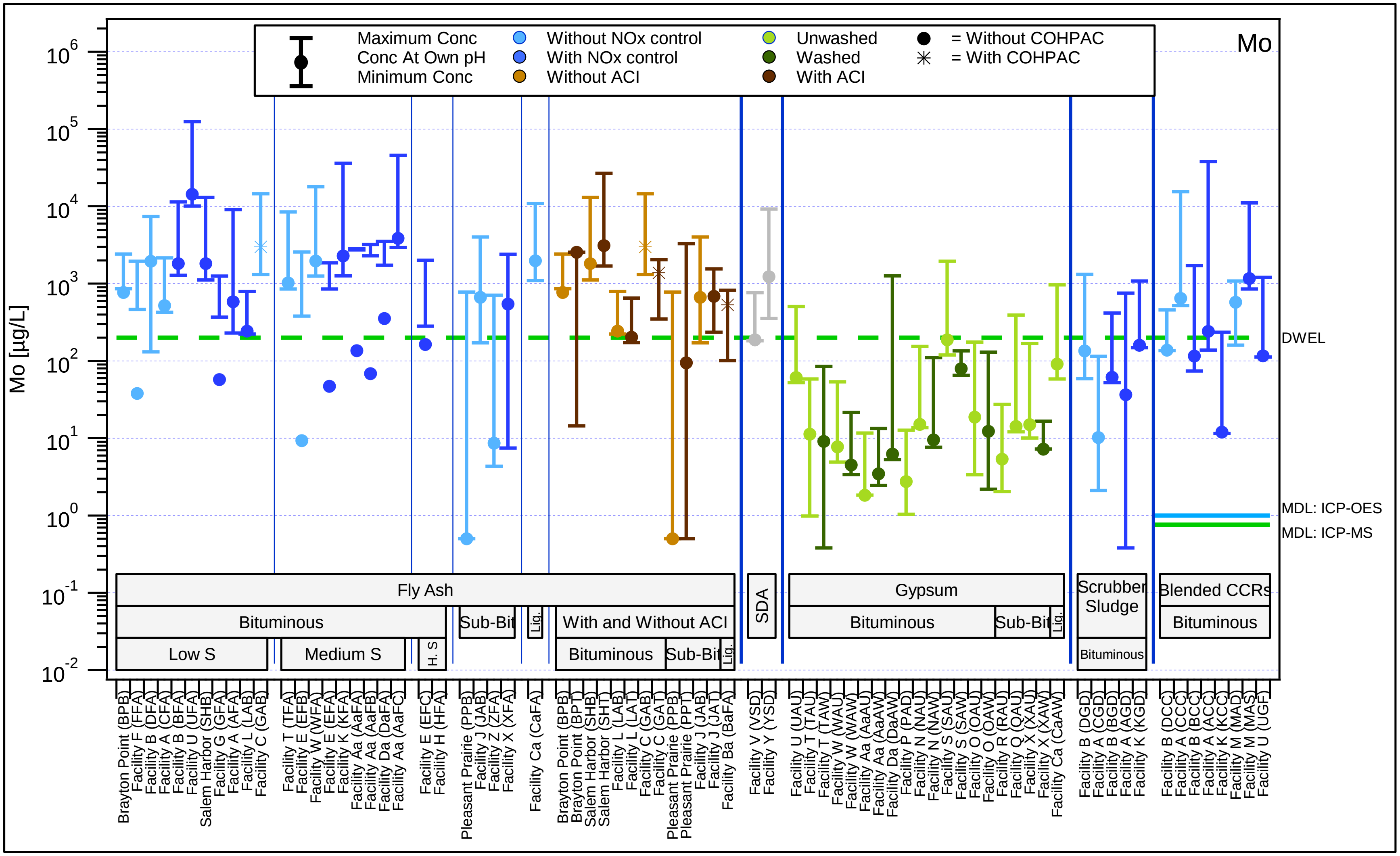


Figure 62. Molybdenum. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

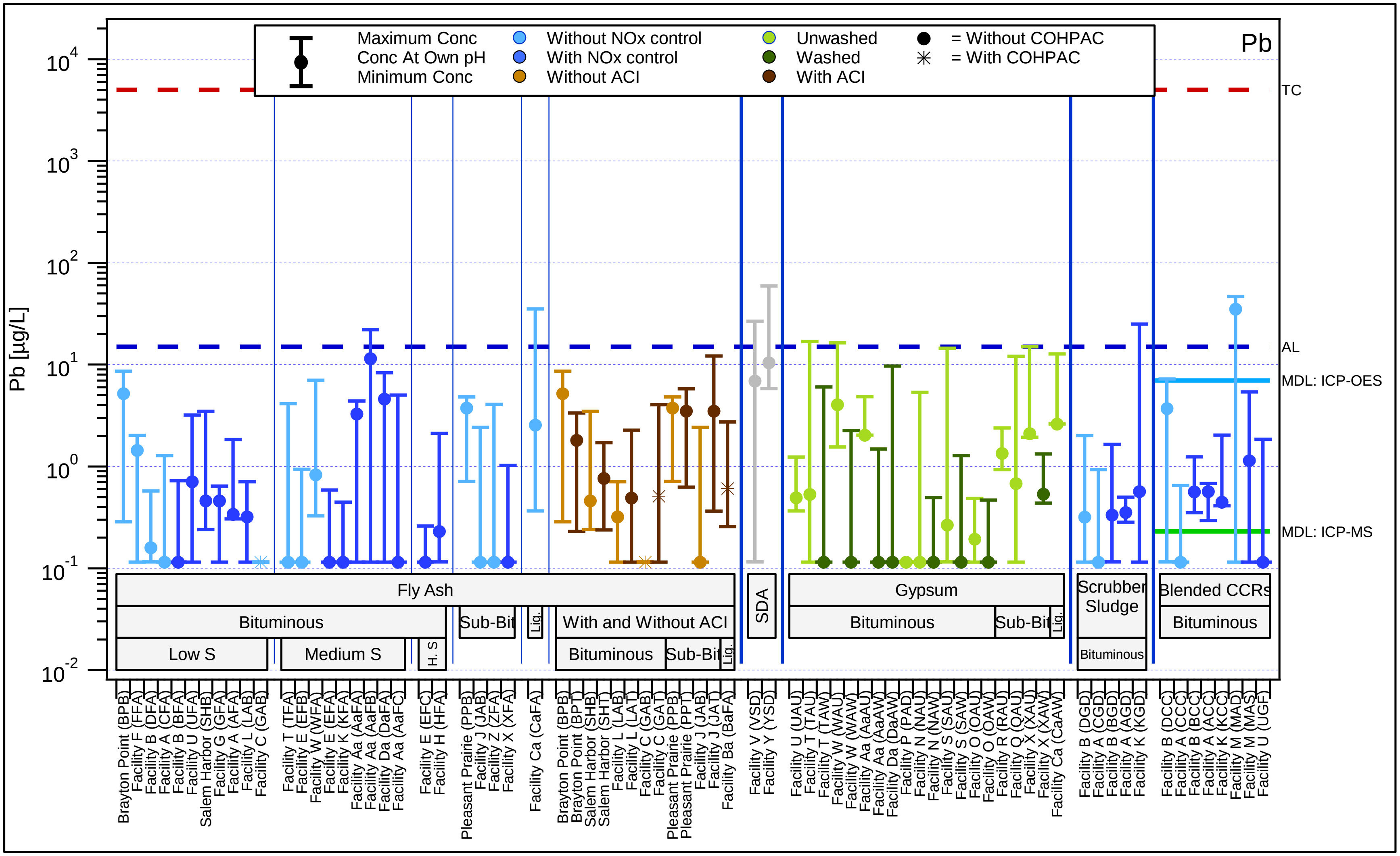


Figure 63. Lead. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

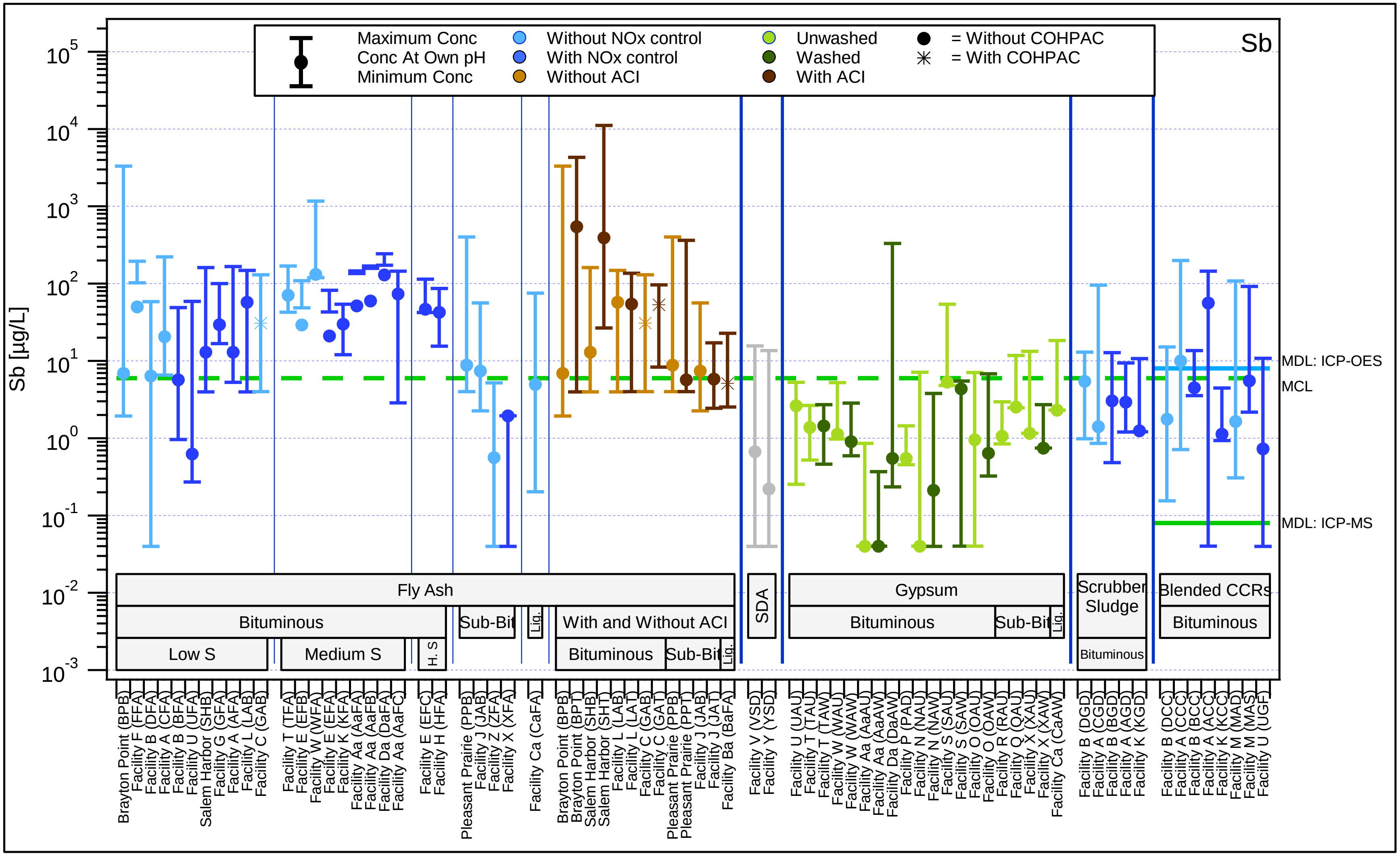


Figure 64. Antimony. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

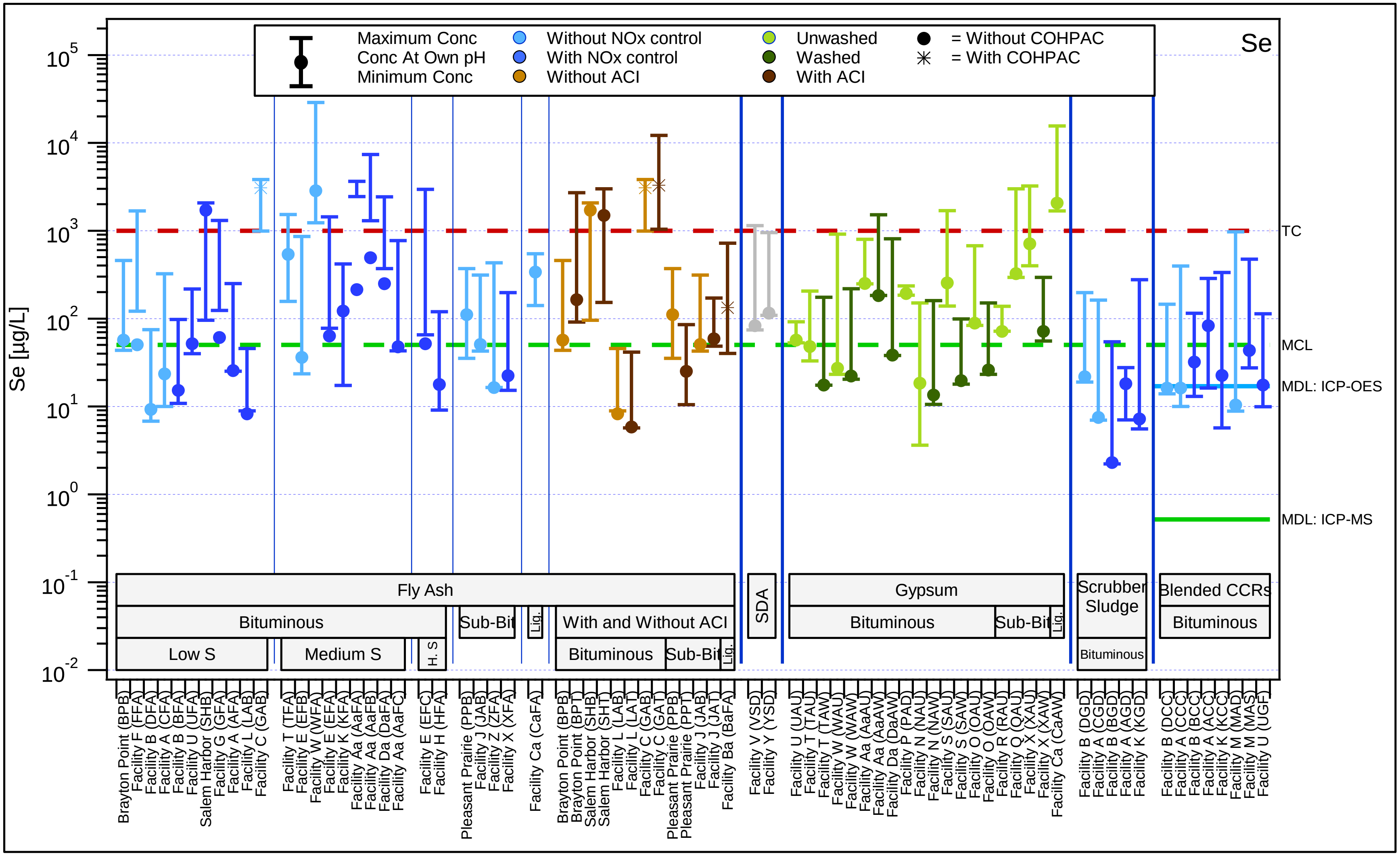


Figure 65. Selenium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

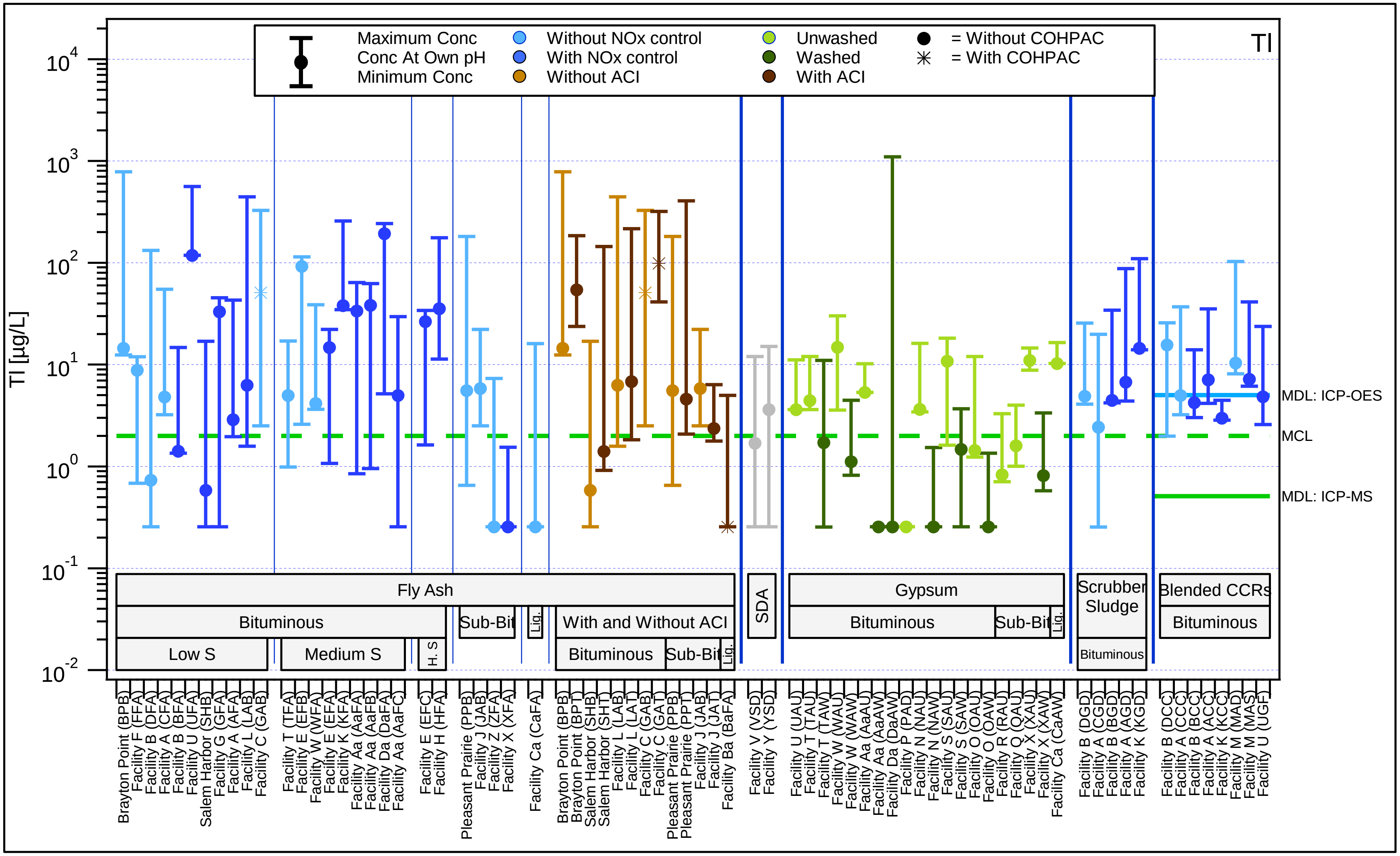


Figure 66. Thallium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

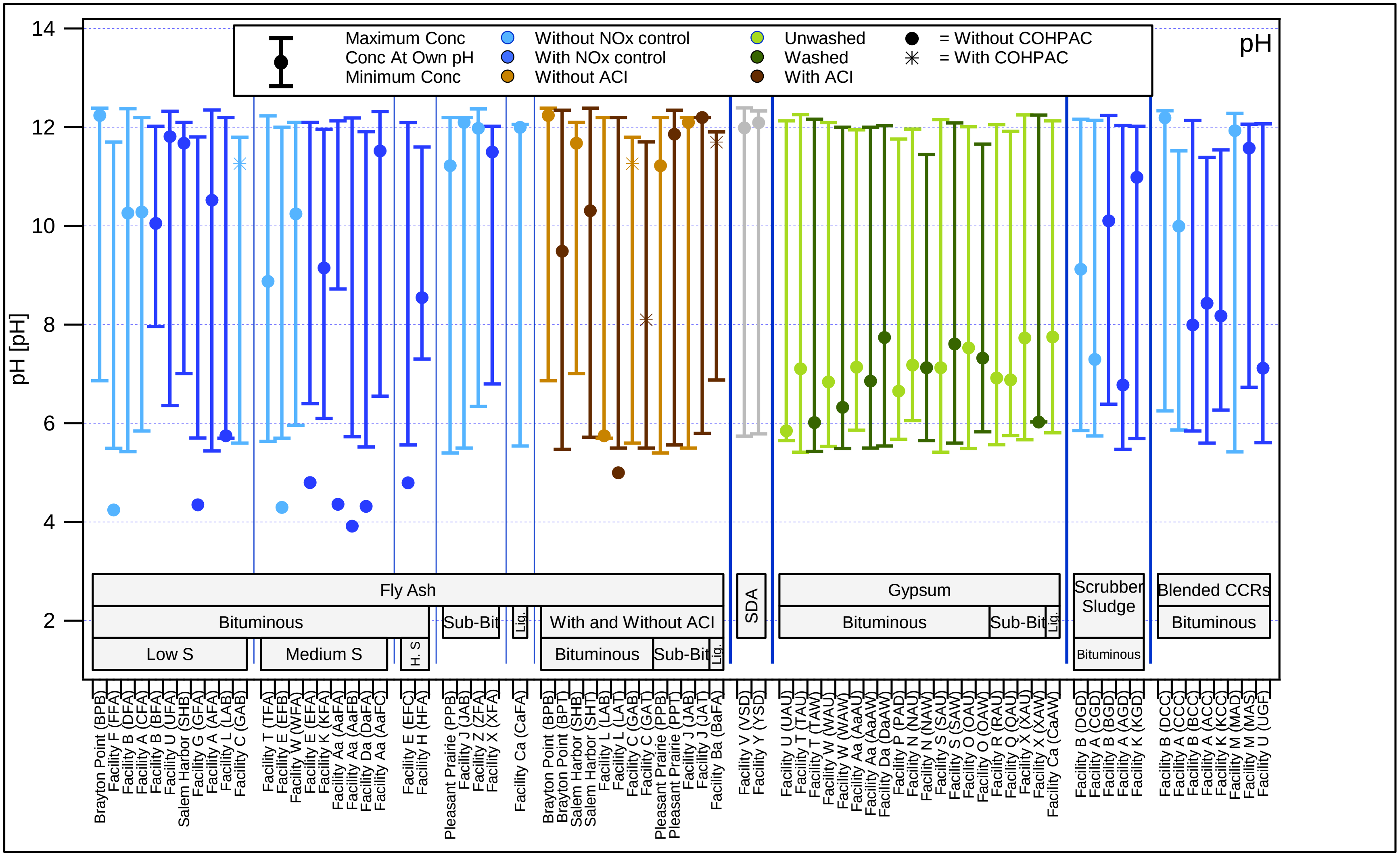
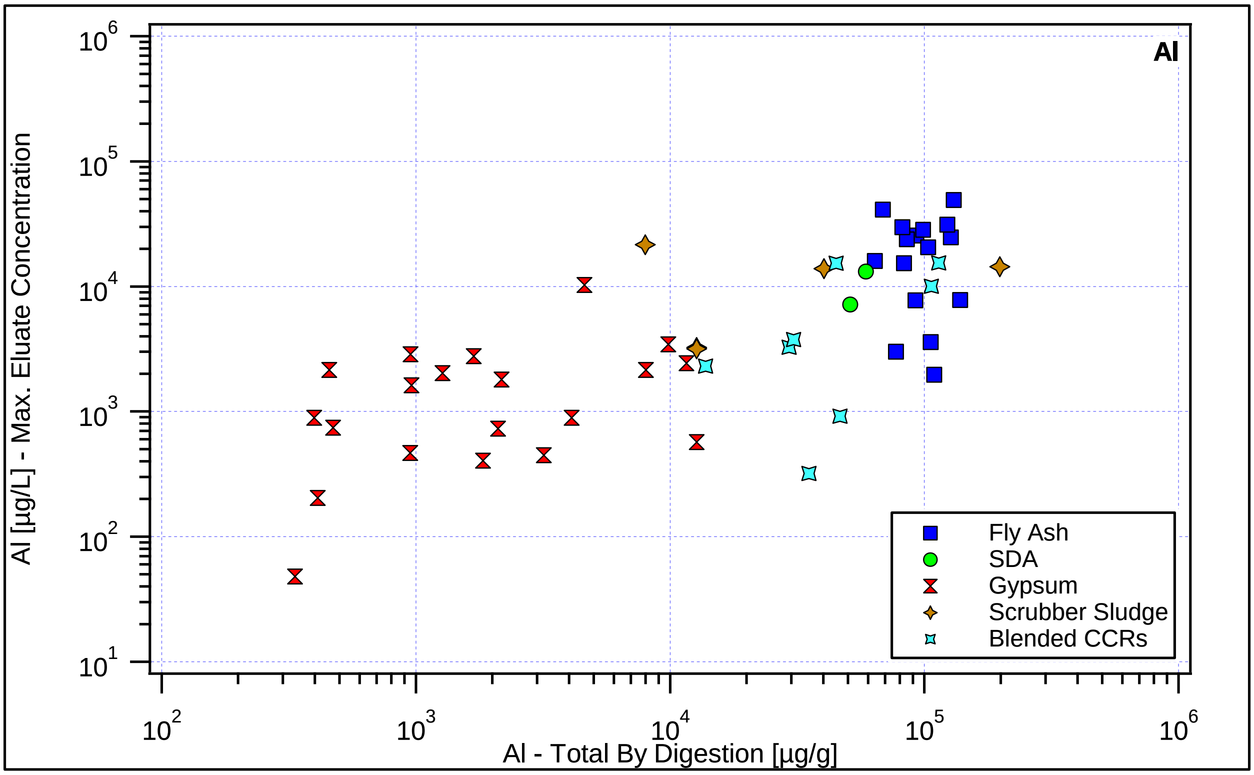


Figure 67. pH. Comparison of maximum, minimum and own pH observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4. SDA samples were from facilities burning sub-bituminous coal.

3.2.3. Leaching Dependency on Total Content

An on-going question has been whether or not total content of an element in a CCR sample is a useful indicator of potential environmental impact by leaching. This question was evaluated by comparing for the COPCs (i) the maximum eluate concentration over the pH domain $5.4 \leq pH \leq 12.4$ with the total content by digestion (Figure 68 to Figure 79), and (ii) the eluate concentration at own pH with the total content by digestion (results not shown). The maximum eluate concentration as a function of total content is presented in Figure 68 to Figure 79 because in understanding the meaning of research results, the focus is often on the potential for exceedance of a particular threshold value. However, results of own pH eluate concentration as a function of total content were similar. Results are annotated on Figure 69 (arsenic) for illustration purposes.

Each of these figures show (i) there is a poor correlation between leachate concentration and total content of any of the elements considered, (ii) a wide range of total content values (over more than one order of magnitude) can result in the same or very similar eluate concentrations, and (iii) a wide range of eluate concentrations (over more than one order of magnitude) can be observed for CCRs with similar total content values. If leaching correlated closely with total concentration, the data on these figures would be expected to show strong linearity, and relatively less scatter. Thus, it is clear that leaching phenomena is controlled by complex solid-liquid partitioning chemistry and that total content is not a good indicator of leaching. Furthermore, the absence of a linear or unique monotonic relationship between total content and eluate concentrations indicates that representation of leaching as a linear partitioning phenomenon (i.e., the linear distribution coefficient, K_d, approach) is not appropriate.



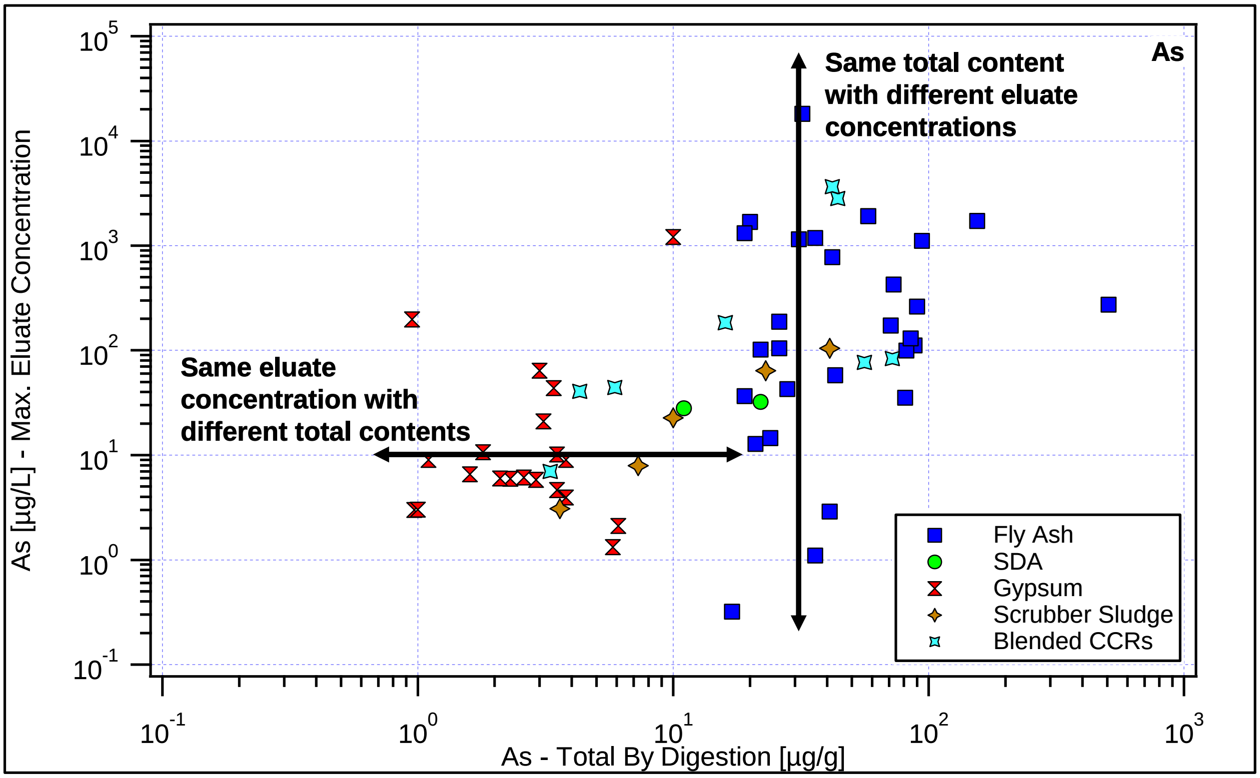


Figure 68 and Figure 69. Aluminum and Arsenic. Maximum eluate concentration (5.4 ≤ pH ≤ 12.4) as a function of total content by digestion.

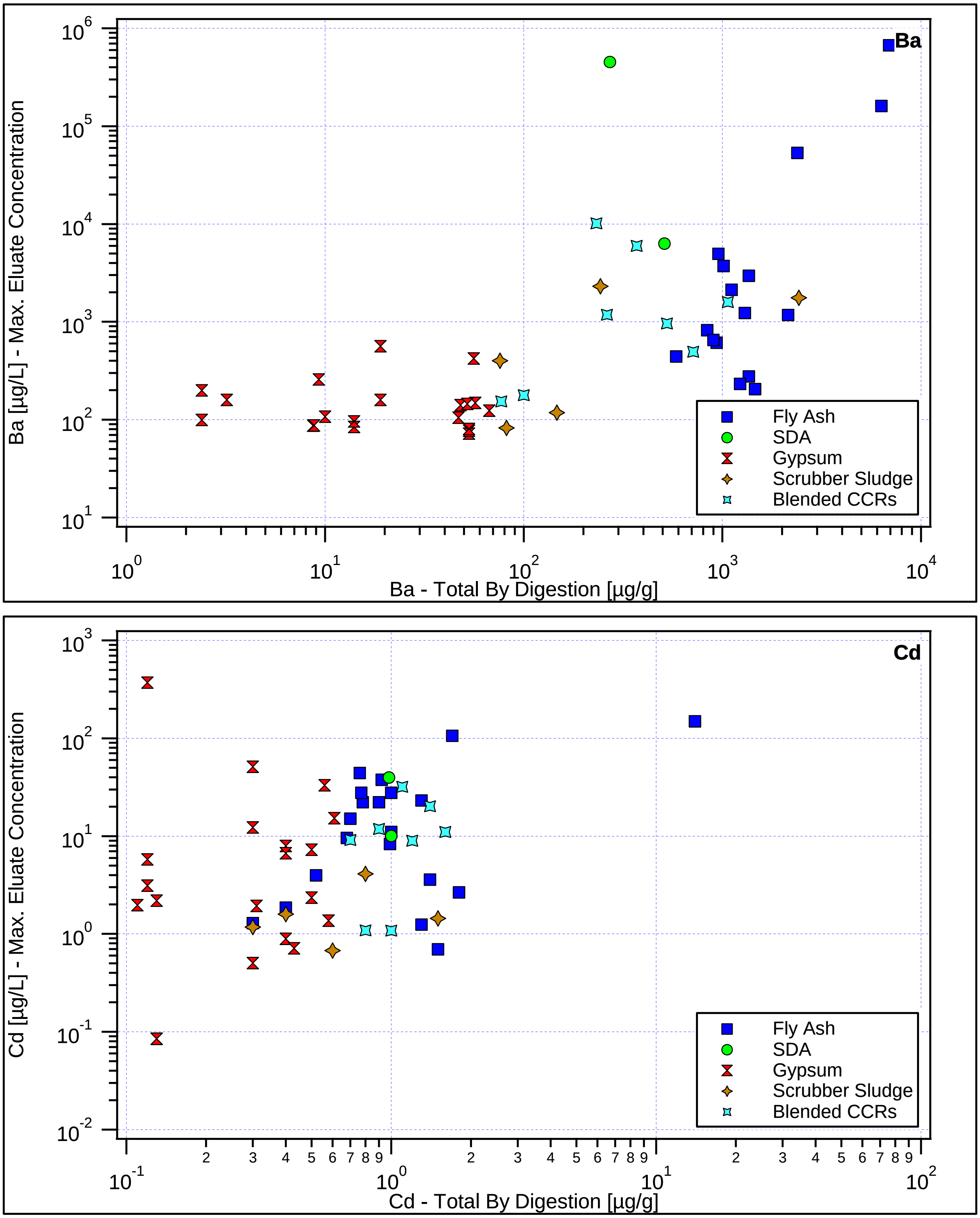


Figure 70 and Figure 71. Barium and Cadmium. Maximum eluate concentration ($5.4 \leq pH \leq 12.4$) as a function of total content by digestion.

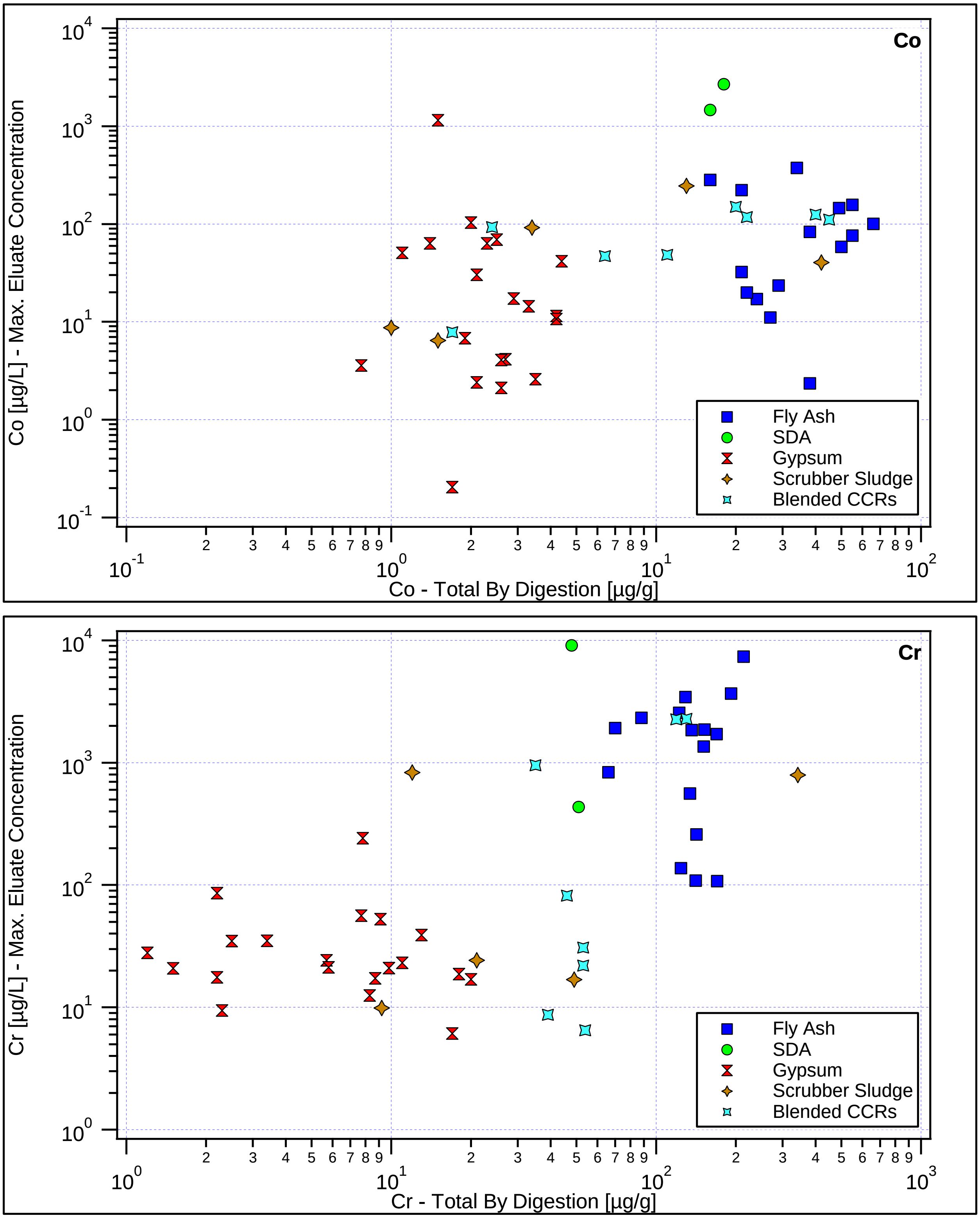


Figure 72 and Figure 73. Cobalt and Chromium. Maximum eluate concentration ($5.4 \leq pH \leq 12.4$) as a function of total content by digestion.

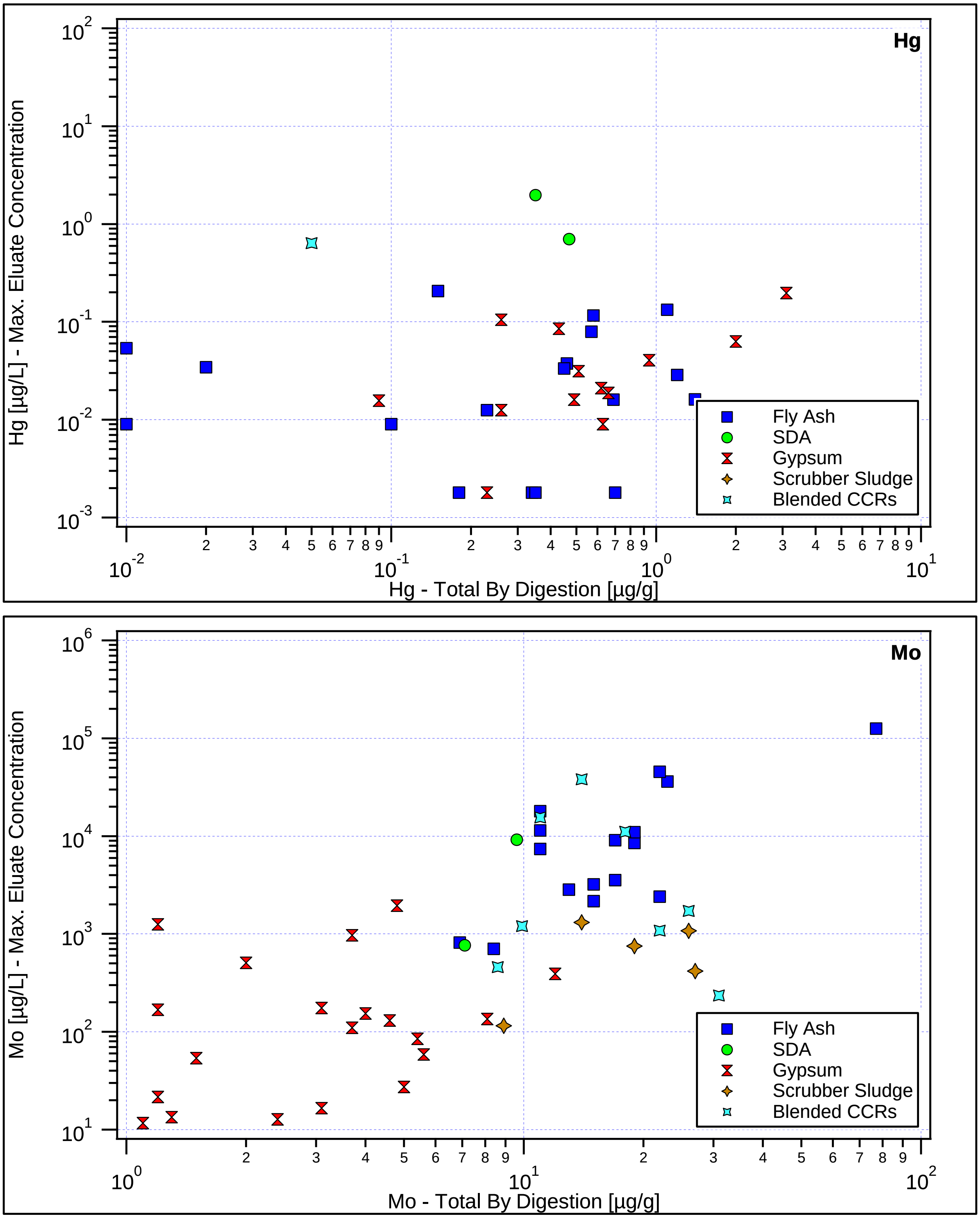
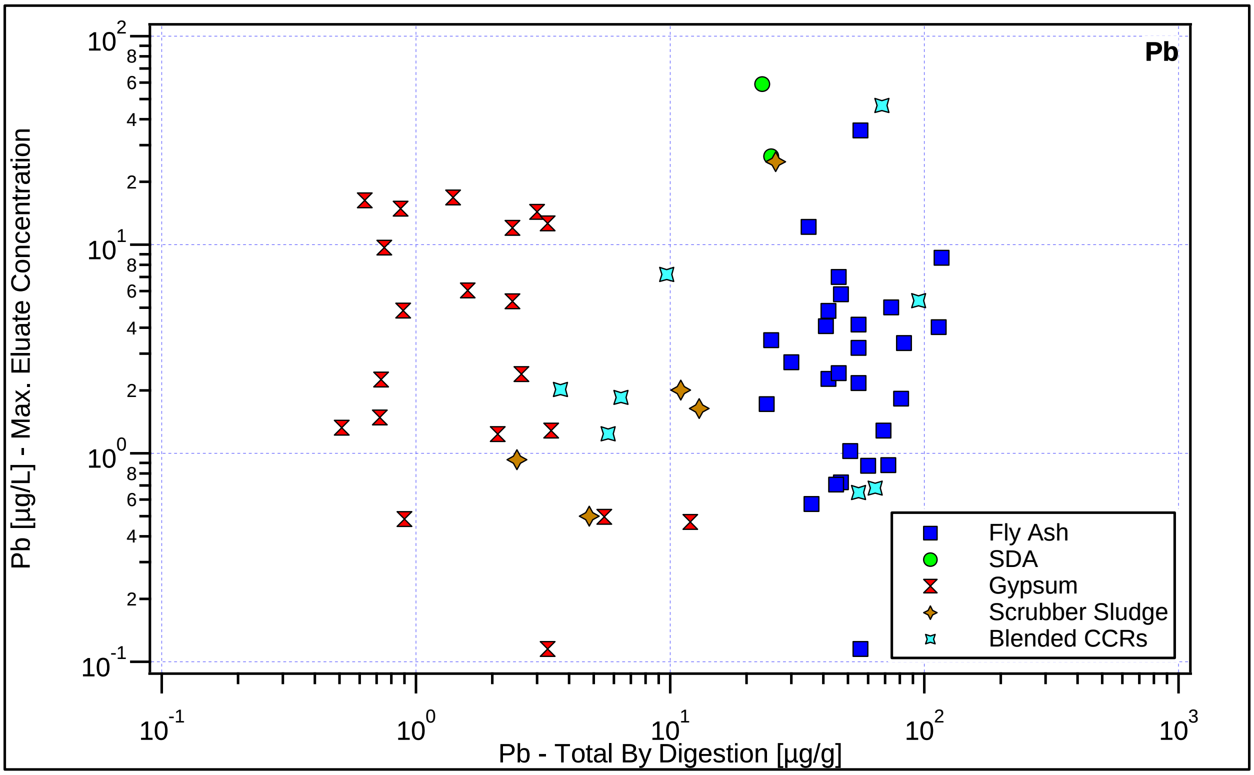


Figure 74 and Figure 75. Mercury and Molybdenum. Maximum eluate concentration (5.4 ≤ pH ≤ 12.4) as a function of total content by digestion.



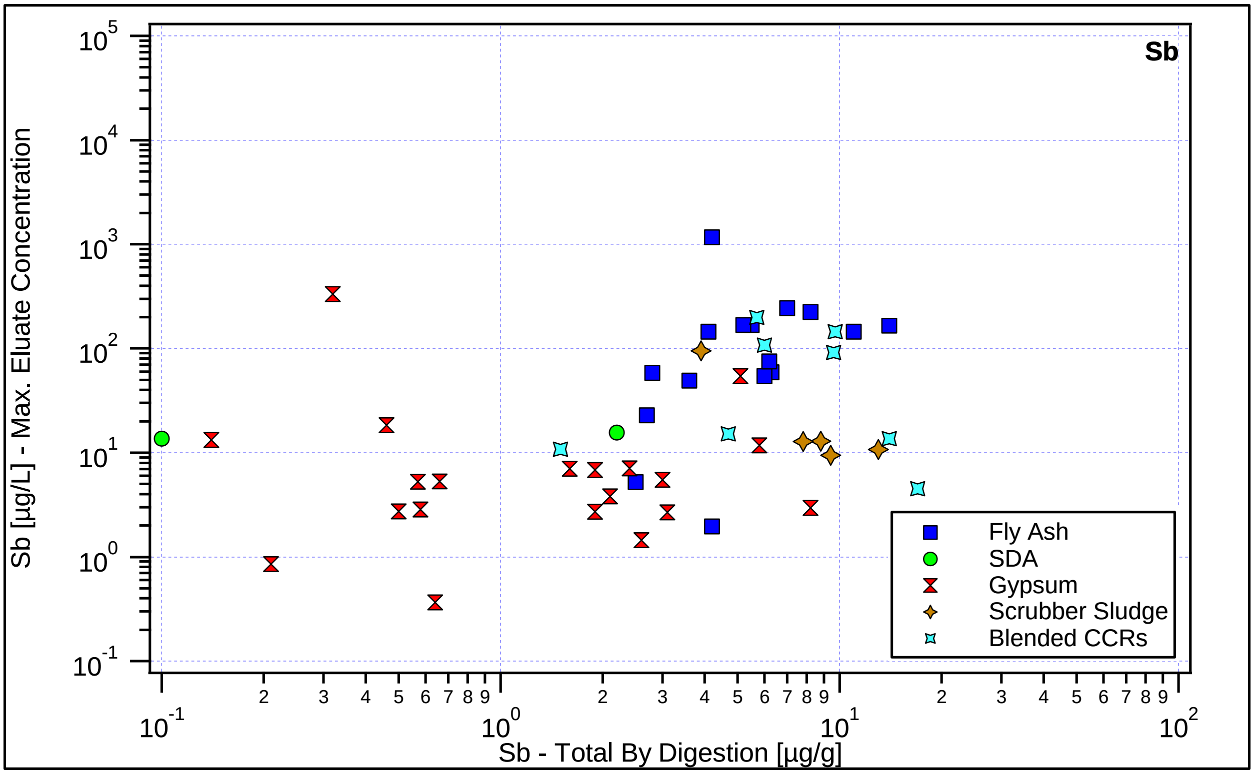


Figure 76 and Figure 77. Lead and Antimony. Maximum eluate concentration (5.4 ≤ pH ≤ 12.4) as a function of total content by digestion.

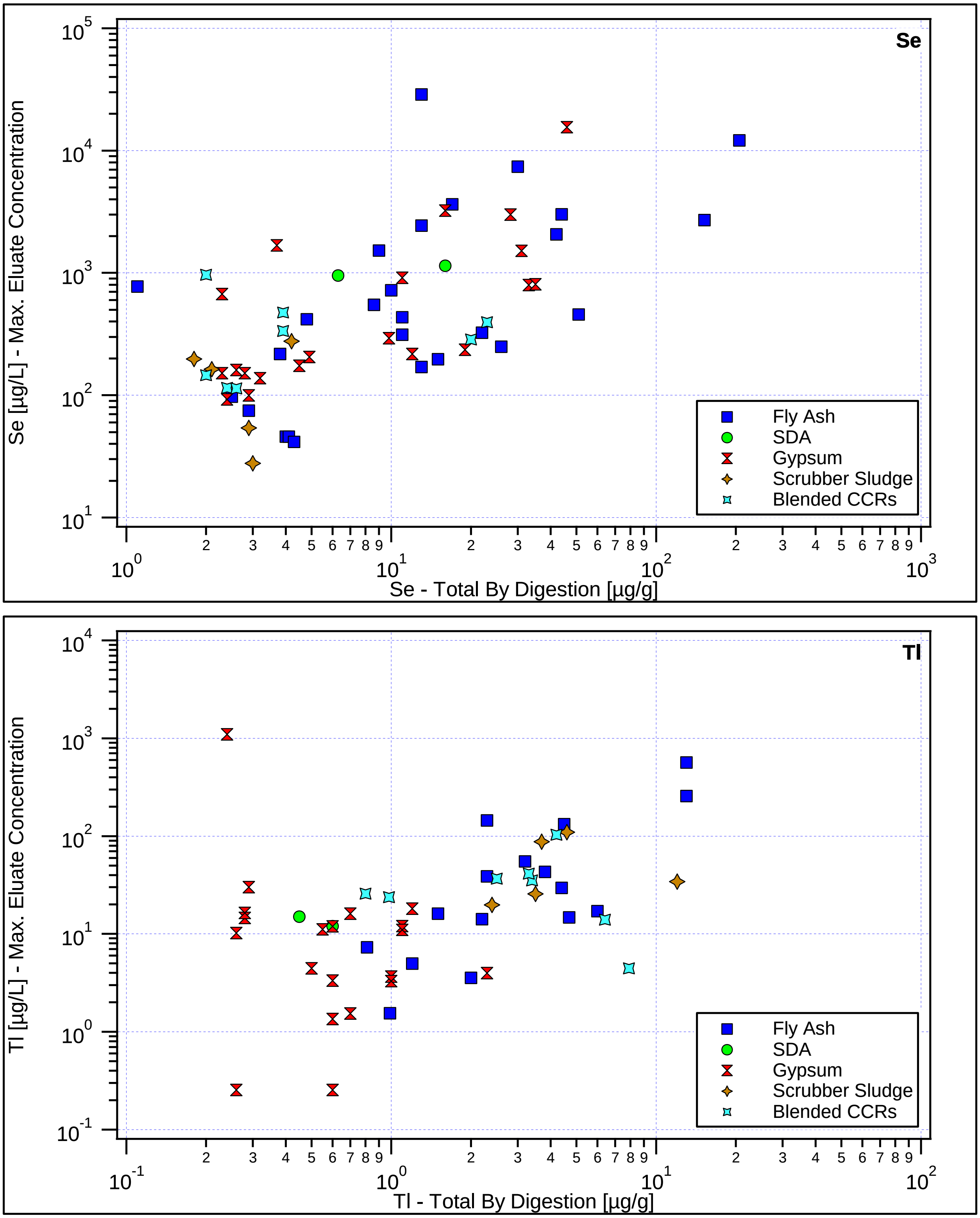


Figure 78 and Figure 79. Selenium and Thallium. Maximum eluate concentration (5.4 ≤ pH ≤ 12.4) as a function of total content by digestion.

3.2.4. pH at the Maximum Concentration Value versus the Materials' Own pH

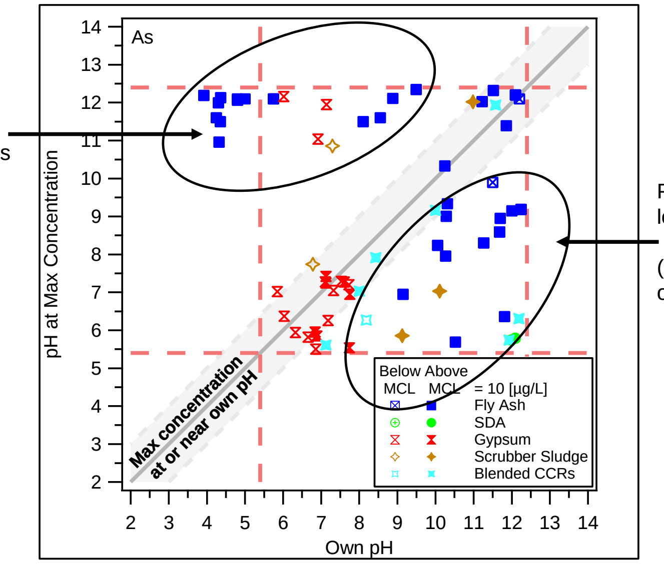
Figure 81 through Figure 93 plot the pH at which the maximum eluate concentration for a CCR sample occurs over the domain $5.4 \leq \text{pH} \leq 12.4$ as a function of the own pH for the same sample. Results for arsenic are annotated as Figure 80. The diagonal gray line indicates a slope equal to one; when a data point falls on or near (within the light gray band) this line, the maximum eluate concentration occurs at or near the own pH for the specific CCR sample. Data points indicated with an open symbol have maximum eluate concentrations that are less than either the MCL or DWEL as indicated for the element of interest. Data points indicated with a filled symbol have maximum eluate concentrations that are greater than either the MCL or DWEL. When a sample falls above the gray diagonal line, processes that result in increased elution pH (e.g., mixing with other materials such as lime, other CCRs or other alkaline materials) are indicated to lead to increased leachate concentration for that element. When a sample falls below the gray diagonal line, processes that result in decreased elution pH (e.g., mixing with other more acidic materials or uptake of atmospheric carbon dioxide) are indicated to lead to increased leachate concentration for that element. For example, uptake of atmospheric carbon dioxide (carbonation) occurs when pore solution pH is greater than 8, with the most pronounced effect when pore solution pH is greater than 10. Carbonation results in decreases in pH typically to between 8 and 9. These potential changes must be qualified with the caveat that changes that result in increased or decreased elution pH may also result in significantly changed chemistry (e.g., redox changes) that may also influence leaching.

Important observations from these figures include:

1. Often the maximum eluate concentration occurs at a pH other than the material's own pH, regardless of the element or material being evaluated.
2. The maximum eluate concentration varies over a wide range in pH and is different for different CCR types and elements. This indicates that there is not a single pH for which testing is likely to provide confidence in release estimates over a wide range of disposal and beneficial use options, emphasizing the benefit of multi-pH testing.
3. Multi-pH testing provides useful insights into the CCR management scenarios that have the potential to increase release of specific constituents beyond that indicated by monofill management scenarios.

Processes **increasing pH** may lead to increased concentration

(e.g., mixing with other materials such as lime, other CCRs, or alkaline materials)



Processes **decreasing pH** may lead to increased concentration

(e.g., carbonation or mixing with other more acidic materials)

Figure 80. An example of pH identity plot. Dashed red lines are used to indicate the pH domain of 5.4 to 12.4.

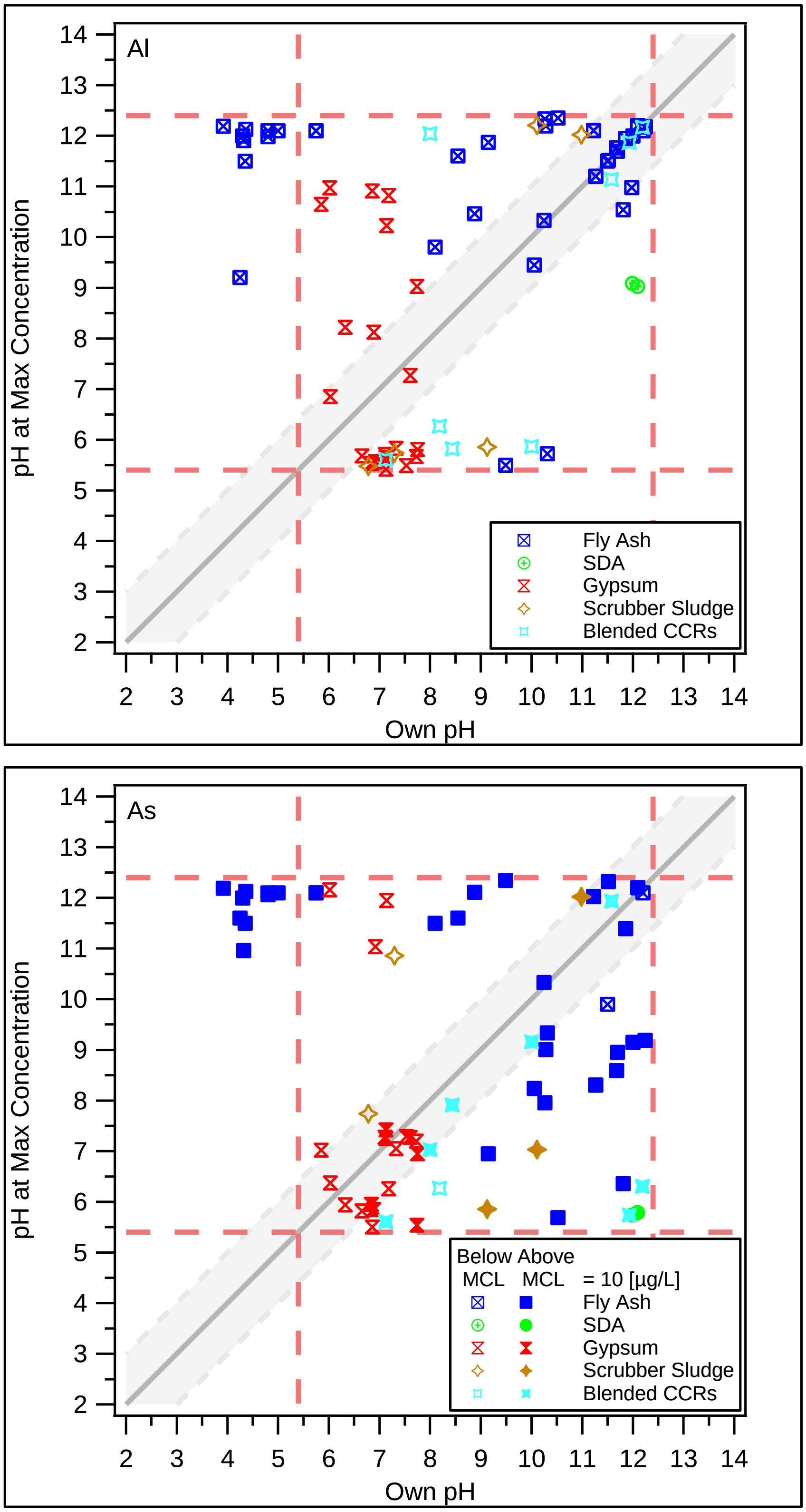
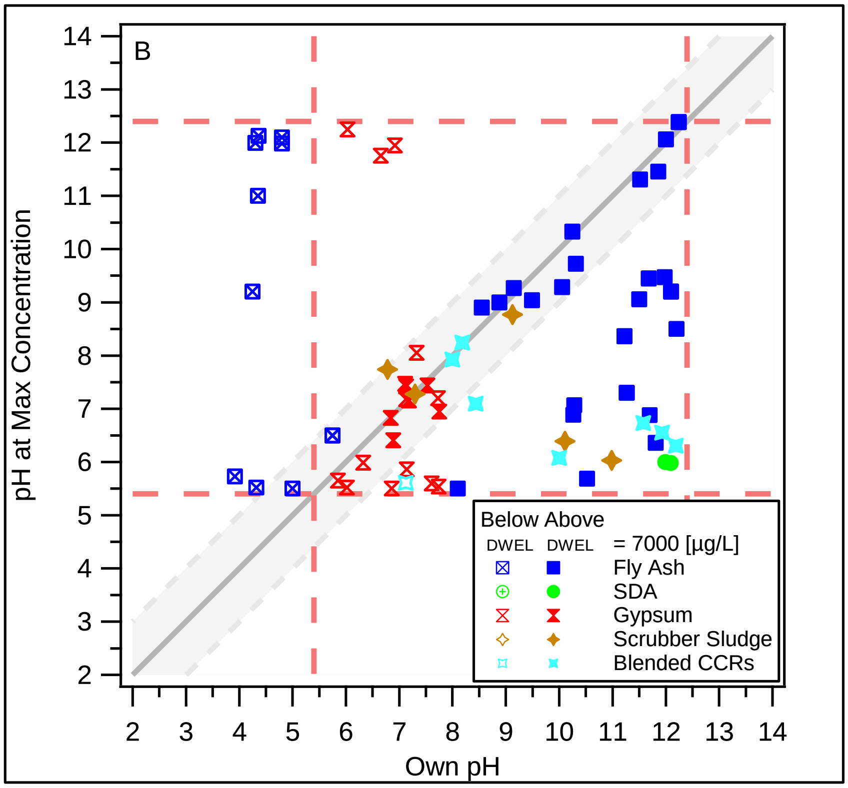


Figure 81 and Figure 82. Aluminum and Arsenic. pH identity plots.



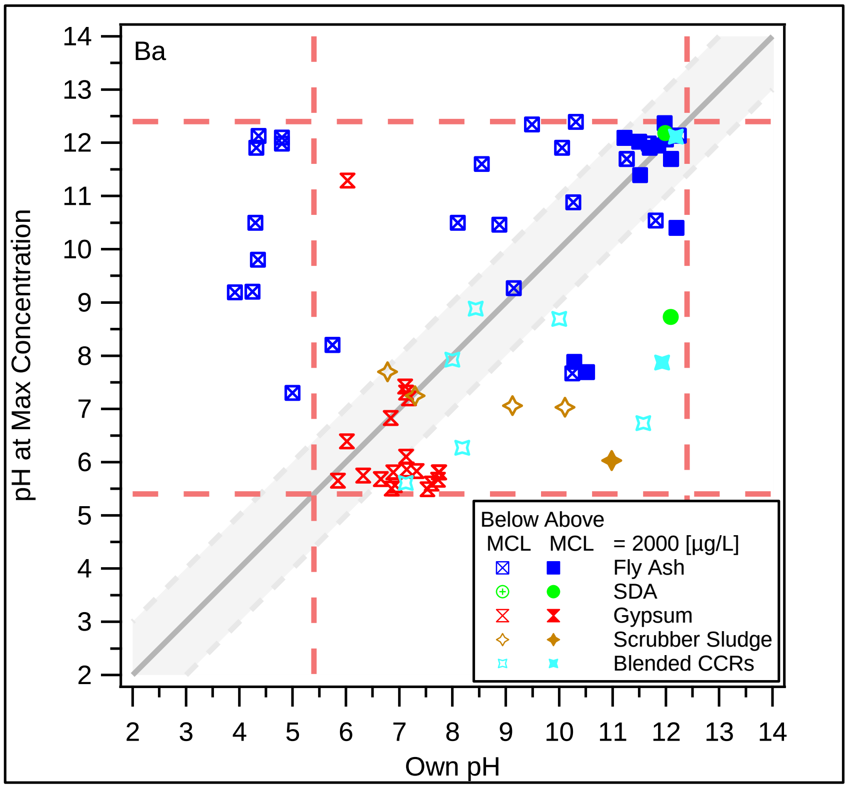


Figure 83 and Figure 84. Boron and Barium. pH identity plots.

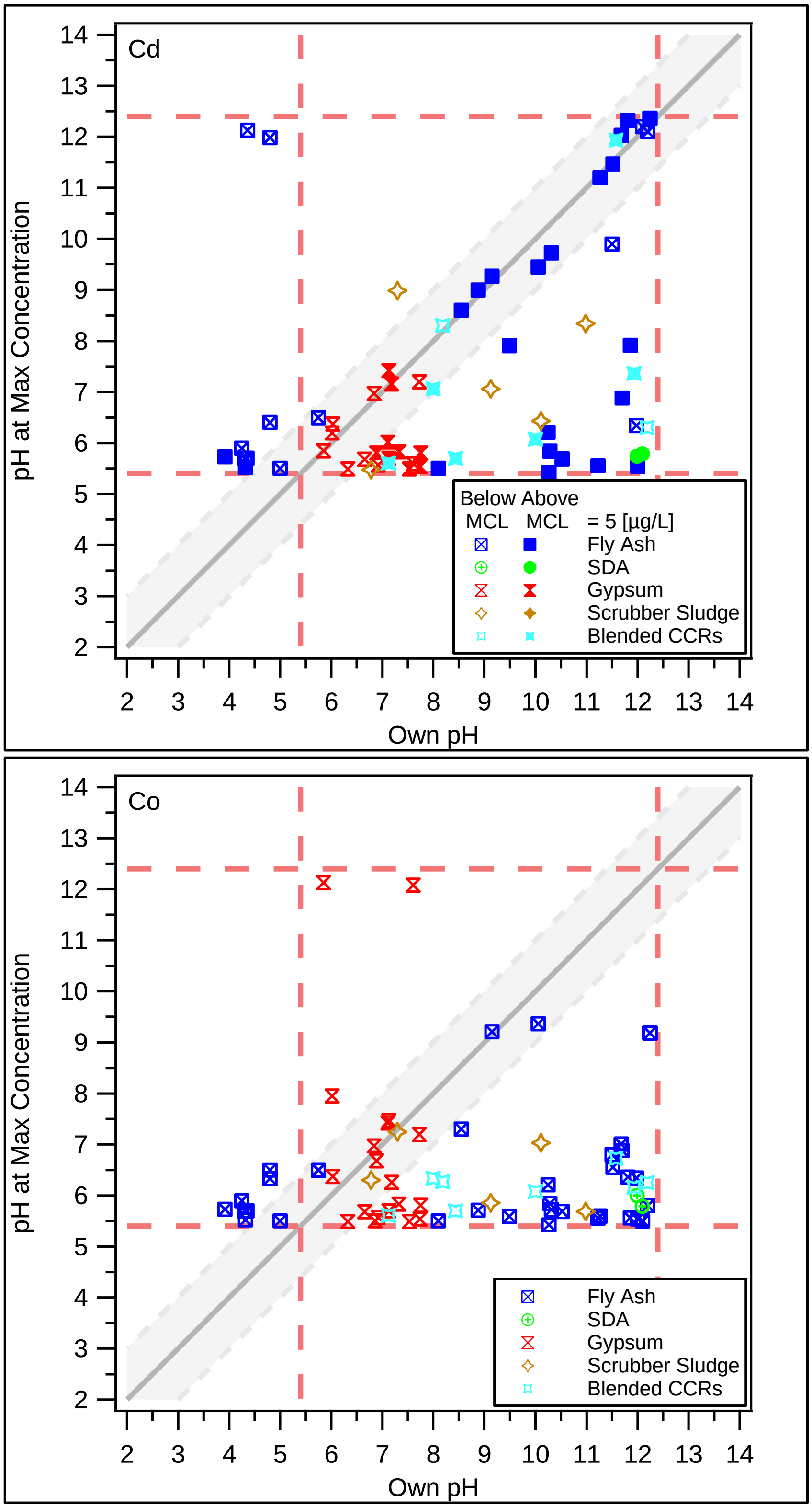


Figure 85 and Figure 86. Cadmium and Cobalt. pH identity plots.

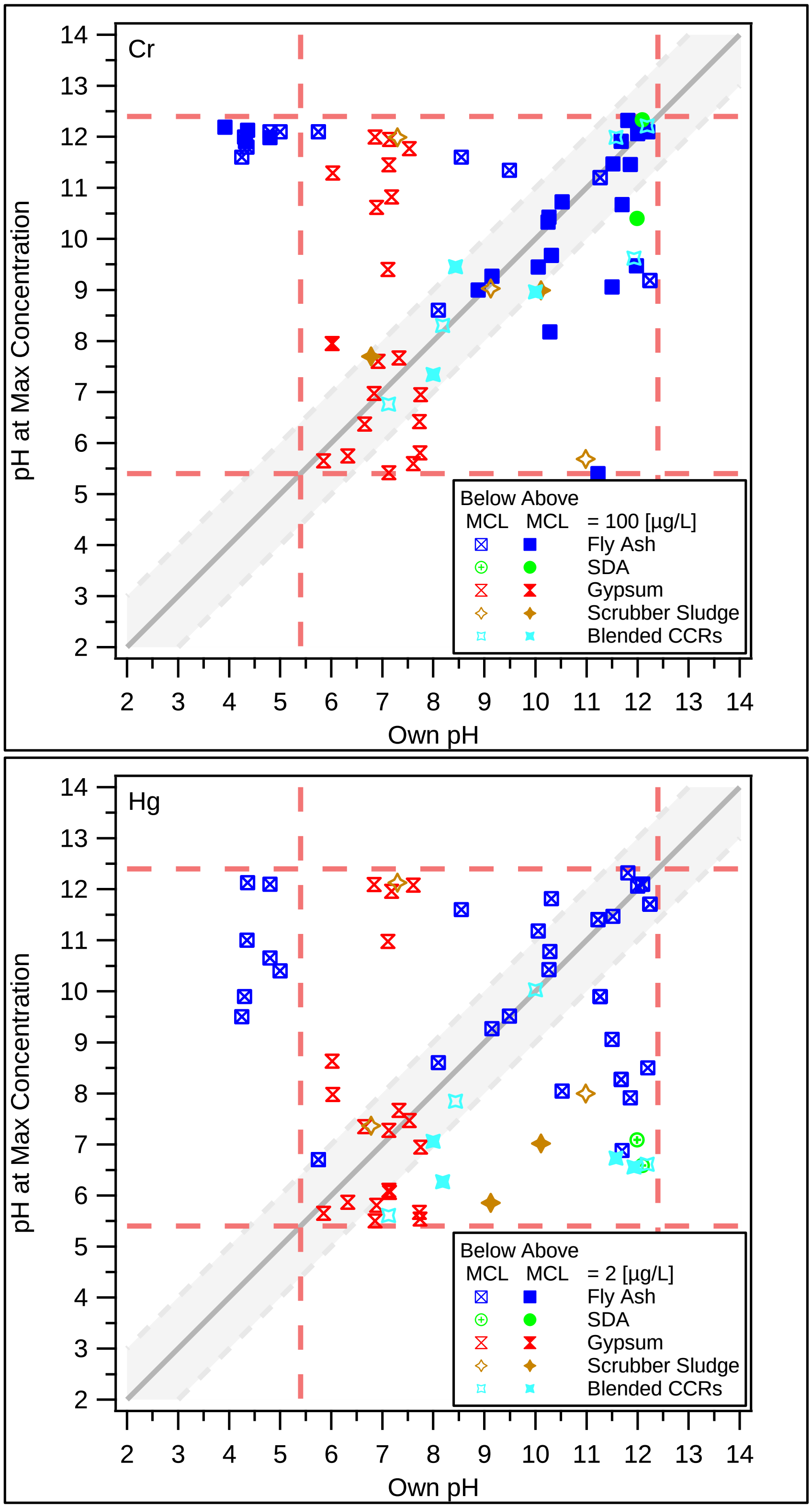


Figure 87 and Figure 88. Chromium and Mercury. pH identity plots.

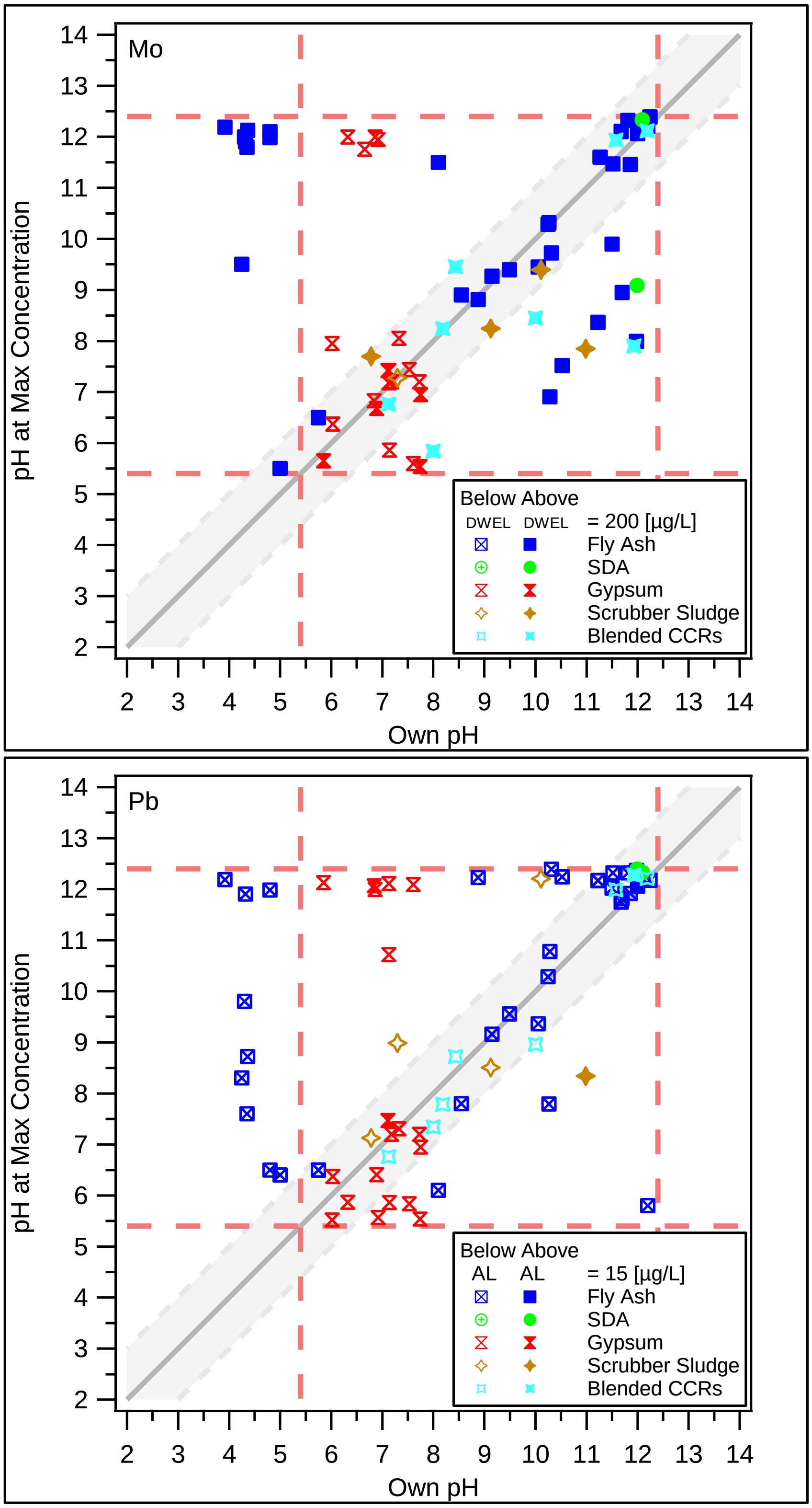


Figure 89 and Figure 90. Molybdenum and Lead. pH identity plots.

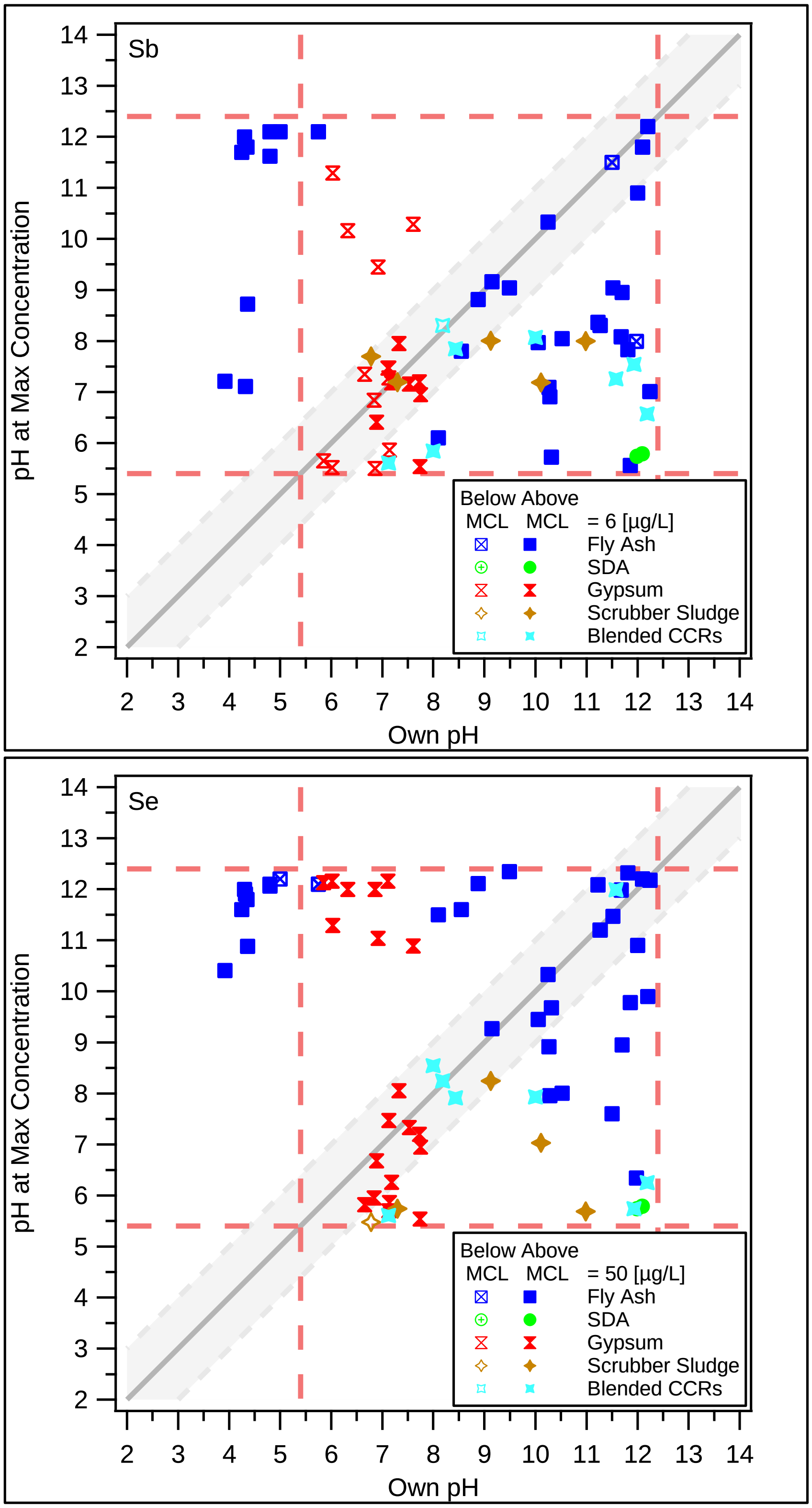


Figure 91 and Figure 92. Antimony and Selenium. pH identity plots.

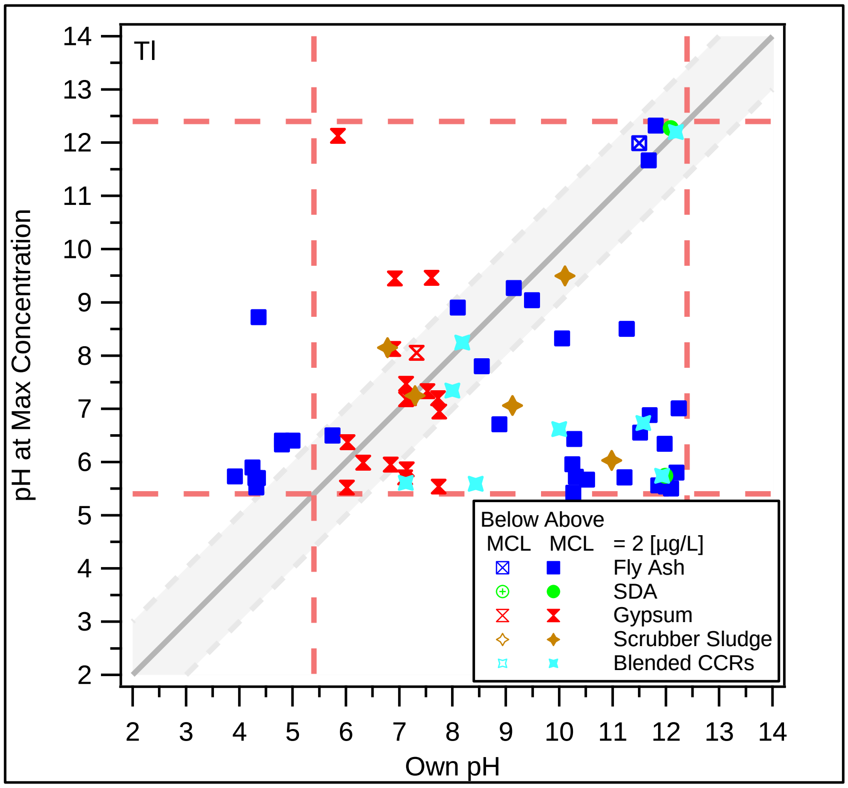


Figure 93. Thallium. pH identity plots.

3.2.5. Comparison of Constituent Maximum Concentrations and Concentrations at the Materials' Own pH from Laboratory Testing Grouped by Material Type with Measurements of Field Samples and the EPA Risk Report Database

Figure 94 through Figure 106 provide summary comparisons for each element by material type of (i) the maximum eluate concentration observed during leaching testing as a function of pH (SR002.1) and as a function of LS (SR003.1)[42] over the domain $5.4 \leq pH \leq 12.4$, and (ii) the eluate concentration observed at "own pH" by leaching with deionized water at LS=10 mL/g (SR002.1), and (iii) reference data ranges derived from the EPRI database of field leachate and pore water concentrations (surface impoundments - "EPRI SI"; landfills – "EPRI LF") and derived from the EPA Risk Report (EPA, 2007b). These are the same reference data ranges used previously as part of this study (Sanchez et al., 2008). Tabular results are provided in Appendix J.

The category "Fly Ash" includes data from all fly ash samples tested (n=34), including those from all coal types and all air pollution control configurations. The category "SDA" represents the results of the two samples of spray dryer residue tested. The category "Gypsum" represents the results from all FGD gypsum samples tested (n=20), including unwashed and washed gypsum samples from all coal types and air pollution control configurations. The category "FGD Residues" represents the results from all FGD scrubber residue samples (n=5) except gypsum. The category "Blended CCRs" represents mixed residues as managed (n=8), including mixtures of fly ash with scrubber residues and with or without added lime, and one as managed sample that was comprised of mixed fly ash with gypsum. The distinction between Blended CCRs and SDA categories was made because Blended CCRs are formed by blending materials captured as separate streams in the air pollution control system, while for SDA fly ash and scrubber residue are captured together.

When five or more data points were available in a given category of test data ("Maximum Values" and "Values at Own pH"), a "box plot" was used to represent the data set, with the following information indicated (from bottom to top of the box and whisker symbol): (i) minimum value (the lowermost whisker), (ii) 5th percentile (mark on lower whisker), (iii) 10th percentile (mark on lower whisker), (iv) 25th percentile (bottom of box), (v) 50th percentile or median value (middle line in box), (vi) 75th percentile (top of box), (vii) 90th percentile (mark on upper whisker), (viii) 95th percentile (mark on upper whisker), (ix) maximum value (the uppermost whisker). To the left of each box plot figure, open circles represent each individual value within the data set. This representation of individual values is used to provide an indication of the distribution of values within the data set because they typically are not normally distributed and in some cases the maximum or minimum values may be very different from the next value or majority of the data. For the SDA category, only each value is displayed because only two data values are contained in the set.

Representation of "Reference Data Ranges" indicates the 5th, median, and 95th percentile of field data for surface impoundments ["EPRI SI"] and landfills ["EPRI LF"]. Ranges of field observations are included for comparison as derived from the EPRI database, considering only observations from disposal sites associated with facilities that have wet FGD scrubbers. Surface

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[42] Including results from testing as a function of LS allows consideration of potentially higher concentrations observed for initial releases that may occur at low LS ratios in the field.

impoundment data are comparable with scrubber sludge results because scrubber sludges are most likely to be disposed in this manner. Landfill data are comparable to blended CCR data because these blended materials are likely to be disposed in landfills. Also included for comparison is the 5th percentile, median, and 95th percentile of the database used to carry out human and ecological health risk evaluations in the EPA Risk Report (EPA, 2007) ("CCW Ash," "CCW FGD," and "CCW Ash and Coal Waste" referring to monofilled fly ash, disposed FGD scrubber sludge, and combined CCR disposal, respectively).

The MCL or DWEL or AL (for lead) if available is included in each figure as a green dashed horizontal line to provide a reference value. The TC, if available, is included in each figure as a maroon dashed line as a second reference value. However, the concentration ranges indicated in the figures as results of this study are direct measurements of laboratory eluates and do not consider attenuation that may occur in the field.

For almost all constituents, a greater range of observed values was evident from laboratory testing compared to the reference data sets. The upper bound concentrations observed for laboratory testing over the domain of $5.4 \leq \text{pH} \leq 12.4$ exceeded the upper bound of reference data sets by one or more orders-of-magnitude for Ba, Cr, Hg, Mo, Sb, Se, and Tl. The upper bound concentrations observed for laboratory testing over the domain of $5.4 \leq \text{pH} \leq 12.4$ were less than the upper bound of reference data sets by one or more orders-of-magnitude for Co and Pb. The MCL or DWEL values were exceeded by the maximum laboratory eluate concentration by one or more samples for fly ash (As, B, Ba, Cd, Cr, Mo, Sb, Se, Tl), SDA residues (As, B, Ba, Cd, Cr, Mo, Sb, Se, Tl), gypsum (As, B, Cd, Cr, Mo, Sb, Se, Tl), FGD residues (As, B, Ba, Cr, Hg, Mo, Sb, Se, Tl), and blended CCRs (As, B, Ba, Cd, Cr, Hg, Mo, Sb, Se).

The observation that most constituent concentrations, both maximum values and own pH values in laboratory eluates, as well as field observations spanned several orders-of-magnitude indicates the very substantial roles that coal type, facility design and operating conditions, and field conditions have on expected concentrations of constituents of concern in leachates from beneficial use or disposal. For example, the observed laboratory eluate concentrations from fly ash samples spanned more than four orders of magnitude, both for maximum values and own pH values.

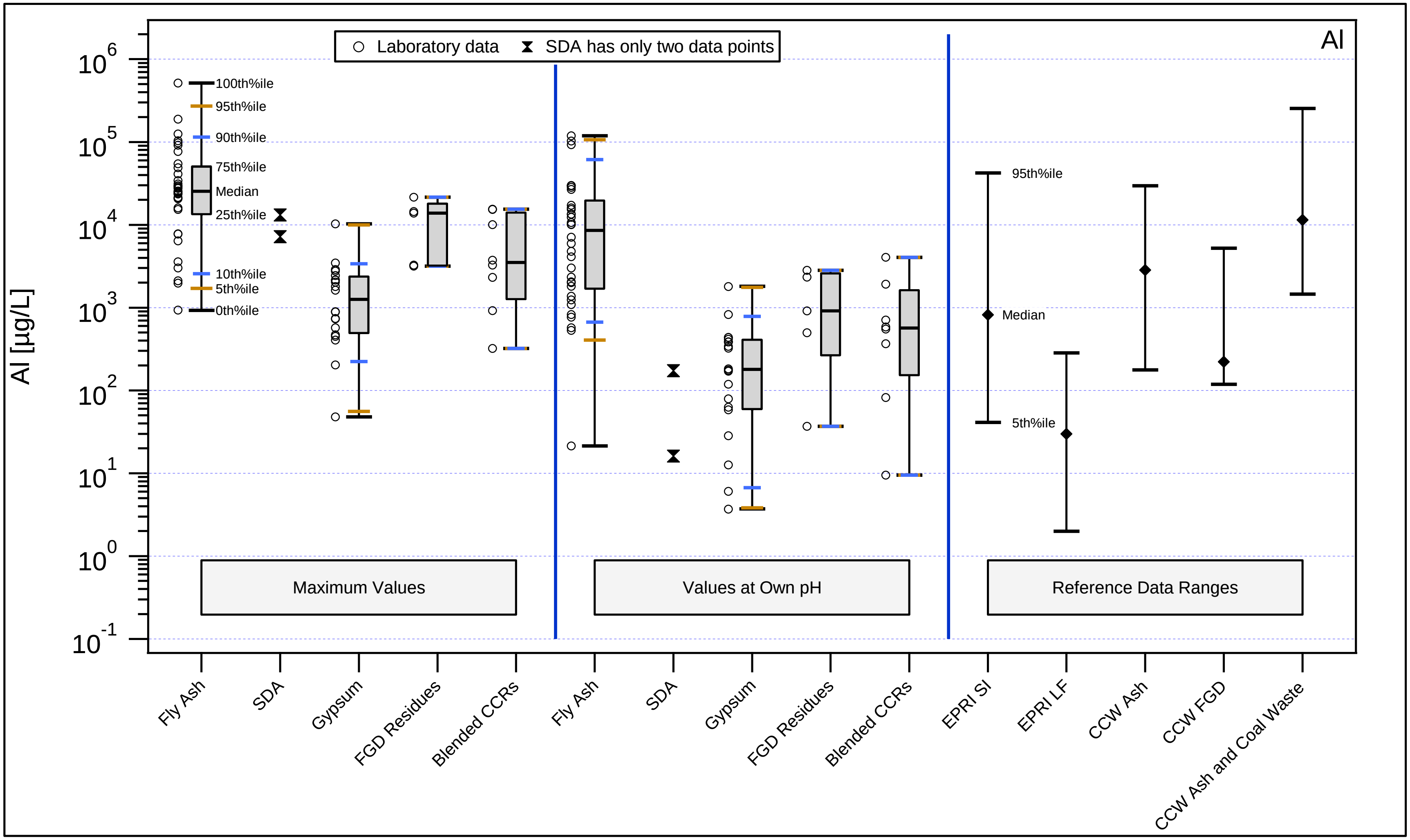

Figure 94. Aluminum. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

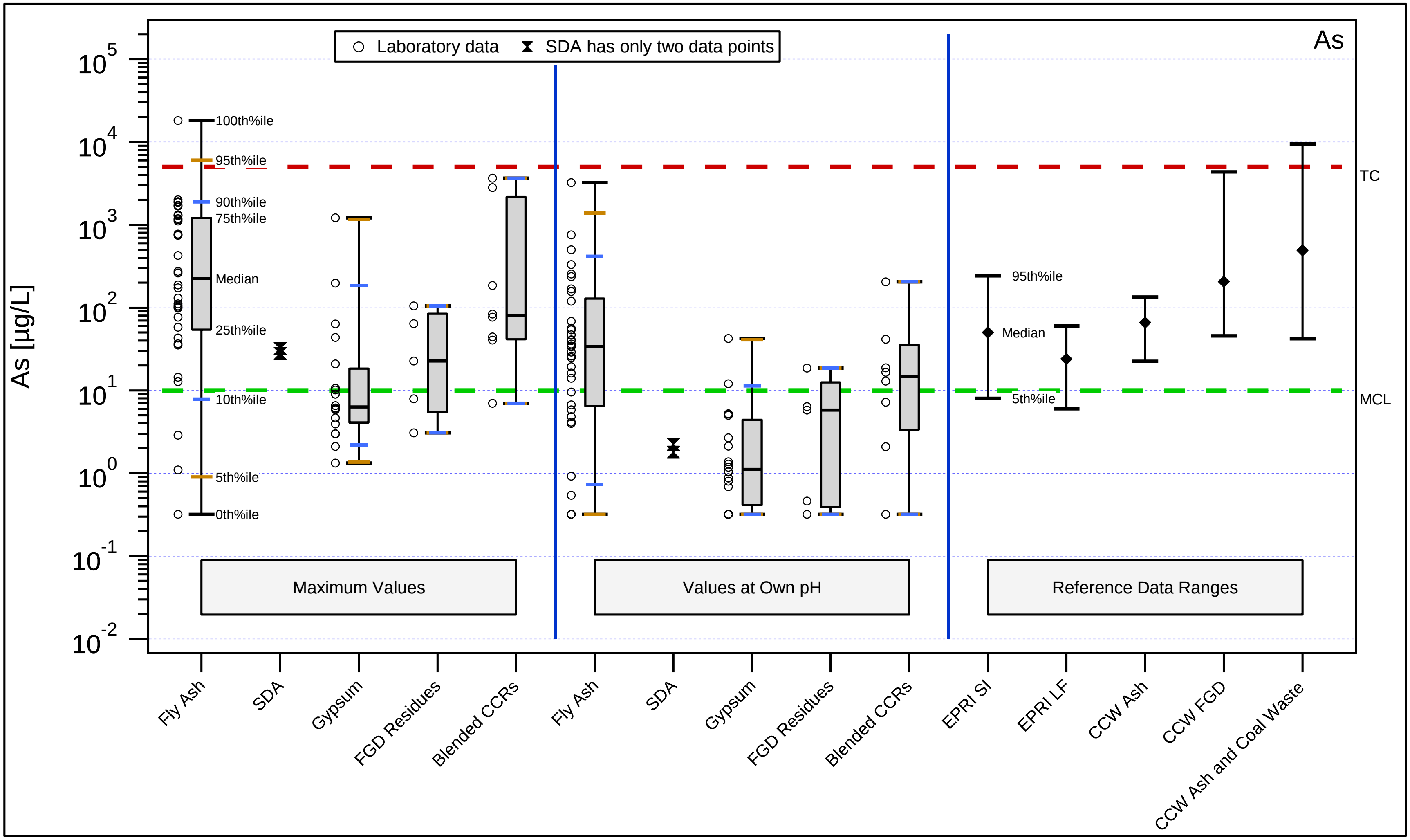

Figure 95. Arsenic. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

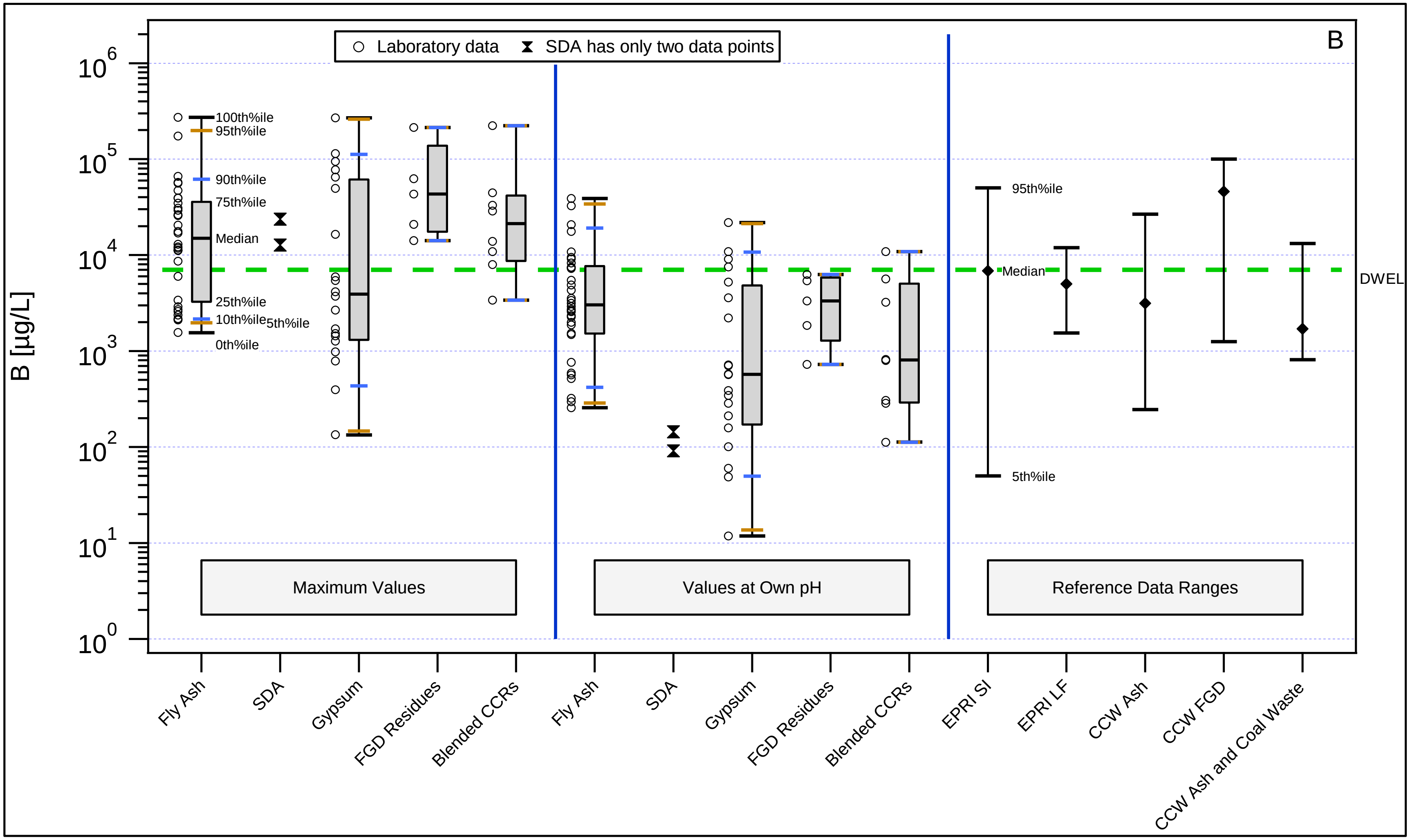

Figure 96. Boron. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

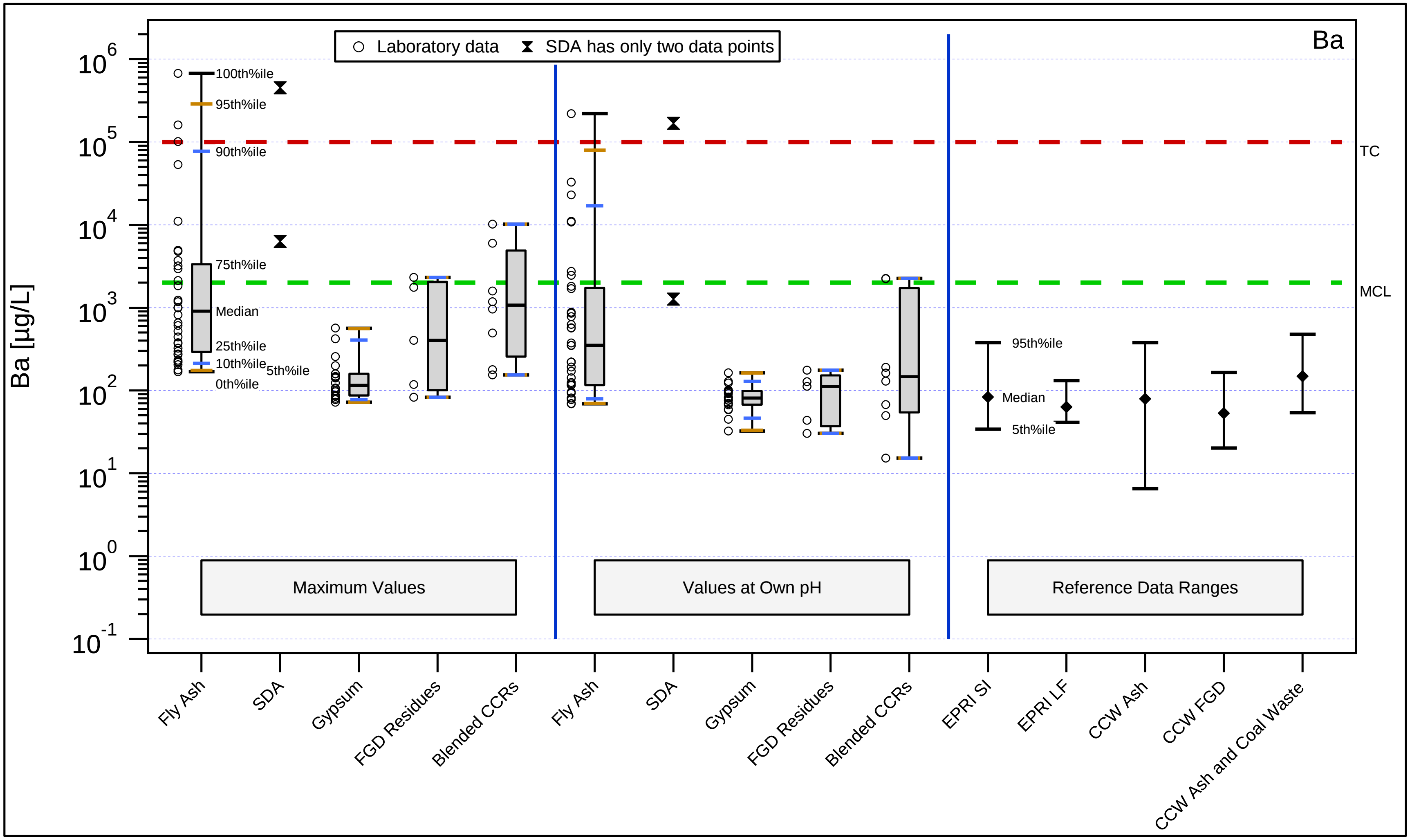

Figure 97. Barium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

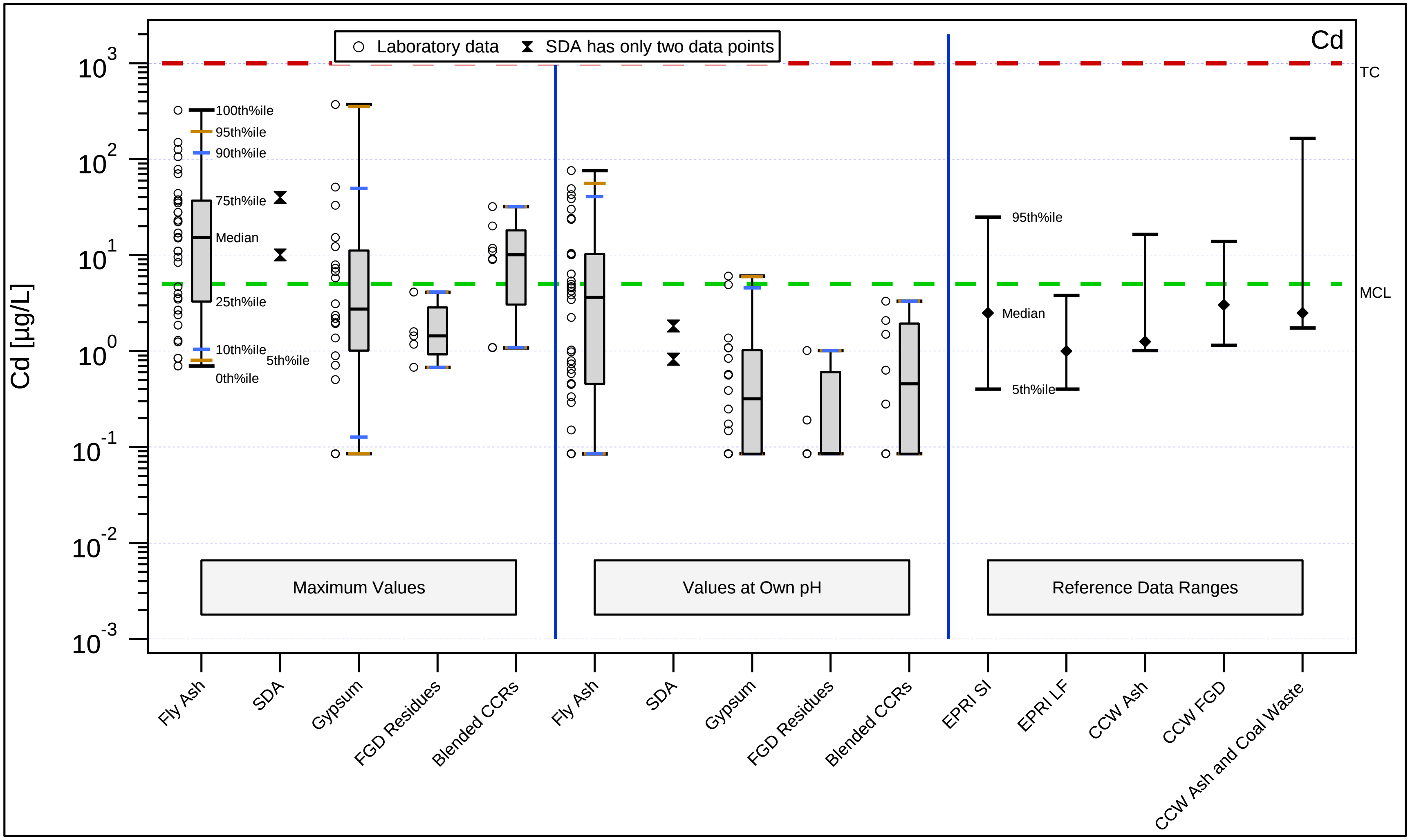

Figure 98. Cadmium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

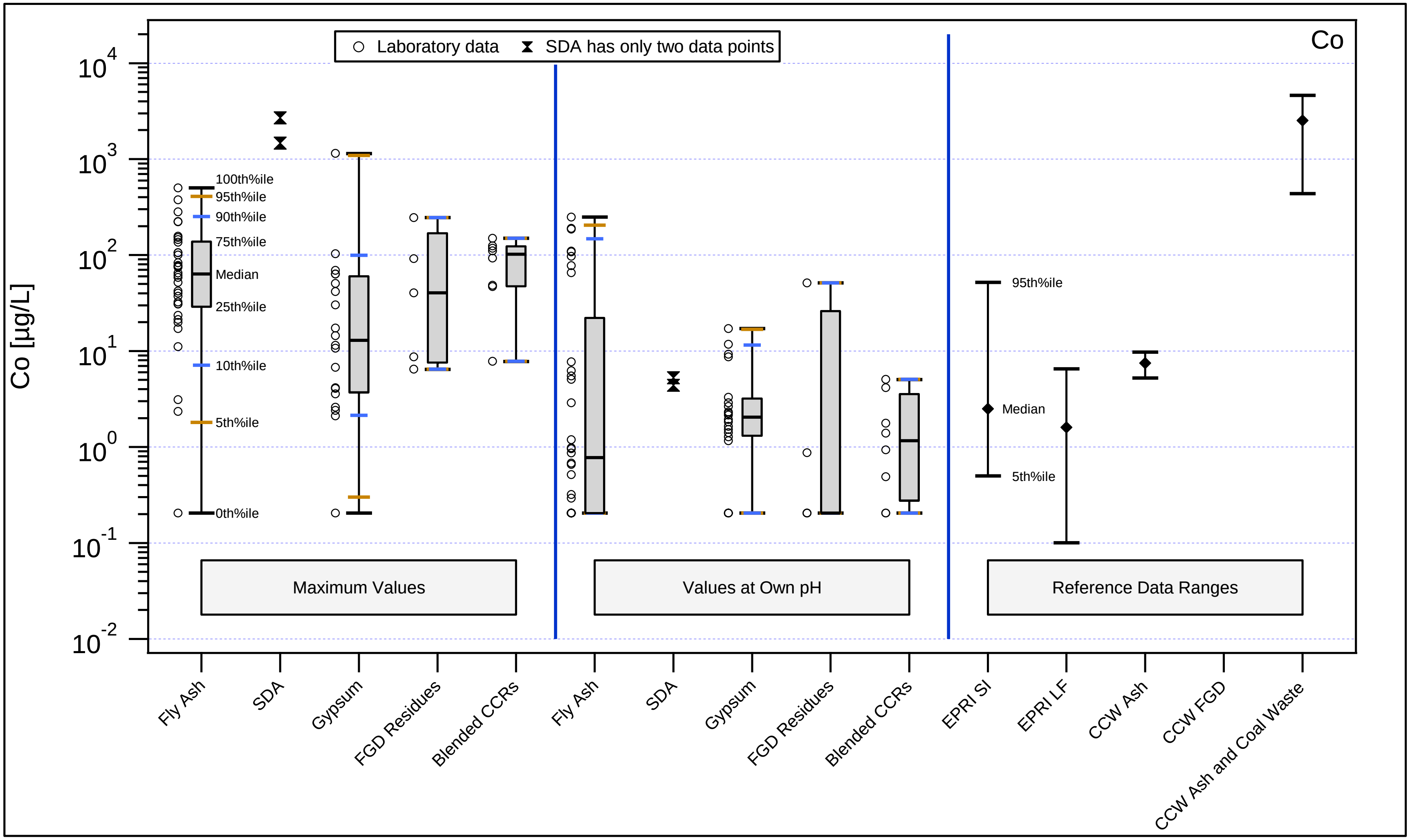

Figure 99. Cobalt. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

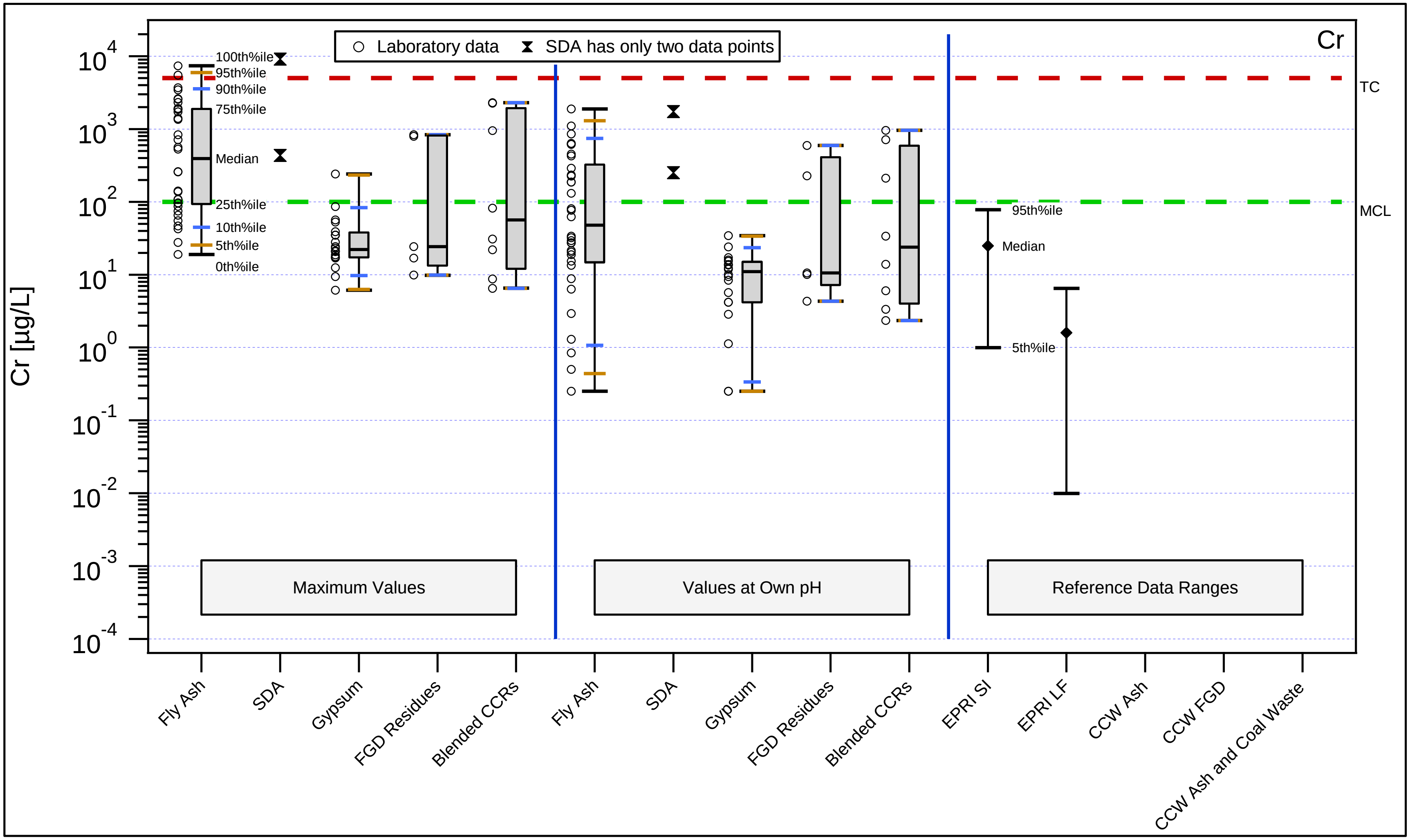

Figure 100. Chromium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

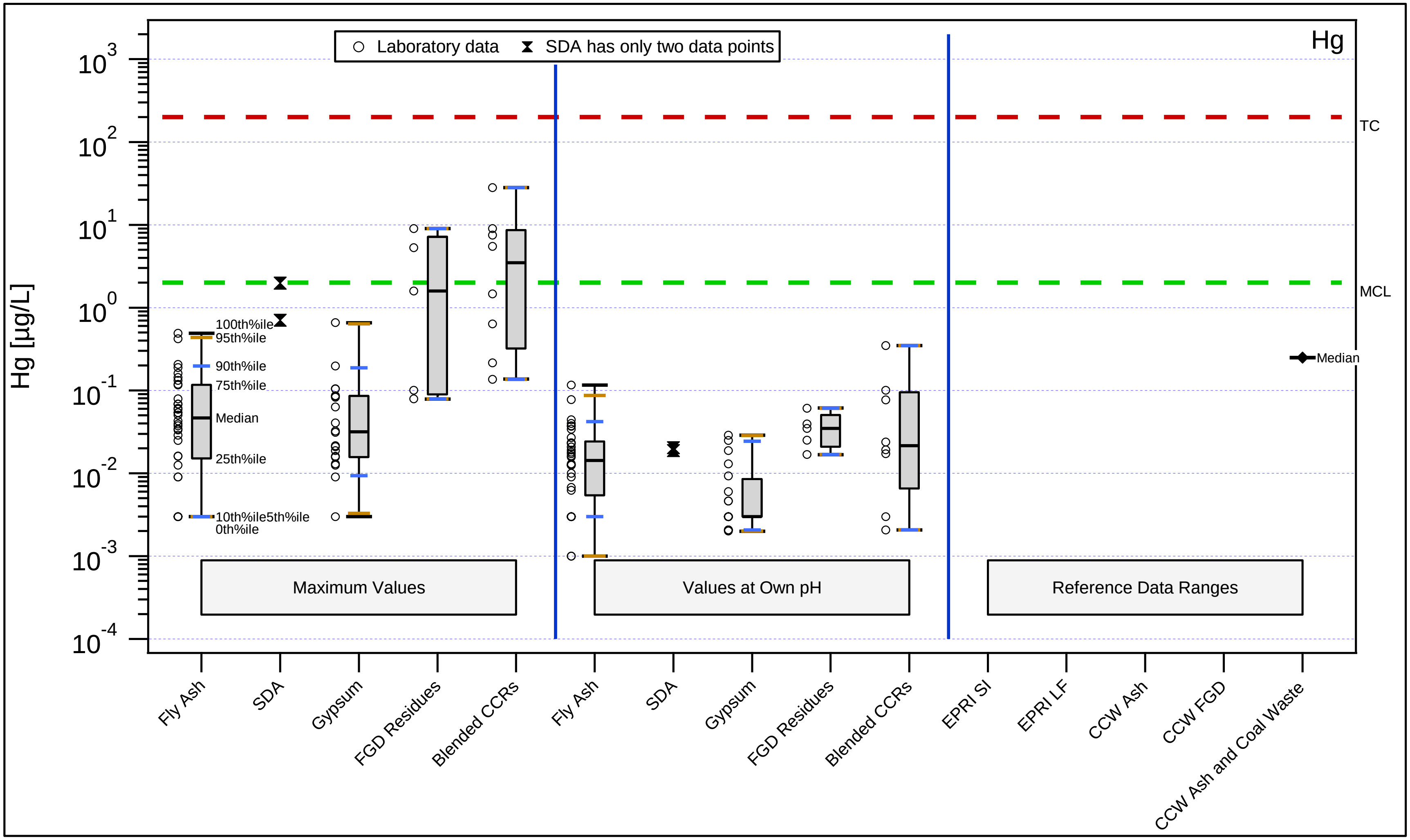

Figure 101. Mercury. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

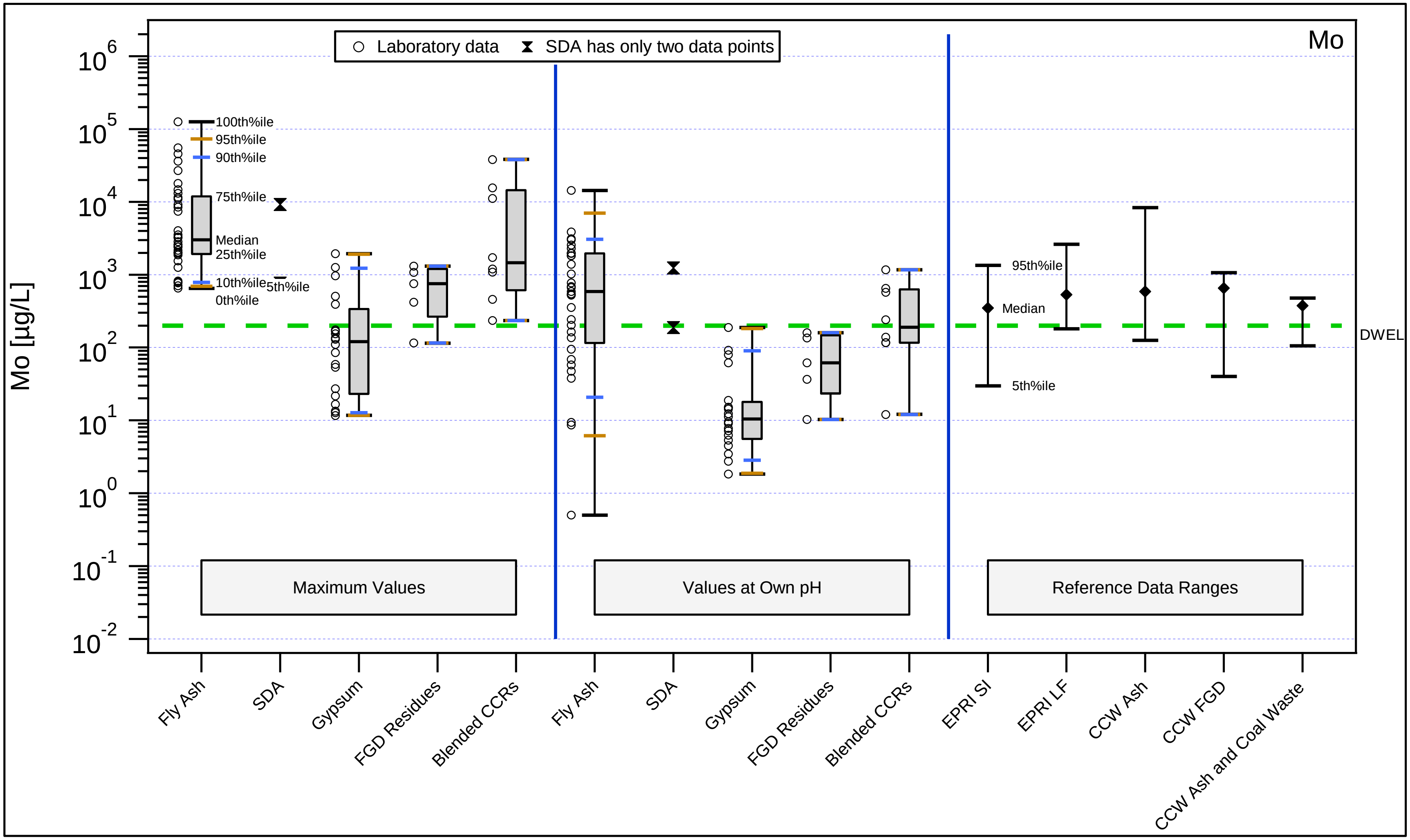

Figure 102. Molybdenum. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

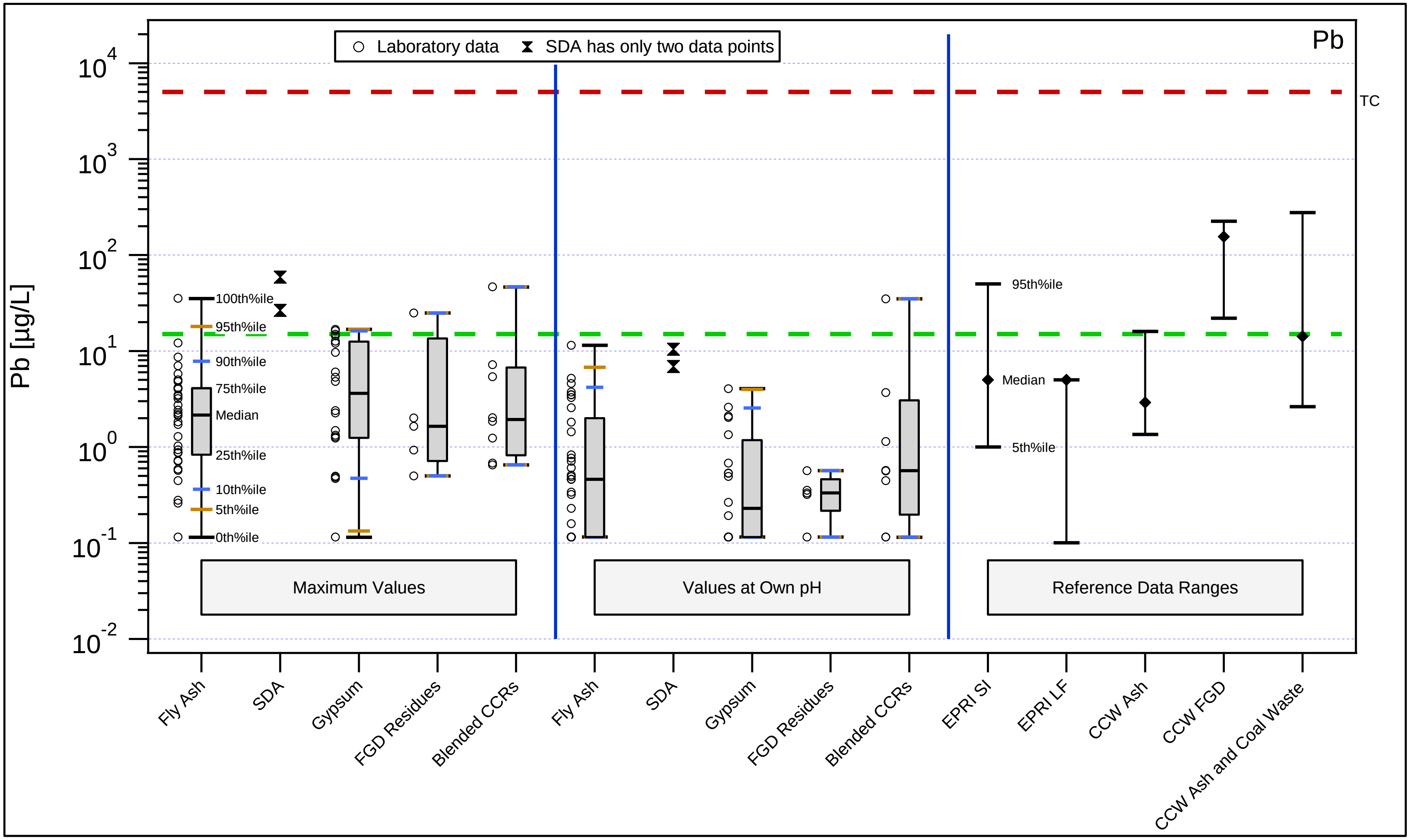

Figure 103. Lead. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

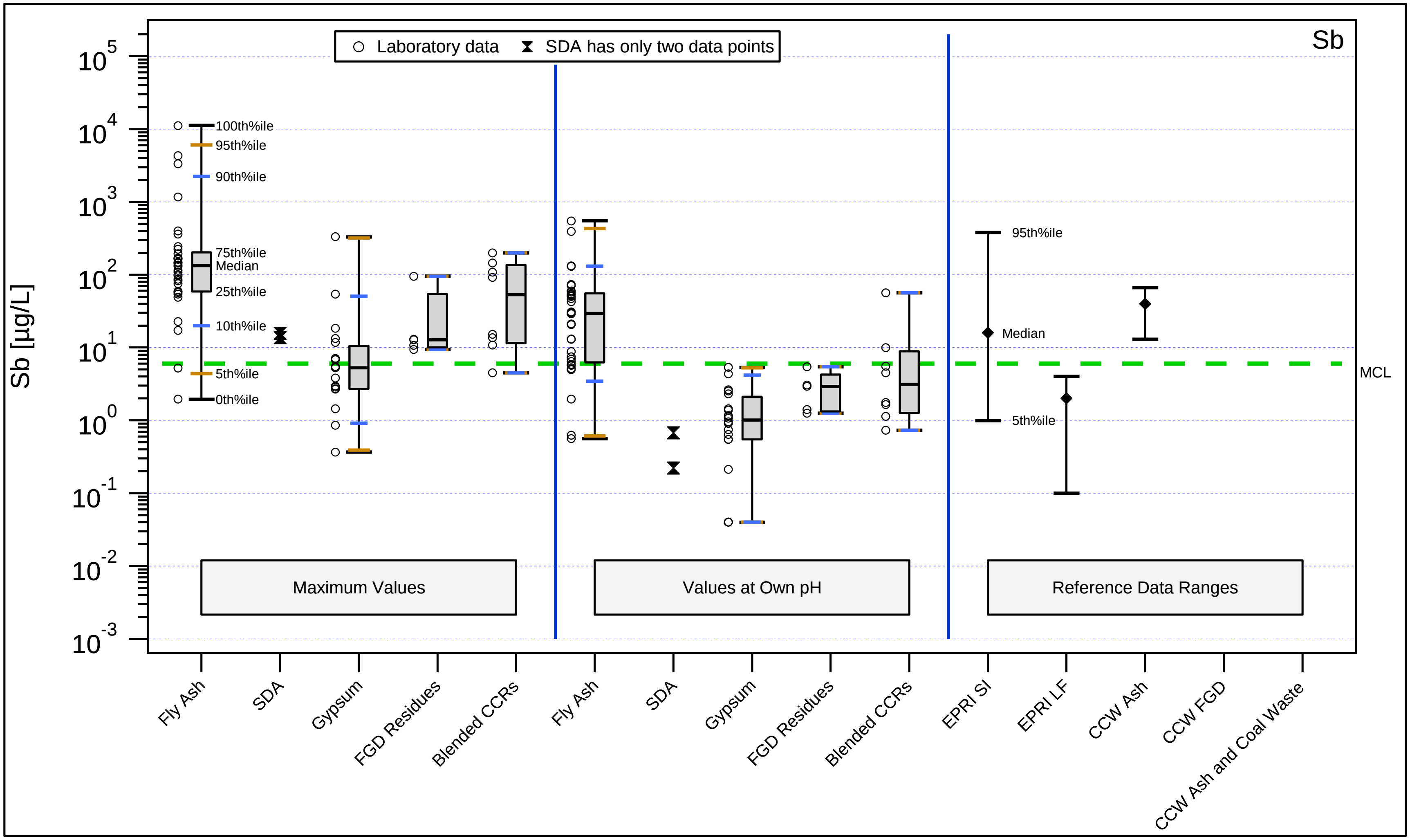

Figure 104. Antimony. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

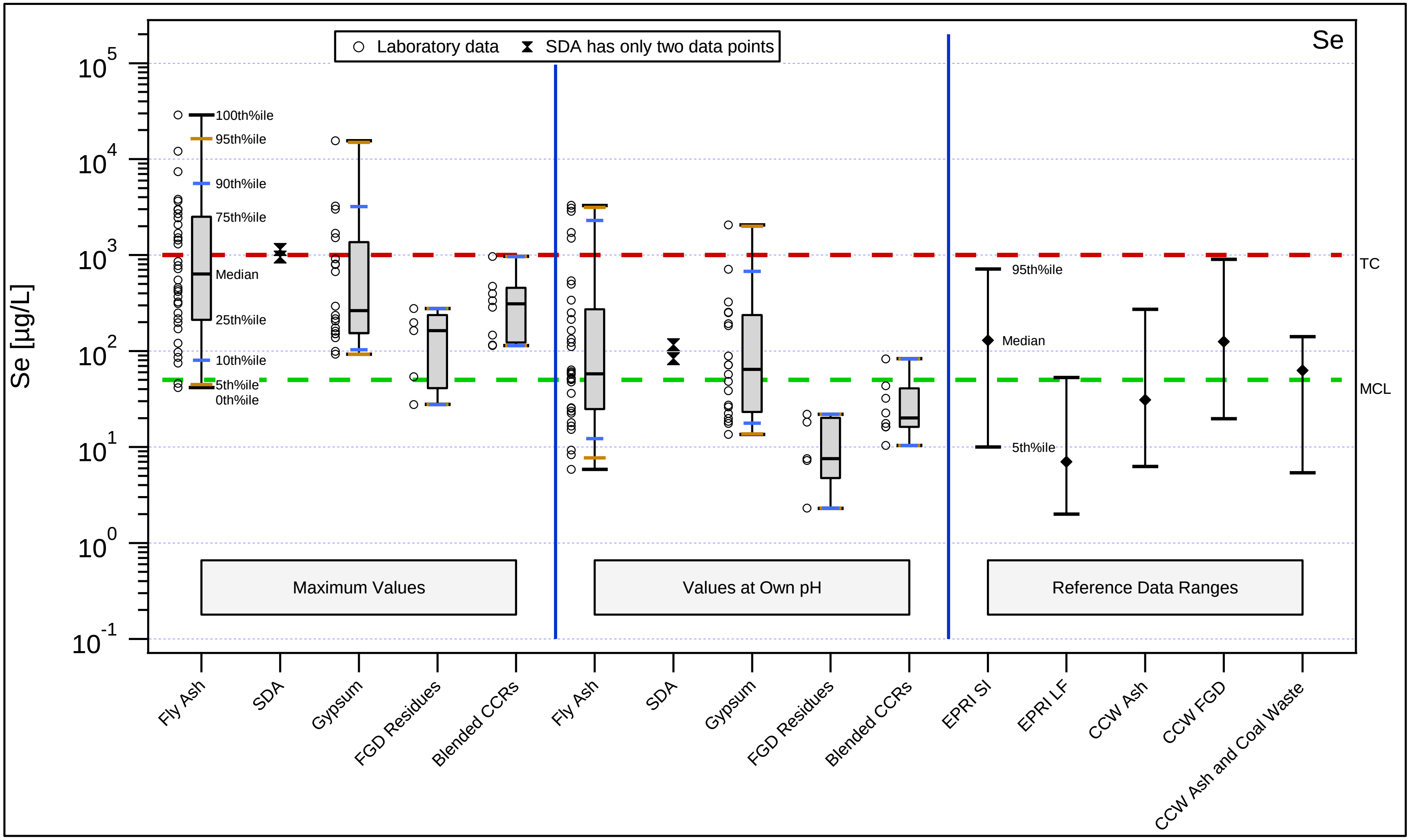

Figure 105. Selenium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

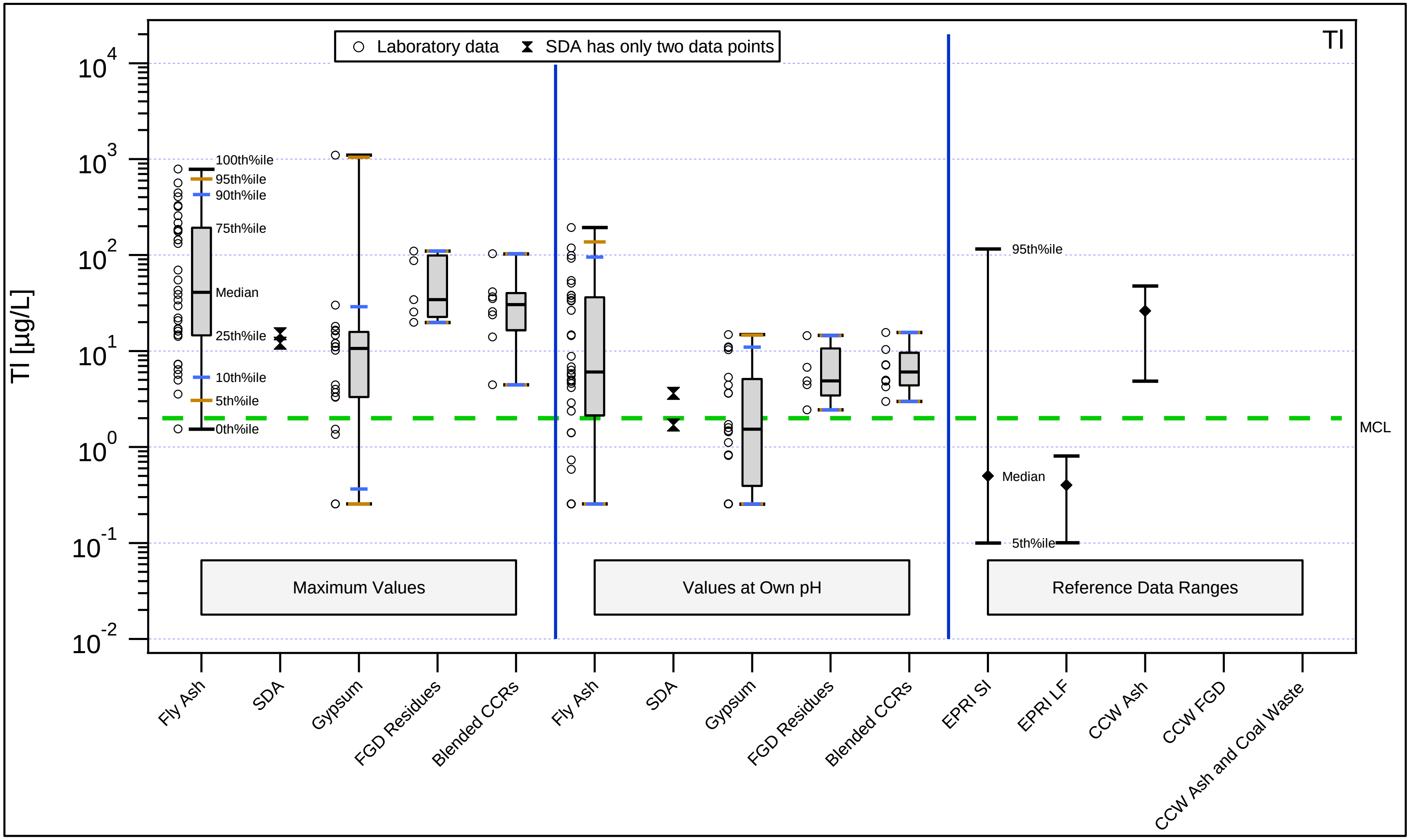

Figure 106. Thallium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain 5.4 ≤ pH ≤ 12.4, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (EPRI SI – surface impoundments; EPRI LF – landfills) and the EPA Risk Report (EPA, 2007b).

3.2.6. Attenuation Factors Needed to Reduce Estimated Leachate Concentrations to Less Than Reference Indicators

Comparison of leaching test results to reference indicators does not consider dilution and attenuation factors (collectively referred to here as attenuation factors) that arise as a consequence of disposal or beneficial use designs that limit release and attenuation that occurs during transport from the point of release to the potential receptor. Minimum attenuation factors needed to reduce maximum leach concentrations (based on laboratory test results for $5.4 \leq \text{pH} \leq 12.4$) to less than MCL or DWEL values were calculated for each COPC to illustrate the importance of consideration of attenuation factors during evaluation of management options Minimum attenuation factors needed to reduce own pH leach concentrations (based on laboratory test results using DI water as the eluant) to less than MCL or DWEL values also were calculated. The resulting attenuation values were calculated by dividing the appropriate measured laboratory leaching test concentration by the respective MCL or DWEL for each COPC. Thus, values greater than one reflect concentrations greater than the MCL or DWEL. Appendix L provides figures comparing attenuation factors calculated for CCR for individual elements and also provides a summary table of all calculated values.

Based on evaluation of the results for each COPC, one consideration was to evaluate across the entire set of COPCs the minimum attenuation factor needed for each CCR sample to result in all COPCs being less than the MCL or DWEL. Furthermore, this evaluation was used to identify the specific COPC (e.g., As, Cd, etc.) that required the greatest attenuation factor for each CCR sample (i.e., the controlling COPC). Results of this analysis are provided in Figure 107 and Figure 108. For each CCR sample, the minimum attenuation factor needed for all COPCs to be less than the MCL or DWEL is graphed, along with identification of the specific COPC driving the result. Two important observations result from this data analysis:

1. Maximum leaching concentrations between pH 5.4 and 12.4 from all CCRs tested in this study require some attenuation to reduce concentrations to less than the MCL or DWEL across all COPCs evaluated; and,
2. For fly ash, the controlling constituent (i.e., the constituent within each sample that required the largest attenuation factor) and the number of samples (..) in which that constituent is controlling are As (11), Ba (3), Cr (4), Sb (5), Se (3), Tl (8); for gypsum the controlling constituents are As (2), Se (13), Tl (5); for scrubber sludge the controlling constituents are Sb (1), Tl (5); for blended, as managed CCRs the controlling constituents are As (3), Cr (1), Hg (1), Sb (2), Tl (1). Thus, it is important to consider these constituents when evaluating the potential impacts from CCR management on human health and the environment.

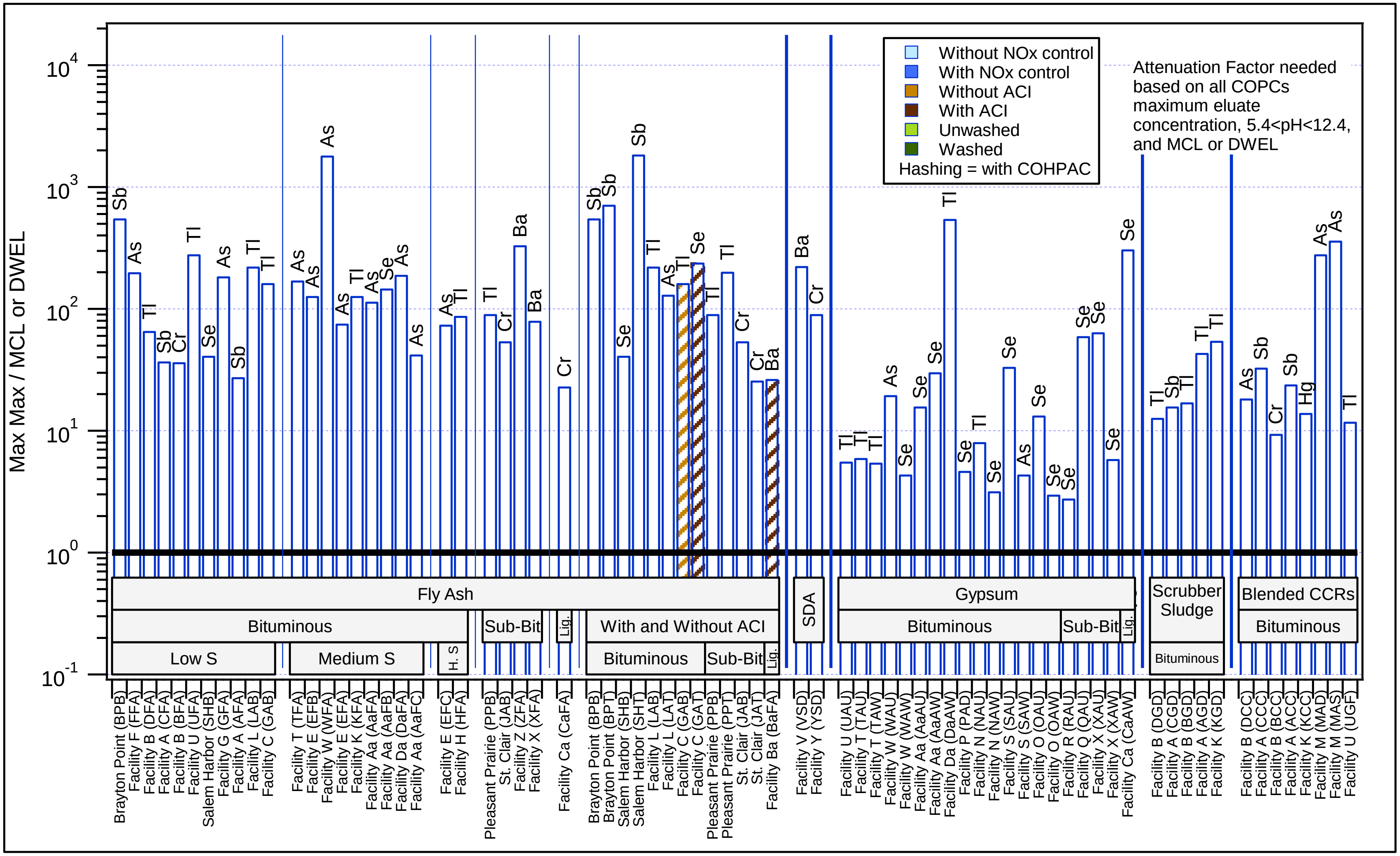

Figure 107. **Minimum attenuation factor** needed for the **maximum eluate concentration** (5.4 ≤ pH ≤ 12.4) to be reduced below the MCL or DWEL for all COPCs considered in this study. COPC requiring the greatest attenuation factor is indicated for each CCR.

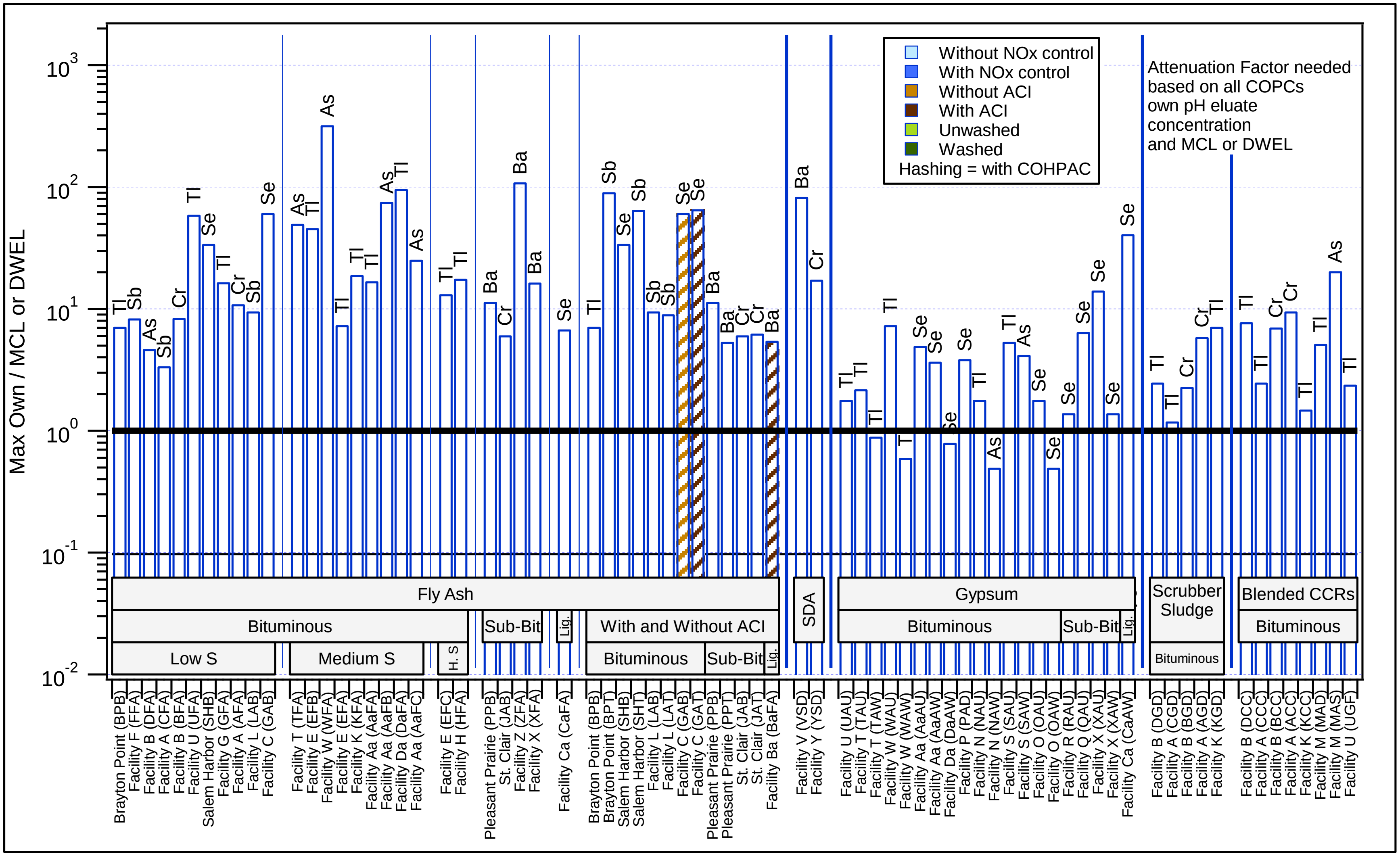

Figure 108. **Minimum attenuation factor** needed for **the own pH eluate concentration** to be reduced below the MCL or DWEL for all COPCs considered in this study. COPC requiring the greatest attenuation factor is indicated for each CCR.

4. SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

The following sections present conclusions from the results presented in this report.

Changes to fly ash and other coal combustion residues (CCRs) are expected to occur as a result of increased use and application of advanced air pollution control technologies in coal-fired power plants. These technologies include flue gas desulfurization (FGD) systems for SO_2 control, selective catalytic reduction (SCR) systems for NO_x control, and activated carbon injection systems for mercury control. These technologies are being or are expected to be installed in response to federal regulations [e.g., Clean Air Interstate Rule (CAIR), Utility MACT Rule], state regulations, legal consent decrees, and voluntary actions taken by industry to adopt more stringent air pollution control.

The Air Pollution Prevention and Control Division (APPCD) of EPA's Office of Research and Development (ORD) has been working since 2000, to evaluate the potential for leaching and cross media transfer of mercury and other constituents of potential concern (COPCs) from management of these modified CCRs (primarily disposal, but also reuse). This research was cited as a priority in EPA's Mercury Roadmap (http://www.epa.gov/mercury/roadmap.htm) to ensure that the solution to one environmental problem is not causing another.

CCR samples of each material type were collected in an attempt to span the range of likely coal types [i.e., low, medium and high sulfur bituminous, sub-bituminous and lignite] and air pollution control configurations reflecting use of more stringent air pollution control. This report presents results from the evaluation of 73 CCRs from 31 coal-fired power plants with various combinations of particulate matter, NO_x, Hg, and SO_2 control. For several of the 31 plants, samples were obtained before and after changes were made in air pollution control.

CCRs have been grouped into the five categories as shown in Table 12. Each of the CCR samples was analyzed for a range of physical properties, total metals content, and leaching characteristics. The testing methods used in this research assess CCR leaching potential over a range of values for two parameters that both vary in the environment and can affect the rate of constituent leaching from a material. These are: (1) the pH and (2) the amount of water contact [in the test, the ratio of liquid-to-solids (LS) being tested]. These are considered improved leaching test methods that address key concerns with single point testing that were raised by EPA's Science Advisory Board and the National Academy of Sciences. An advantage of using this testing approach is that analysis of the data can be tailored or targeted to particular waste management or use conditions. When key material management conditions are known, the data can be used to estimate leaching over the range of plausible management conditions for that particular material. This can be done for either a broad range of conditions (e.g., in assessing release potential on a national basis) or more narrowly (as in estimating release potential at a particular site or limited set of sites).

Table 12. Identification of CCRs evaluated and included in this Report.

Samples Evaluated by CCR Category	Report 1*	Report 2**	Additional Samples Collected for this report	Total Samples Evaluated in this Report
1. Fly Ash	12	5	17	34
2. FGD Gypsum	-	6	14	20
3. "Other" FGD Residues (primarily calcium sulfite from scrubbers that do not use oxidation to generate gypsum)	-	5	2	7
4. Blended CCRs (typically a mixture of fly ash, calcium sulfite, and lime)	-	7	1	8
5. Wastewater Treatment Filter Cake	-		4	4

* (Sanchez et al., 2006).

** (Sanchez et al., 2008).

Provided below in a summary table for each CCR category are the range of leach results over the pH range of 5.4 and 12.4[43], along with comparison to available regulatory or reference indicators including TC, MCL, and DWEL. In making such comparisons, it is critical to bear in mind that these test results represent an estimate of constituent release from the material as disposed or used on the land. They do not include any attempt to estimate the amount of constituent that may reach an aquifer or drinking water well. Leachate leaving a landfill is invariably diluted in ground water or constituent concentration attenuated by sorption and other chemical reactions in groundwater and sediment. Also, groundwater pH may be different from the pH at the site of contaminant release, and so the solubility and mobility of leached contaminants may change when they reach groundwater. None of these dilution or attenuation processes is incorporated into the leaching values presented, and so comparison with regulatory reference values, particularly drinking water values, must be done with caution.

The principle conclusions are:

1. Review of the data presented in Table 13 and Table 14, for fly ash and FGD gypsum, show a range of total concentration of constituents, but a much broader range (by orders of magnitude) of leaching values, in nearly all cases. This much greater range of leaching values only partially illustrates what more detailed review of the data shows: that for CCRs, the rate of constituent release to the environment is affected by leaching conditions (in some cases dramatically so), and that leaching evaluation under a single set of conditions will, in many cases, lead to inaccurate conclusions about expected leaching in the field.

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[43] This pH range could understate potential concerns when these materials are used in agricultural, commercial, and engineering applications if the field conditions are more variable than during disposal. For example, 9 of the 34 fly ash samples evaluated indicated the eluate pH in deionized water (i.e., the pH generated by the tested material itself) to be more acidic than pH 5.4.

2. Comparison of the ranges of totals values and leachate data also supports earlier conclusions that the rate of constituent leaching cannot be reliably estimated based on total constituent concentration alone or with use of linear K_d partitioning values.
3. The maximum eluate concentration from leaching test results varies over a wide range in pH and is different for different CCR types and elements. This indicates that there is not a single pH for which testing is likely to provide confidence in release estimates over a wide range of disposal and beneficial use options, emphasizing the benefit of multi-pH testing.
4. Distinctive patterns are observed in leaching behavior over the range of pH values that would plausibly be encountered on CCR disposal, depending upon the type of material and element.
5. Summary data in Table 14 on the leach results from evaluation of 34 fly ash samples across the plausible management pH range of 5.4 to 12.4, indicates leaching concentration ranges over several orders of magnitude as a function of pH and ash source:
    a. the leach results at the upper end of the concentration ranges exceeded the TC values for As, Ba, Cr, and Se.
    b. the leach results at the upper end of the concentration ranges exceeded the MCL or DWEL for Sb, As, Ba, B, Cd, Cr, Pb, Mo, Se, and Tl.
6. Summary data in Table 15 on the leach results from evaluation of 20 FGD gypsum samples across the plausible management pH domain of 5.4 to 12.4, indicates leaching concentration ranges over several orders of magnitude as a function of pH and FGD gypsum source:
    a. the leach results at the upper end of the concentration ranges exceeded the TC values for Se.
    b. the leach results at the upper end of the concentration ranges exceeded the MCL or DWEL for Sb, As, B, Cd, Cr, Mo, Se, and Tl.
7. There is considerable variability in total content and the leaching of constituents of potential within a material type (e.g., fly ash, gypsum) such that while leaching of many samples, without adjustment for dilution and attenuation, exceeds one or more of the available reference indicators, many of the other samples within the material type may be less than the available regulatory or reference indicators. This suggests that materials from certain facilities may be acceptable for particular disposal and beneficial use scenarios while the same material type from a different facility or the same facility produced under different operating conditions (i.e., different air pollution controls) may not be acceptable for the same management scenario.

In interpreting these results, please note that the CCRs analyzed in this report are not considered to be a representative sample of all CCRs produced in the U.S. For many of the observations, only a few data points were available. It is hoped that through broader use of the improved leach test methods (as used in this report), that additional data from CCR characterization will become available. That will help better define trends associated with changes in air pollution control at coal-fired power plants.

Table 13. **Fly Ash -** Laboratory leach test eluate concentrations for 5.4 ≤ pH ≤ 12.4 and at "own pH" from evaluation of thirty-four fly ash samples.

	Hg	**Sb**	**As**	**Ba**	**B**	**Cd**	**Cr**	**Co**	**Pb**	**Mo**	**Se**	**TI**
Total in Material (mg/kg)	0.01 – 1.5	3 – 14	17 – 510	590 – 7,000	NA	0.3 – 1.8	66 – 210	16 – 66	24 – 120	6.9 – 77	1.1 – 210	0.72 – 13
Leach results (µg/L)	<0.01 – 0.50	<0.3 – 11,000	0.32 – 18,000	50 – 670,000	210 – 270,000	<0.1 – 320	<0.3 – 7,300	<0.3 – 500	<0.2 – 35	<0.5 – 130,000	5.7 – 29,000	<0.3 – 790
TC (µg/L)	200	-	5,000	100,000	-	1,000	5,000	-	5,000	-	1,000	-
MCL (µg/L)	2	6	10	2,000	7,000 DWEL	5	100	-	15	200 DWEL	50	2

Note: The shade is used to indicate where there could be a potential concern for a metal when comparing the leach results to the MCL, DWEL, or TC. Note that MCL and DWEL values represent well concentrations; leachate dilution and attenuation processes that would occur in groundwater before leachate reaches a well are not accounted for, and so MCL and DWEL values are compared to leaching concentrations here to provide context for the test results and initial screening.

Table 14. **FGD Gypsum -** Laboratory leach test eluate concentrations for 5.4 ≤ pH ≤ 12.4 and at "own pH" from evaluation of twenty FGD gypsum samples.

	Hg	**Sb**	**As**	**Ba**	**B**	**Cd**	**Cr**	**Co**	**Pb**	**Mo**	**Se**	**TI**
Total in Material (mg/kg)	0.01 – 3.1	0.14 – 8.2	0.95 – 10	2.4 – 67	NA	0.11 – 0.61	1.2 – 20	0.77 – 4.4	0.51 – 12	1.1 – 12	2.3 – 46	0.24 – 2.3
Leach results (µg/L)	<0.01– 0.66	<0.3 – 330	0.32 – 1,200	30 – 560	12 – 270,000	<0.2 – 370	<0.3 – 240	<0.2 – 1,100	<0.2 – 12	0.36 – 1,900	3.6 – 16,000	<0.3 – 1,100
TC (µg/L)	200	-	5,000	100,000	-	1,000	5,000	-	5,000	-	1,000	-
MCL (µg/L)	2	6	10	2,000	7,000 DWEL	5	100	-	15	200 DWEL	50	2

Note: The shade is used to indicate where there could be a potential concern for a metal when comparing the leach results to the MCL, DWEL, or TC. Note that MCL and DWEL values represent well concentrations; leachate dilution and attenuation processes that would occur in groundwater before leachate reaches a well are not accounted for, and so MCL and DWEL values are compared to leaching concentrations here to provide context for the test results and initial screening.

5. REFERENCES

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Appendix A

Facility Descriptions and CCR Sample Locations

Facility Descriptions

Facility Flow Diagrams

Appendix A

Facility and Sampling Descriptions

Brayton Point

Brayton Point Station (Somerset, MA) is operated by PG&E National Energy Group. This facility is composed of four fossil fuel fired units designated as Units 1, 2, 3, and 4. The test unit selected, unit 1, has a tangentially fired boiler rated at 245 MW. Brayton Point Unit 1 was chosen for this evaluation because of its combination of firing low-sulfur bituminous coal with a cold-side ESP. This configuration represents a wide range of coal-fired power plants located in the eastern U.S. (Senior et al., 2003a).

The primary particulate control equipment consists of two CS-ESPs in series, with an EPRICON flue gas conditioning system that provides SO_3 for fly ash resistivity control.

The EPRICON system is not used continuously, but on an as-needed basis. The first ESP ("Old ESP") in this particular configuration was designed and manufactured by Koppers. The Koppers ESP has a weighted wire design and a specific collection area (SCA) of 156 ft^2/1000 acfm. The second ESP ("New ESP") in the series configuration was designed and manufactured by Research-Cottrell. The second ESP has a rigid electrode design and an SCA of 403 ft^2/1000 acfm. Total SCA for the unit is 559 ft^2/1000 acfm. The precipitator inlet gas temperature is nominally 280 ^oF at full load (Senior et al., 2003a).

Hopper ash is combined between both precipitators in the dry ash-pull system. The ash is processed by an on-site Separation Technology Inc. (STI) carbon separation system, to reduce the carbon content. This processed ash is sold as base for concrete and the remainder of the higher carbon ash is land disposed (Senior et al., 2003a).

The injection rate of the PAC was 20 lb of sorbent used for each million actual cubic feet of gas (lb/MMacf) at the time when the CCR with ACI in use was collected from this facility.

The baseline and post-control ashes used for this study were collected as composite samples from the C-row ash hoppers of the new ESP before processing for carbon separation. Ash for this study was collected before processing for carbon separation because not all facilities do this processing.[1] The baseline ash was collected on 6 June 2002. The post-control fly ash was collected on 21 July 2002. Both fly ashes were stored in covered five gallon buckets in the onsite trailer at ambient temperatures.

Pleasant Prairie

Wisconsin Electric Power Company, a subsidiary of Wisconsin Energy, owns and operates Pleasant Prairie Power Plant located near Kenosha, WI. The plant has two 600 MW balanced-draft coal-fired boilers designated Units 1 and 2. Unit 2 is the test unit. This site was of key interest because it was the only plant in the NETL program that burns a variety of Powder River

Basin (PRB) low sulfur, sub-bituminous coals. In addition, this facility has the ability to isolate one ESP chamber (1/4 of the unit) (Starns et al., 2002).

The primary particulate control equipment consists of CS-ESPs of weighted wire design with a Wahlco gas conditioning system that provides SO3 for fly ash resistivity control. The precipitators were designed and built by Research-Cottrell. The design flue gas flow was 2,610,000 acfm. The precipitator inlet gas temperature is nominally 280 ^{O}F at full load (Starns et al., 2002).

Precipitator #2 is comprised of four electrostatic precipitators that are arranged piggyback style and designated 2-1, 2-2, 2-3, and 2-4. Each of the four precipitators is two chambers wide and four mechanical fields deep with eight electrical fields in the direction of gas flow. The SCA is 468 ft^{2}/kacfm (Starns et al., 2002).

Hopper ash is combined from all four precipitators in the dry ash-pull system and sold as base for concrete (Starns et al., 2002). The PAC injection rate was 10 lb/MMacf at the time when the CCR with ACI in use was collected from this facility.

The baseline ash was collected as a composite sample from ash hoppers 7-1 and 7-2 of ESP 2-4. The post-control ash was collected as a grab sample from ash hopper 7-2 of ESP 2-4 (see Appendix B for flow diagram). The baseline ash was collected on 11 September 2001, and the post-control fly ash was collected on 13 November 2001. Both fly ashes were stored in covered five gallon buckets in the onsite trailer at ambient temperatures.

Salem Harbor

PG&E National Energy Group owns and operates Salem Harbor Station located in Salem, MA. There are four fossil fuel fired units at the facility designated as Units 1, 2, 3, and 4. Units 1–3 fire a low sulfur, bituminous coal and use oil for startup. Unit 4 fires #6 fuel oil. Unit 1, the test unit, is a B&W single-wall-fired unit with twelve DB Riley CCV90 burners. It is rated at 88 gross MW. Salem Harbor Unit 1 was chosen for this evaluation because of its combination of firing low-sulfur bituminous coal with urea-based SNCR, high LOI, and a CS-ESP. The opportunity to quantify the impact of SNCR on mercury removal and sorbent effectiveness is unique in this program. In addition, test results from prior mercury tests have indicated 87% to 94% mercury removal efficiency on this unit without sorbent injection (Senior et al., 2003a). However, fly ash from this facility has a relatively high percentage of total carbon without carbon injection (7.8%, see Table 6), which likely serves as a sorbent for mercury.

The particulate control equipment consists of a two-chamber CS-ESP (chambers designated 1-1 and 1-2), which provides two separate gas flow paths from the outlet of the tubular air heaters to the ID fan inlets. This Environmental Elements ESP has a rigid electrode design and a SCA of 474 ft^{2}/1000 acfm. The precipitator inlet gas temperature is nominally 255 ^{O}F at full load. Typical LOI or carbon content of the Unit 1 ash is about 25%. This ash is landfilled.
The PAC injection rate was 10 lb/MMacf at the time when the CCR with ACI in use was collected from this facility.

The baseline and post-control ashes used for this study were collected as grab samples from the first ash hopper (hopper A) of row 1-1 of the ESP. The baseline ash was collected on 6 June 2002, and the post-control fly ash was collected on 7 July 2002. Both fly ashes were stored in covered five gallon buckets in an onsite trailer at ambient temperatures.

Facility A

Facility A is a 440-MW coal-fired power plant with a reverse-air fabric filter followed by a wet FGD system. The unit burns ~1 percent sulfur eastern bituminous coal. The unit operated at nominally full load for the duration of the test program. The unit is equipped with a pulverized-coal boiler and in-furnace selective SNCR; urea was injected into the boiler during the course of operations within the duration of the initial part of this test program. However, urea was not injected into the boiler for the final comparison test ("SNCR off"). Gas exiting the furnace is split between two flues equipped with comparable control equipment. Particulate is removed with a reverse-air fabric filter. Flue gas is then scrubbed through a multiple tower wet FGD unit; FGD is a limestone natural-oxidation design. The two flues are joined prior to exhausting to a common stack. The annular stack rises 308 feet above the top of the incoming flue. The stack is operated in a saturated condition with no reheat. The fly ash and FGD waste are combined and then dewatered before landfill disposal.

Facility A was sampled in September 2003. During the period of time while the SCR was operating, two 5 gallon buckets of fly ash (AFA), two 5 gallon buckets of scrubber sludge (AGD), and two buckets of scrubber sludge fixated with lime (ACC) were collected. In February 2004, during the period of time while the SCR was bypassed and not operating, two 5 gallon buckets of fly ash (CFA), two 5 gallon buckets of scrubber sludge (CGD), and two buckets of scrubber sludge fixated with lime (CCC) were collected. All samples were collected by plant personnel.

Facility B

Facility B is a 640 MW coal-fired power plant with cold side ESP followed by a wet FGD system with Mg-lime. The unit burns medium to high sulfur eastern bituminous coals. The unit is equipped with a pulverized coal boiler and selective catalytic reduction composed of vanadium pentoxide (V_2O_5) and tungsten trioxide (WO_3), on titanium dioxide (TiO_2) supporting matrix. One set of samples was collected during the season of elevated ozone, when ammonia is injected into the ductwork in front of the SCR catalyst, resulting in a flue gas mixture with a concentration of 320 ppm ammonia as it enters the catalyst. Samples were also collected during the winter when ammonia was not being injected ("SCR off"). Particulate is removed with a cold-side ESP. Flue gas is then scrubbed through a wet FGD unit; FGD is an inhibited mag-lime design. The FGD sludge is thickened and then mixed with fly ash and magnesium-enhanced lime before landfill disposal in a clay-lined site.

Three samples were collected in September 2003 when the SCR was operating: one fresh fly ash sample collected from the ash hopper (sample BFA), one scrubber sludge filter cake sample collected after the centrifuge but before mixing with other materials in the pug mill (sample BGD), and one fixated scrubber sludge sample collected after mixing the scrubber sludge with fly ash and magnesium-enhanced lime in the pug mill (sample BCC). Three additional samples were collected from the same locations in February 2004 when the SCR was not in use (samples DFA, DGD and DCC, respectively). Each sample consisted of one 5-gallon pails of the material, and all were collected by Natural Resource Technology (NRT) personnel contractors working for EPRI.

Facility C

This plant has four 270 MW balanced draft coal-fired boilers designated as Units 1–4. All of these units fire a variety of low-sulfur, washed, Eastern bituminous coals. Unit #3 was used for the ACI studies.

All of the units at this plant employ HS-ESP as the primary particulate control equipment. The HS-ESP of unit #3 is followed by COHPAC. The COHPAC system is a pulse-jet cleaned baghouse designed to treat flue gas volumes of 1,070,000 acfm at 290 °F. The COHPAC baghouse consist of two sides, with the A-side being the control and the B-side being the side where activated carbon was injected after the HS-ESP but before the COHPAC. An ESP followed by COHPAC and combined with sorbent injection is referred to as the TOXECON configuration.
The injection rate of the PAC was 1.5 lb/MMacf at the time when the CCR with ACI in use was collected from this facility.

One 5-gallon bucket of fly ash without the PAC injection (GAB) and one 5 gallon bucket of fly ash with PAC injection (GAT) were collected.

Facility E

This test site has four boilers producing 2,424 megawatt (MW) of power. The plant eastern-bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on three units and hot-side ESP on one unit for particulate control. One five gallon bucket of fly ash was collected from each of the four boilers. Sample EFA was collected from a cold-side ESP from Boiler #1 burning medium sulfur eastern bituminous coal which when the SCR was operating. Sample EFB was collected from a cold-side ESP from Boiler #2 burning medium sulfur eastern bituminous coal which when the SCR was not operating. Sample EFC was collected from a cold-side ESP from Boiler #3 burning high sulfur eastern bituminous coal which when the SCR was operating.

Facility F

This test site unit has is a 165 megawatt (MW) per boiler power plant. The plant burns low sulfur eastern bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used for particulate control. One 5 gallon bucket of fly ash (FFA) was collected from the ESP hopper by NRT personnel in August 2004.

Facility G

This test site is a 165 megawatt (MW) power plant. The plant burns low sulfur eastern-bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used for particulate control. A SNCR system was operating to control NO_x. One 5 gallon bucket of fly ash (GFA) was collected from the ESP hopper by NRT personnel in August 2004.

Facility H

Facility H is a 500 MW power plant. The plant burns Illinois Basin coal in a dry-bottom pulverizer boiler. Cold-side ESPs are used on all units for particulate control, an SCR system was operating, and wet FGD systems were used to reduce SO_2 emissions. The wet FGD systems utilize limestone slurry sorbents and an inhibited oxidation process. The FGD sludge, consisting primarily of calcium sulfite, is pumped from the absorber to a thickener. Liquid overflow from the thickener is recycled back into the FGD system, and the thickened sludge is pumped to a series of drum vacuum filters for further dewatering. Water removed by the drum vacuum filters is recycled back into the FGD system, and the filter cake is taken by conveyor belt to a pug mill, where it is mixed with dry fly ash and dry quicklime for stabilization. The resulting scrubber FGD solids are taken by conveyor to a temporary outdoor stockpile, and then transported by truck either to a utilization site or to an on-site landfill. One 5 gallon bucket of fly ash (HFA) was collected from the ESP hopper by NRT personnel in August 2004.

Facility J

Facility J has a 160 MW boiler that typically burns a 85:15 blend of PRB and bituminous coals. The unit sometimes switches to 100% PRB on the weekends. However, during our flue gas/fly ash sampling, the unit was burning the PRB/bituminous blend. The flue gas from the boiler splits and is directed into two parallel CS-ESPs (designated the “South ESP” and the “North ESP”, each treating half of the flue gas). The flue gas is then recombined before exiting the stack. During testing, B-PAC was injected upstream of the South ESP. The unit has no NO_X or SO_2 controls.

The injection rate of the B-PAC was 5 lb/MMacf at the time when the CCR with B-PAC in use was collected from this facility.

One 5-gallon bucket of fly ash without the B-PAC injection (JAB) and one 5 gallon bucket of fly ash with PAC injection (JAT) were collected.

Facility K

Facility K is two tangentially fired 400 MW coal-fired boilers with cold side ESP followed by a wet flue gas desulfurization system with wet Mg-lime natural oxidation. These units burn medium sulfur eastern bituminous coals from Ohio, Pennsylvania and West Virginia. Flue gas is scrubbed through a common wet FGD unit; FGD is a wet Mg-lime natural oxidation design. FGD sludge is mixed with fly ash and quicklime for stabilization prior to disposal.

Two samples were collected on November 29, 2004: one scrubber sludge filter cake before mixing in the pug mill (sample KGD), and one fixated scrubber sludge collected after mixing the scrubber sludge with fly ash and 2-3% lime in the pugmill (sample KCC). On January 12, 2005, one fly ash sample was collected directly from the ESP before the fly ash storage silo (sample KFA, collected in January 2005). Each sample consisted of four 5-gallon bucket of the material, and were collected by plant personnel.

Facility L

This facility is configured similarly to St. Clair except that it used one HS-ESP with two compartments rather than two CS-ESPs, and it uses separated overfired air (SOfA) ports for NO_x control. As a result, the fly ash collection temperature is between 300 and 450 °F. Samples were collected from hoppers which were evacuated under negative pressure. The pneumatic hopper controls were turned off to allow enough samples to collect for the leaching evaluation. The controls were off for about 4 hr. There is concern that because of the high temperature within the fly ash collection hoppers, some mercury may have desorbed prior to sampling. Therefore, the samples obtained for evaluation may have a lower metal content. Because of the concern about mercury desorbing from the fly ash, additional fly ash was collected by turning off the pneumatic transfer for 30 min (2 weeks after the original samples were collected). Total metal content determinations were completed for all samples, which includes with and without brominated powdered activated carbon (BPAC) for fly ash collected after accumulation in the hopper for 4 hr (first sampling) and 30 min (second sampling). The leaching evaluation was conducted only on the samples collected over 4 hr intervals since this provided adequate sample size (5 gallons).

One 5 gallon bucket of fly ash without BPAC (LAB) and one 5 gallon bucket of fly ash with BPAC (LAT) was collected by ARCADIS personnel.

Facility M

Facility M is a 600 MW per unit power plant. The plant burns bituminous coal in a dry-bottom pulverizer boiler. Cold-side ESPs are used on all units for particulate control, and wet FGD systems are used to reduce SO_2 emissions on two units. The wet FGD systems utilize limestone slurry and an inhibited oxidation process. The FGD sludge, consisting primarily of calcium sulfite, is pumped from the absorber to a thickener. Liquid overflow from the thickener is recycled back into the FGD system, and the thickened sludge is pumped to a series of drum vacuum filters for further dewatering. Water removed by the drum vacuum filters is recycled back into the FGD system, and the filter cake is taken by conveyor belt to a pug mill, where it is mixed with dry fly ash and dry quicklime for stabilization. The resulting scrubber FGD solids are taken by conveyor to a temporary outdoor stockpile, and then transported by truck either to a utilization site or to an on-site landfill. The currently active portion of the landfill is lined and includes leachate collection. An older inactive portion of the landfill is clay-lined but does not have leachate collection.

Three samples were obtained from the Pug Mill Area by the EPRI contractor during the week of March 6, 2006 when the SCR was not operating: fly ash, vacuum drum filter cake, and fixated scrubber sludge with lime (only FSSL was used in this study, sample MAD). In each case, the samples were collected daily during the four day sample collection (four daily samples of each), for compositing in the laboratory. All of the samples were collected into clean 5 gallon plastic pails. Excess sample was containerized and discharged back into the appropriate system. The drum filter cake was sampled daily from the conveyor belt leading into the pug mill. Two of the three drum filters were running simultaneously; both were feeding the conveyor belt. The same drums were running each day of sampling. Each 5 gallon bucket was sealed immediately after collection and the lid secured with duct tape. The dry fly ash sample was obtained directly from the day tank via a hose connected to a sampling port. Each 5 gallon bucket was sealed immediately after collection and the lid secured with duct tape. FSS was sampled from the conveyor belt on the outlet side of the pug mill on the first, third and fourth days. A clean, short handled spade was used to collect sample from the conveyor belt into a 2 gallon bucket. The sample in the bucket was placed on a clean piece of 3 mm plastic sheeting; then more sample was collected from the conveyor belt into the bucket and added to the sheet until at least 6 gallons of sample was collected. Each sample was homogenized on the sheet using the spade and placed into a 5 gallon bucket, sealed immediately, and the lid secured with duct tape. A similar process was used to collect three more samples the week of May 9, 2006 when the SCR was in use (FSSL sample MAS).

Facility N

Facility N is a wall fired 715 MW coal-fired power plant with cold side ESP followed by a wet FGD system using wet limestone in a forced oxidation process. The unit burns medium to high sulfur eastern bituminous coals with approximately 3% sulfur. The gypsum is washed, dried and then sold to the wallboard industry.

One 5 gallon bucket of un-washed gypsum (NAU) and one 5 gallon bucket of washed gypsum (NAW) were collected from this site. Facility N was sampled on June 1, 2006. Samples were provided by RMB Consulting & Research, Inc. (Raleigh, NC).

Facility O

Facility O is a tangentially fired 500 MW coal-fired plant with cold side ESP followed by a wet FGD system with wet limestone forced oxidation. The unit is equipped with a pulverized coal boiler and ammonia based SCR. This unit burns high sulfur eastern bituminous coals. Slurry from the absorber goes to a primary hydrocyclone for initial dewatering. The gypsum (hydrocyclone underflow) is dried on a vacuum belt and washed to remove chlorides, before use in wallboard.

Two samples were collected from the FGD gypsum drying facility by compositing samples collected on June 10, 11, and 12, 2006 when the SCR was operating. On each day, two gallon pails of unwashed gypsum and washed/dried gypsum were collected. The unwashed gypsum was collected from the vacuum belt prior to the chloride spray wash. The washed/dried gypsum was collected from the end of the vacuum belt. The three daily samples were sent to Arcadis for compositing to form sample OAU (unwashed gypsum) and sample OAW (washed gypsum). All samples were collected by plant personnel.

Facility P

Facility P is two wall fired 200 MW coal-fired boilers with cold side ESP followed by a wet FGD system with wet limestone forced oxidation. Unit 1 is equipped with SNCR and Unit 2 is equipped with SCR. These units burn medium sulfur eastern bituminous coals. Particulate is removed with a cold-side ESP. Flue gas is then scrubbed through a common wet FGD unit; FGD is a wet limestone forced oxidation design. The gypsum provided was not washed.

Facility P was sampled in October 2006 when both SCR and SNCR were operating and the residues from Unit 1 and Unit 2 were commingled during collection. One 5 gallon bucket of the un-washed gypsum (PAD) was collected by plant personnel.

Facility Q

Facility Q is a 1800 MW coal fired plant with hot side ESP followed by a wet flue gas desulfurization system with wet limestone forced oxidation. This plant burns sub-bituminous coal. FGD is a wet limestone forced oxidation design that includes the addition of dibasic acid to the absorber[1] for to buffer the scrubber liquor and control calcium scaling. Gypsum is not washed, but make up water is added continually rather than operating closed loop to maintain low chloride concentrations.

One 5 gallon bucket of un-washed gypsum (QAU) was collected on October 30, 2006. The sample was collected by NRT personnel. The sample was shipped to ARCADIS for analysis on Mary 4, 2007.

Facility R

This test site is a 175.5 megawatt (MW) power plant. The plant burns sub-bituminous PRB coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on all units for particulate control, and wet FGD systems are used to reduce SO_2 emissions on two units. The wet FGD system utilizes a wet limestone slurry sorbent and a forced oxidation process. Gypsum from the FGD system uses a hydrocyclone and a vacuum drum filter to remove residual water from the product. Gypsum is not washed, but make up water is added continually rather than operating closed loop, so the chlorides stay low. The system was originally designed to wash filter cake. The gypsum material is recycles for use in wallboard.

One 5 gallon bucket of un-washed gypsum (RAU) was collected on May 3, 2007. The sample was collected by a contractor for EPRI.

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[1] Dibasic acid (DBA) is a commercial mixture of glutaric, succinic, and adipic acids: $HOOC(CH_2)_{2\text{-}4}COOH$.

Facility S

This test site is a 600 megawatt (MW) per unit power plant. The plant burns eastern high sulfur bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on all units for particulate control, and wet FGD systems are used to reduce SO_2 emissions on two units. The wet FGD systems utilize limestone slurry sorbents and an forced oxidation process

Samples of washed (SAW) and unwashed (SAU) gypsum were collected at this site in July, 2007. One five-gallon bucket of each was collected by plant personnel.

Facility T

This power plant test site has three boilers producing a total of a 2,000+ megawatts (MW). The plant burns medium sulfur eastern bituminous coal in a dry-bottom pulverizer boiler. Units 1 and 2 have coal cleaning equipment to reduce ash ad SO_x emissions. All three of these units have low NO_x burners and selective catalytic reduction systems for NO_x control. Ammonia was injected upstream of the SCR catalysts. Cold-side electrostatic precipitators (ESPs) are used on all three units for particulate control. A wet FGD systems using limestone in a forced oxidation mode are used to reduce SO_2 emissions on Unit 3.

Four samples were collected by plant personnel on September 17, 2007: one 5 gallon bucket of fly ash from Unit 2 (TFA), one 5 gallon bucket of un-washed gypsum from Unit 3 (TAU), one 5 gallon bucket of washed gypsum from Unit 3 (TAW), and one 5 gallon bucket of FGD waste water treatment plant filter cake from Unit 3 (TFC).

Facility U

This test site has eight boilers producing a total of 1,629 megawatts (MW). The plant burns low sulfur eastern bituminous coal in a dry-bottom pulverizer boiler. Samples from this site were collected from units 7 and 8. Both of these units have low NO_x burners and selective catalytic reduction systems for NO_x control. A cold-side electrostatic precipitator (ESP) were used on unit 7 for particulate control, and a wet FGD system using limestone in a forced oxidation mode is used to reduce SO_2 emissions. Due to low capture efficiency of the ESP on unit 7, approximately 25% of the FGD gypsum is fly ash. Unit 8 has no ESP but has a FGD system that captures approximately 100% of the fly ash with the gypsum.

Four 5-gallon buckets of fly ash were collected from the hoppers of unit 7. The four fly ash samples were combined and homogenized to produce one fly ash sample for the leaching study (UFA). One five gallon bucket of the un-washed fly ash/FGD gypsum material from unit 7 was collected (UAU). One bucket of the fly ash/FGD gypsum material from unit 8 (UGF) was also collected. These samples were collected by plant personnel on March 12, 2008.

Facility V

This test site is a 450 megawatt (MW) power plant. The plant burns sub-bituminous PRB coal in a dry-bottom pulverizer boiler. A SCR system was operating during the collection of this sample. The unit uses a spray dryer with slaked lime for FGD control. A baghouse with a fabric filter is used to control the fly ash and spray dryer ash emissions. The ash is collected in hoppers before disposal in a landfill.

One five gallon bucket of the spray dryer adsorber material (VSD) was collected by NRT personnel in April, 2008. This sample was delivered to ARCADIS on 4/15/08.

Facility W

This site is operated by American Electric Power (AEP) and has two 800 MW coal-fired boilers for a plant total of 1,600 MW. The plant burns eastern bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on both units for particulate control, and wet FGD systems are used to reduce SO_2 emissions on two units. The wet FGD systems utilize limestone slurry sorbents and a forced oxidation process. SO2 concentrations of the inlet FGD are approximately 1990 ppm with removal efficiencies of 98%. The plant has a Trona injection system for SO3 control, but this system was not operating at the time of sampling.

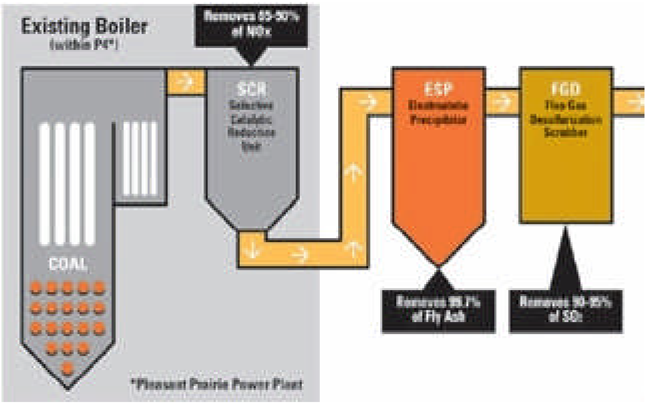
Samples were collected as follows: dry FGD gypsum after water wash (WAW), moist FGD gypsum before the water wash (WAU), wastewater treatment system filter cake (WFC), and dry fly ash (WFA). Five gallon buckets of each of the samples were collected by plant personnel on 11/20/08. Samples were delivered to ARCADIS on 11/28/07.

Facility X

Wisconsin Electric Power Company, a subsidiary of Wisconsin Energy, owns and operates Pleasant Prairie Power Plant located near Kenosha, Wisconsin. The plant has two 600 MW balanced-draft coal-fired boilers designated units 1 and 2. Unit 2 was selected for inclusion in the NETL program because it burns a variety of Powder River Basin low sulfur, sub-bituminous coals. In addition, this facility has the ability to isolate one ESP chamber (1/4 of the unit) (Starns et al., 2002).

The primary pollution control equipment consists of SCR, cold-side ESPs, and a wet-FGD system. NO_x is controlled in the SCR by injecting ammonia in the presenece of a catalyst. The forced oxidation FDG system uses wet-limestone as a sorbent for SO_2 control. This site also contains an additional mercury oxidation catalyst.

Samples were collected as follows: dry FGD gypsum after water wash (XAW), moist FGD gypsum before the water wash (XAU), FGD wastewater treatment system filter cake (XFC), and dry fly ash (XFA). Five gallon buckets of each of the samples were collected by plant personnel and delivered to ARCADIS on 6/16//08.



Facility Y

This test site is a 450 megawatt (MW) power plant. The plant burns sub-bituminous PRB coal in a dry-bottom pulverizer boiler. An SCR before the air preheater was operating at the time of sampling. The unit uses a spray dryer with slaked lime for SO_2 control. A baghouse with a fabric filter is used to control the fly ash and spray dryer adsorber particulate emissions. The ash is collected in hoppers before disposal in a landfill or recycles as an additive for stucco.

One five-gallon bucket of the spray dryer absorber (SDA) material (YSD) sample was collected by plant personnel in December, 2007. This sample was delivered to ARCADIS on 12/18/07.

Facility Z

The samples from this power plant facility are generated from four boilers producing 1,135 megawatt (MW) of power. The plant burns sub-bituminous PRB coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on all units for particulate control. This plant produces approximately 112,000 tons of fly ash and 23,000 tons of bottom ash yearly. The fly ash and bottom materials are stored separately.

Samples of the fly ash from Unit 6 and 7 were collected by plant personnel on 8/28/08. One five gallon bucket of fly ash was collected from Unit 6 (ZFB) and one from Unit 7 (ZFA). Samples were received by ARCADIS on 9/1/08.

Facility Aa

This test site has four boilers producing a total of 2,424 megawatt (MW) of power. The plant burns eastern-bituminous coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (ESPs) are used on three units and hot-side ESP on one unit for particulate control. Unit 1 at this plant was burning medium sulfur coal and the SCR was operating. Unit 2 was burning medium sulfur coal and the SCR was not operating. Unit 3 was burning high sulfur coal and the SCR was operating. Unit 4 was burning low sulfur coal, the SCR was operating, and uses a hot-side ESP to control particulate. A dry handling system is used to collect the fly ash from the ESPs.

Units 3 and 4 were connected to a single FGD system. The wet FGD systems utilize limestone slurry sorbents and a forced oxidation process. Samples of the washed and un-washed FGD gypsum were collected. Fly ash was collected from units 1, 3, and 4. Unit 2 was not operating at the time of sampling.

Facility Ba

This test site has two boilers producing 1,150 megawatt (MW) of power. The plant burns a mixture of 54% Powder River Basin sub-bituminous and 46% Gulf Coast Lignite coal in a dry-bottom pulverizer boiler. Cold-side electrostatic precipitators (CS-ESPs) and a Compact Hybrid Particulate Collector (COPAC) baghouse system are used on both units. To increase the particulate collection efficiency, ammonia injection is used for particulate conditioning. A dry handling system was used to collect the fly ash from the fly ash hoppers.

A combined fly ash sample (BaFA) was collected from units 1 and 2. One five gallon bucket of the fly ash material was collected by plant personnel November 5, 2008.

Facility Ca

This site has one 454 megawatt (MW) boiler and another boiler currently under construction. The plant burns Gulf Coast Lignite coal in a dry-bottom pulverizer boiler. The plant uses low NO_x burners with cold-side electrostatic precipitators (CS-ESPs) for particulate control. A dry handling system was used to collect the fly ash from the ESPs. A wet FGD scrubber using limestone in a forced oxidation configuration is used to control SO_x emissions.

Fly ash from this plant is recycled for use in cinder block and cement. Gypsum is in wallboard.

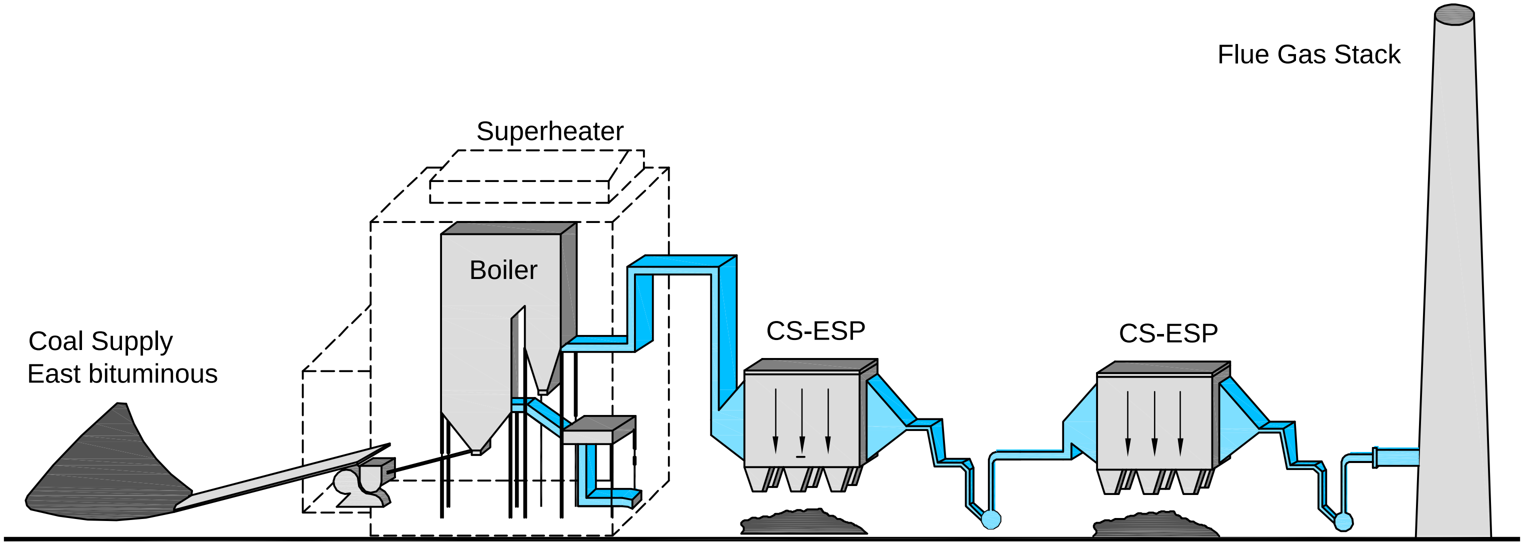
One five gallon bucket of the fly ash material (CaFA) and one five gallon bucket of washed FGD gypsum (CaAW) were collected by plant personnel November 6, 2008.

Facility Da

This test site has two supercritical boilers producing 2,240 megawatts (MW) of power. The plant burns eastern-bituminous coal in a dry-bottom pulverizer boiler. The primary pollution control equipment consists of low NO_x burners, SCR, cold-side ESPs, and a wet-FGD system. NO_x is controlled in the SCR by injecting ammonia in the presence of a catalyst. The forced oxidation FDG system uses wet-limestone as a sorbent for SO_2 control. A dry handling system is used to collect the fly ash from the ESPs.

One five gallon bucket each of fly ash (DaFA), washed gypsum (DaAW), and FGD waste water treatment plant filter cake (DaFC) were collected by plant personnel. Samples were received by ARCADIS on 12/12/2008.

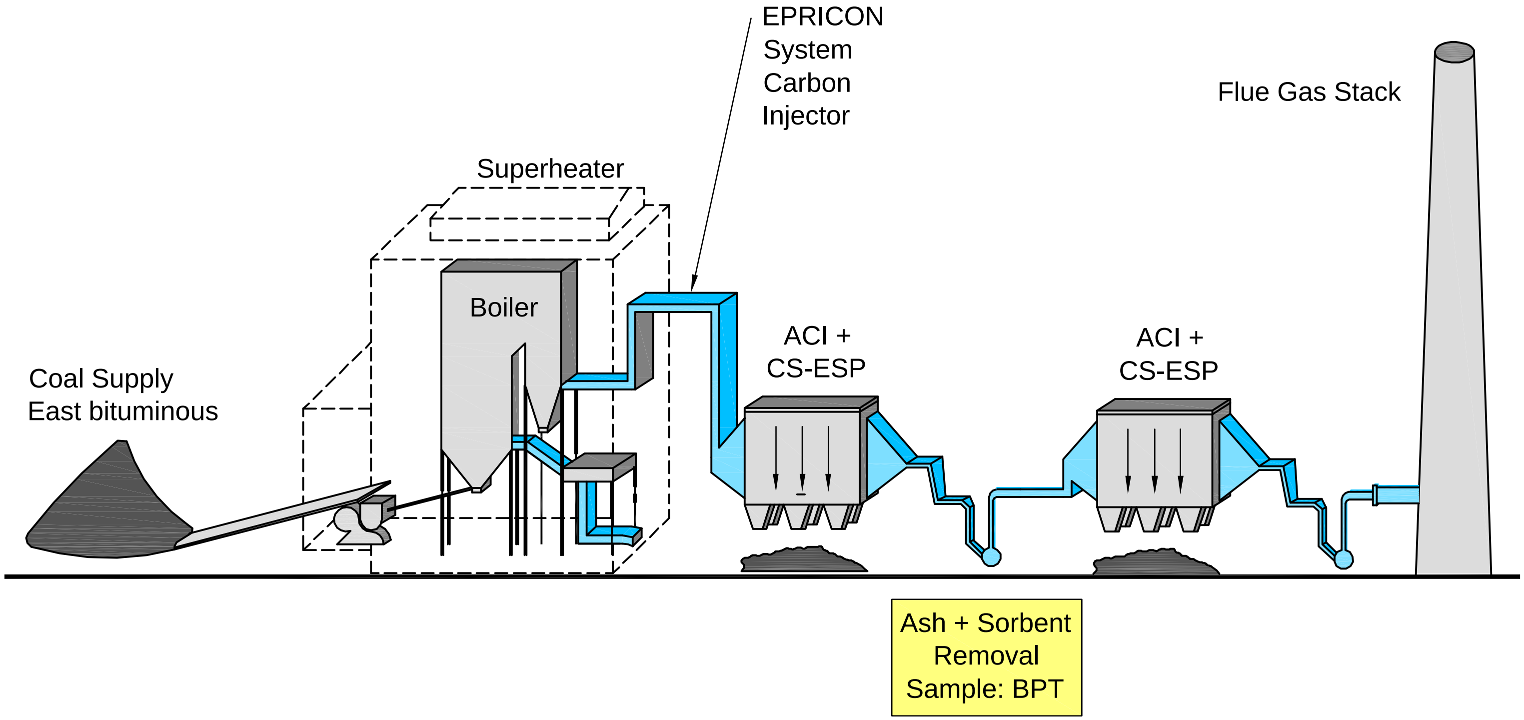
Facility: Brayton Point



Ash + Sorbent Removal Sample: BPB

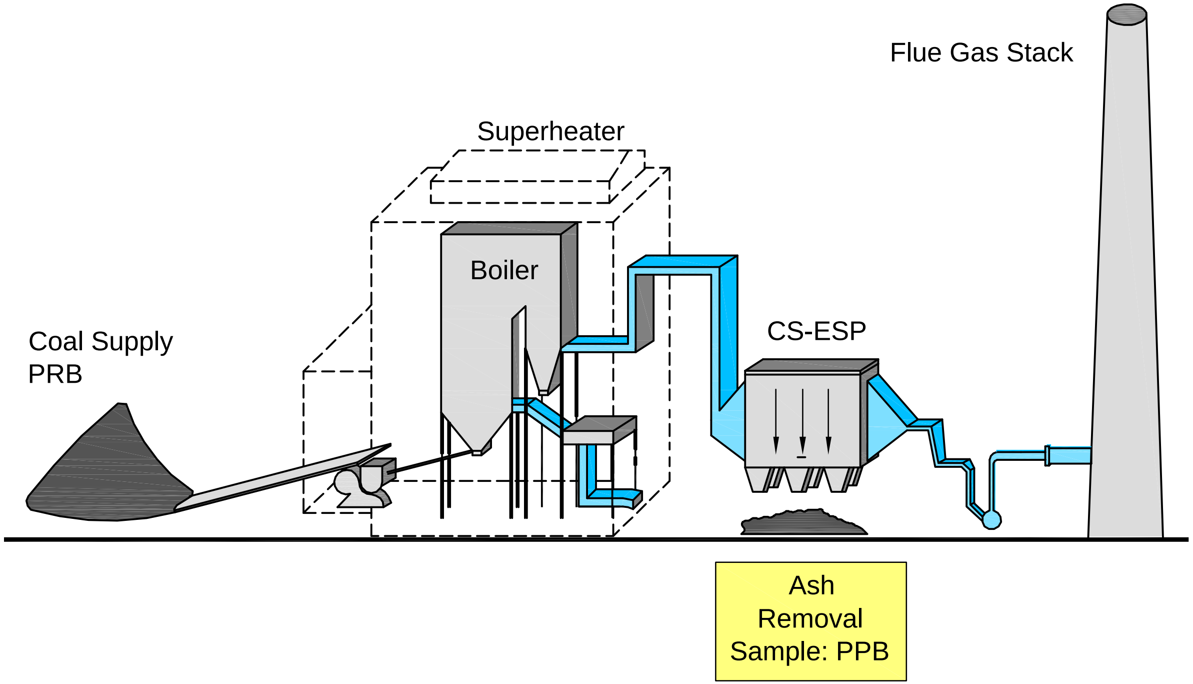
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Brayton Point with ACI



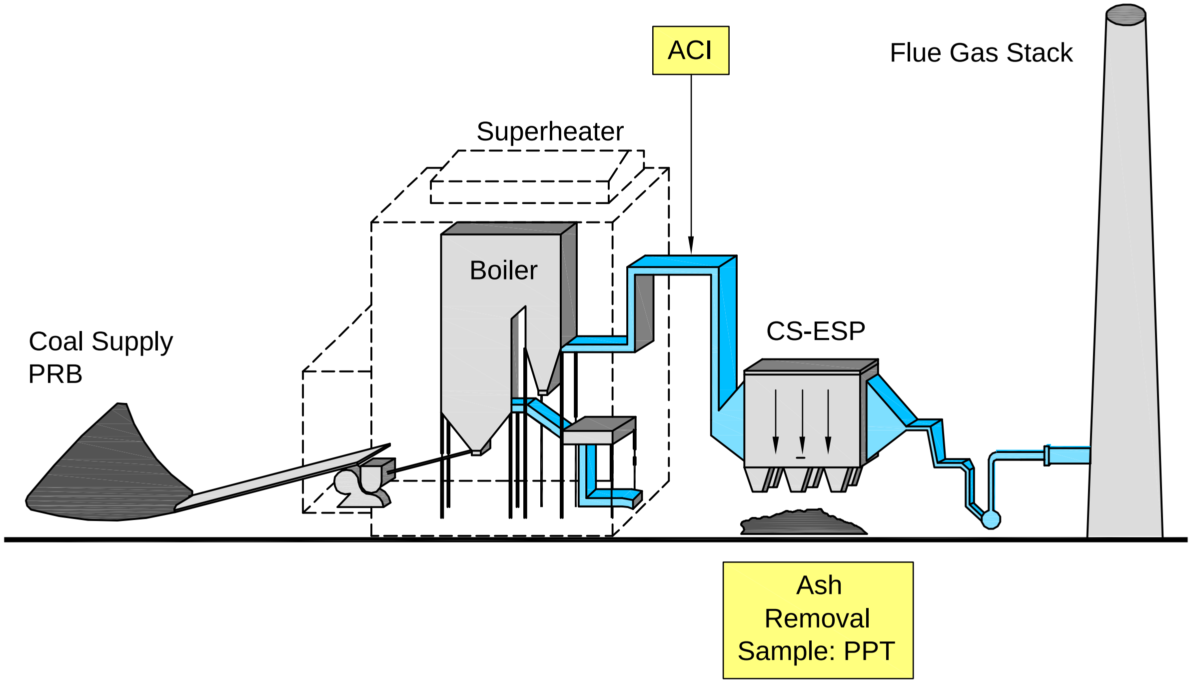
ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Pleasant Prairie



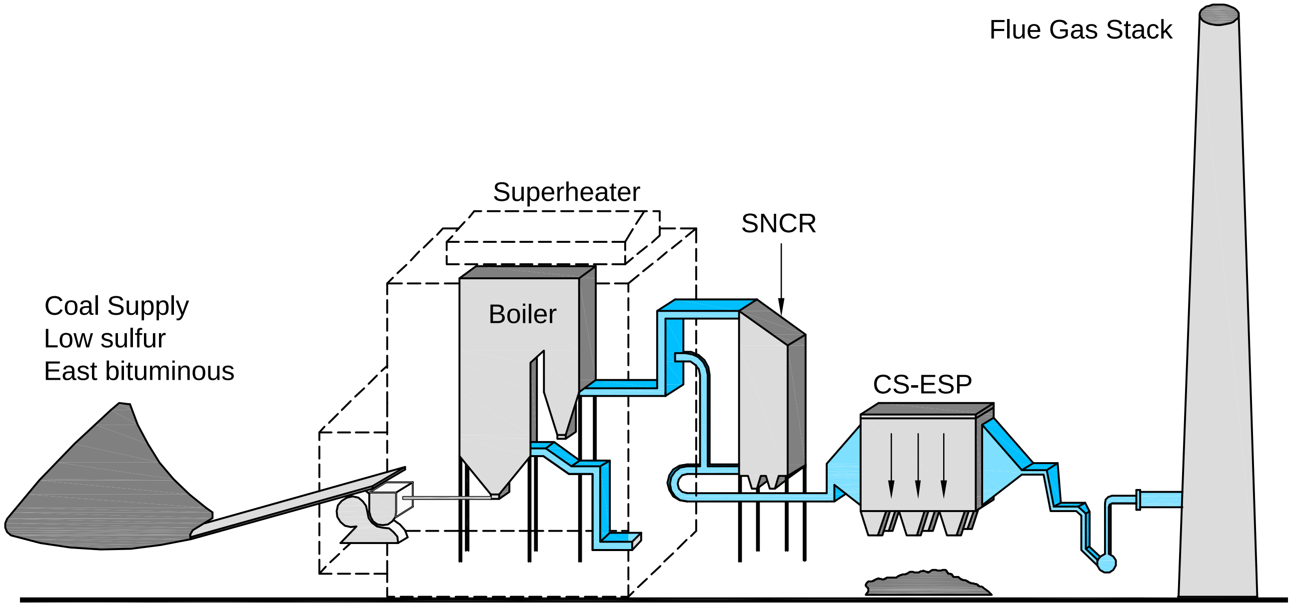
PRB - Powder River Basin
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Pleasant Prairie with ACI



ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

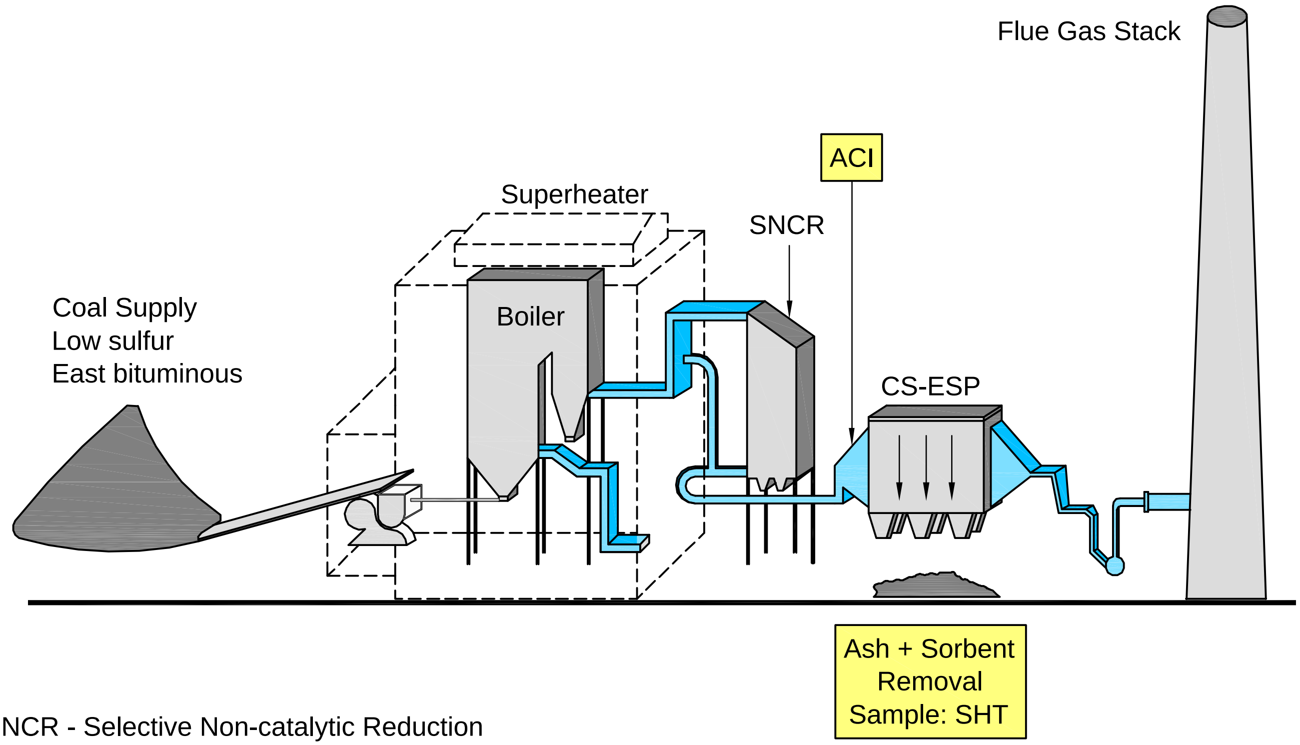
Facility: Salem Harbor



Ash
Removal
Sample: SHB

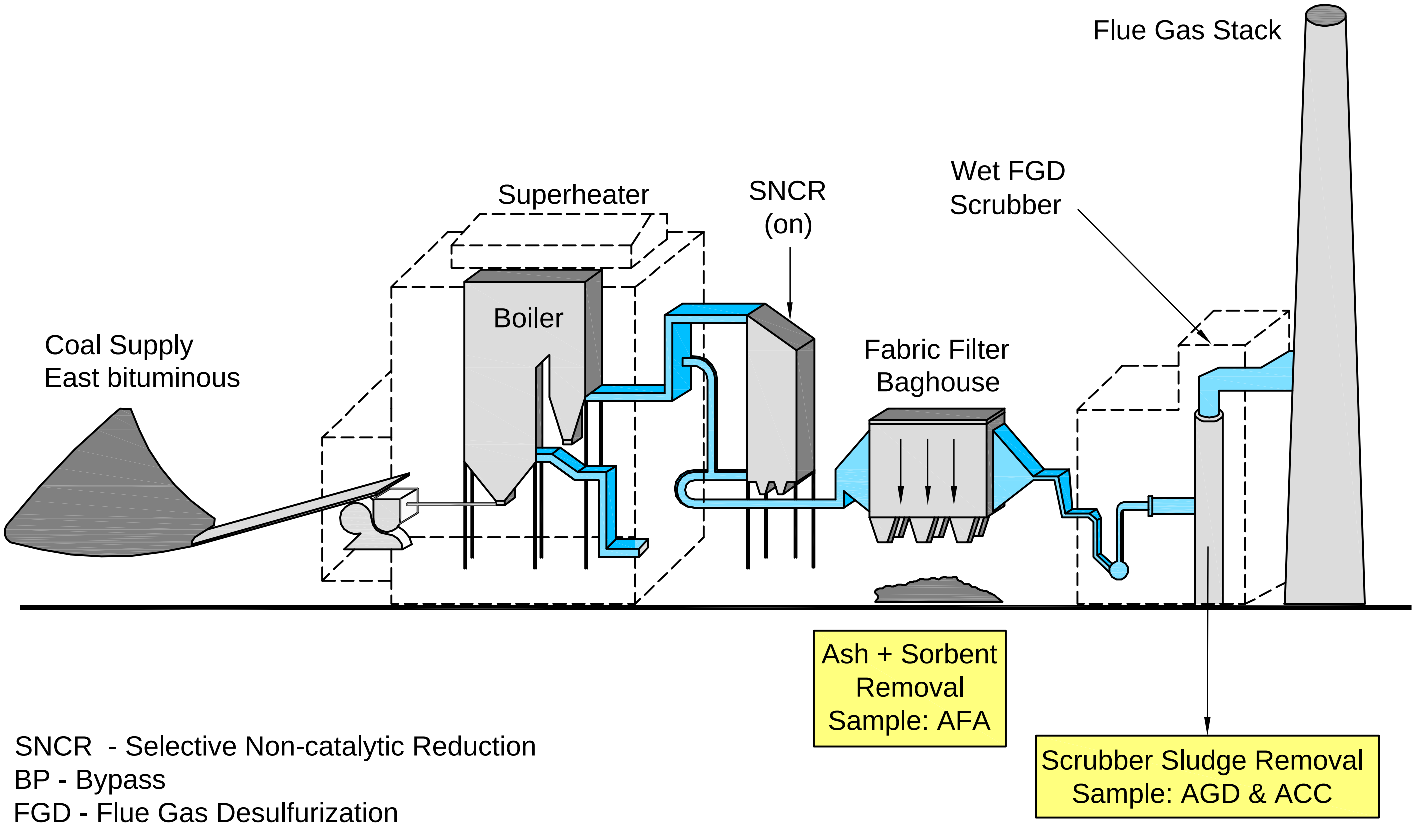
SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Salem Harbor with ACI



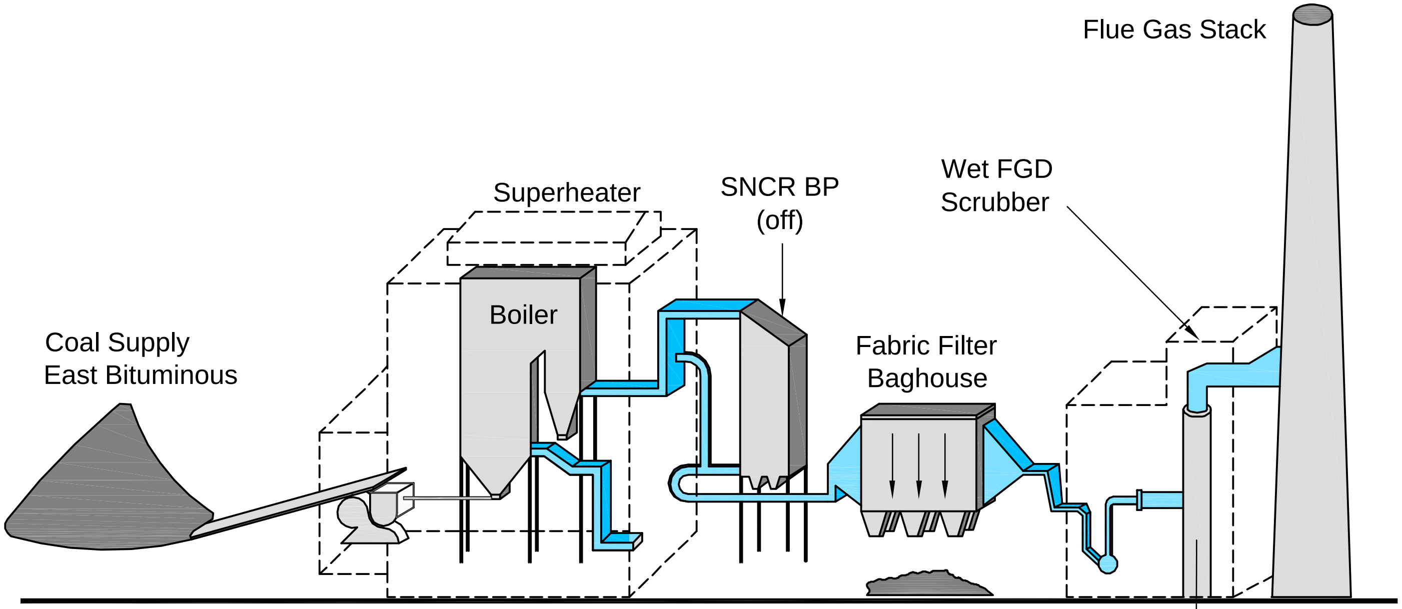
SNCR - Selective Non-catalytic Reduction
ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: A



SNCR - Selective Non-catalytic Reduction
BP - Bypass
FGD - Flue Gas Desulfurization

Facility: C

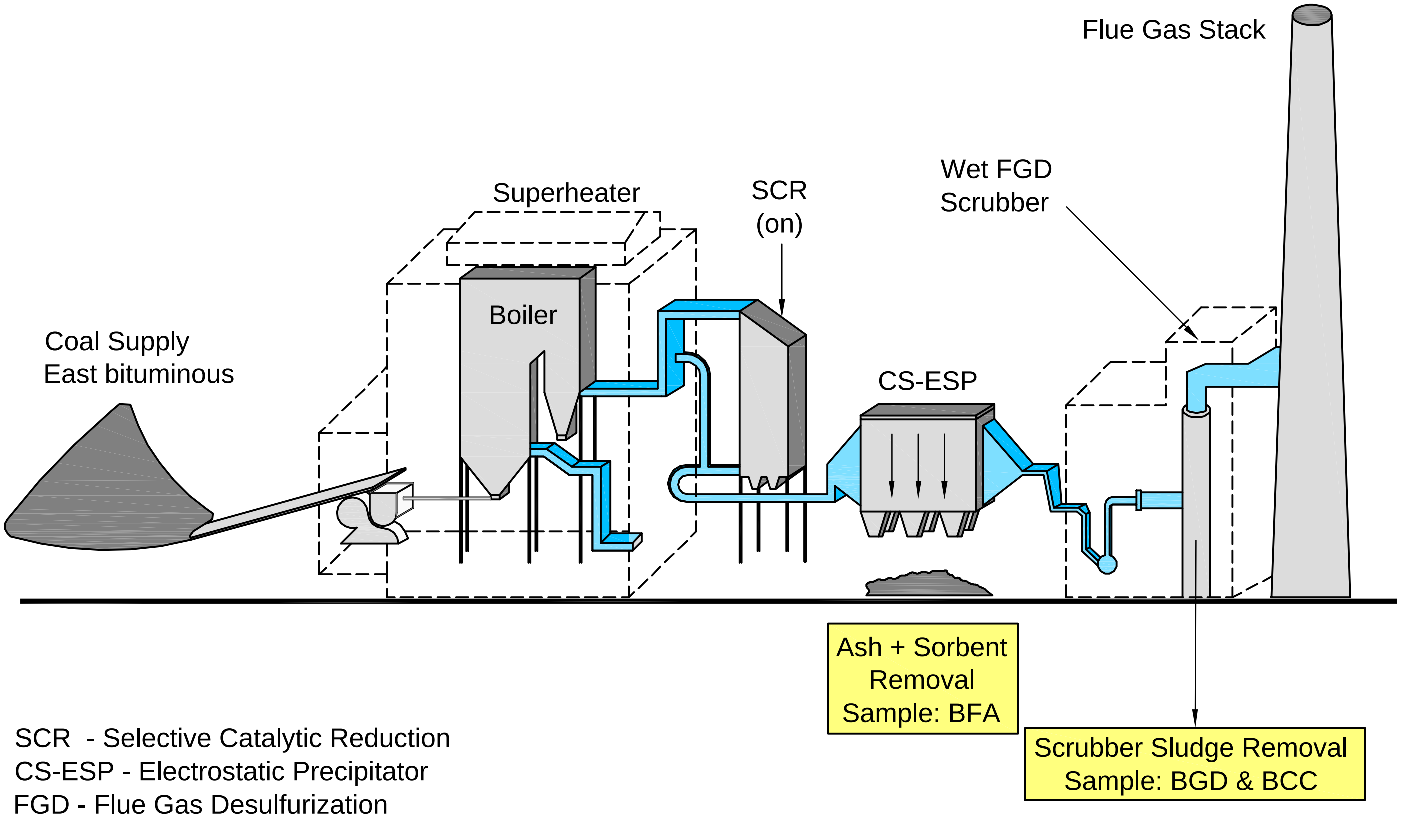


Ash + Sorbent Removal
Sample: CFA

Scrubber Sludge Removal
Sample: CGD & CCC

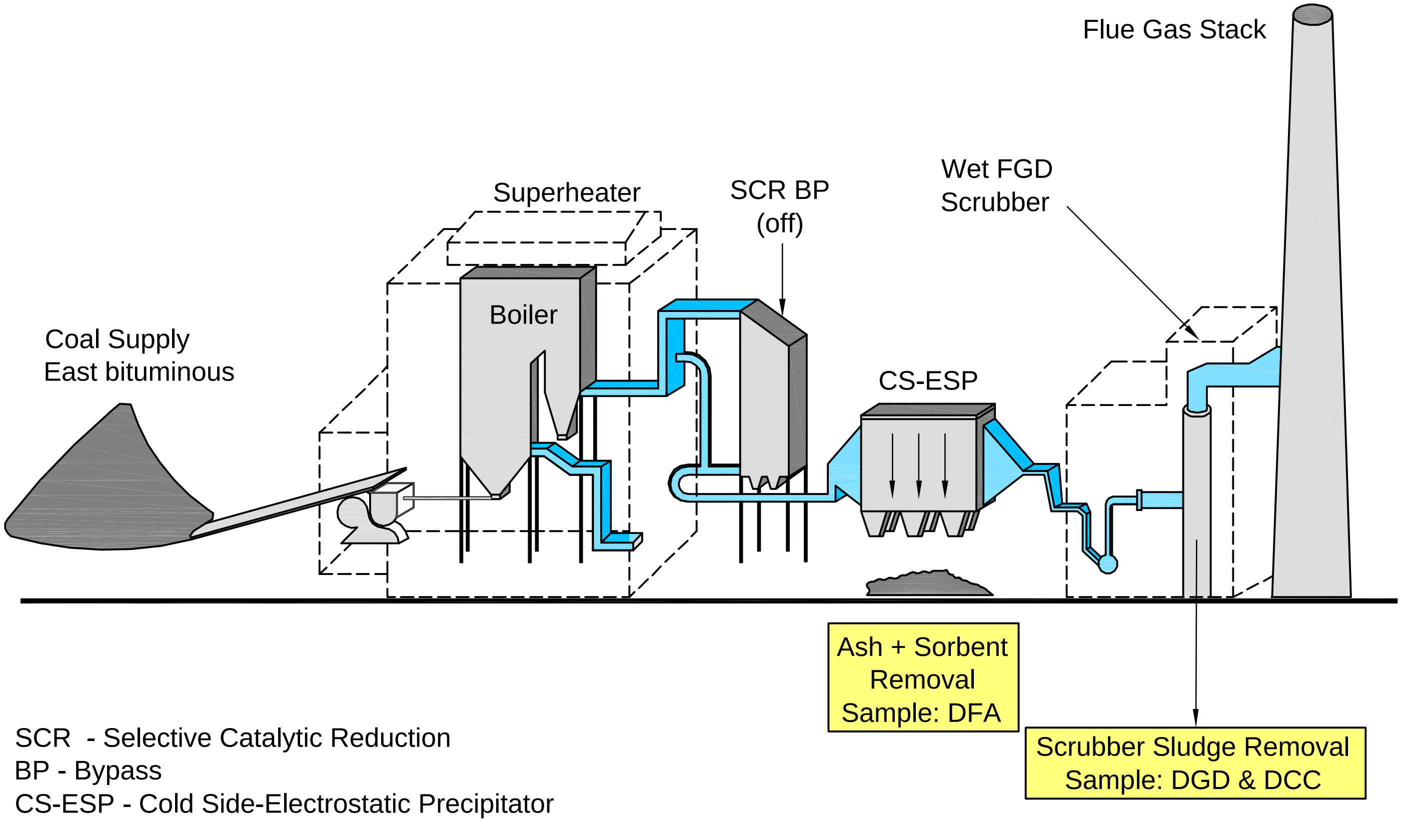
SNCR - Selective Non-catalytic Reduction
FGD - Flue Gas Desulfurization

Facility: B SCR on



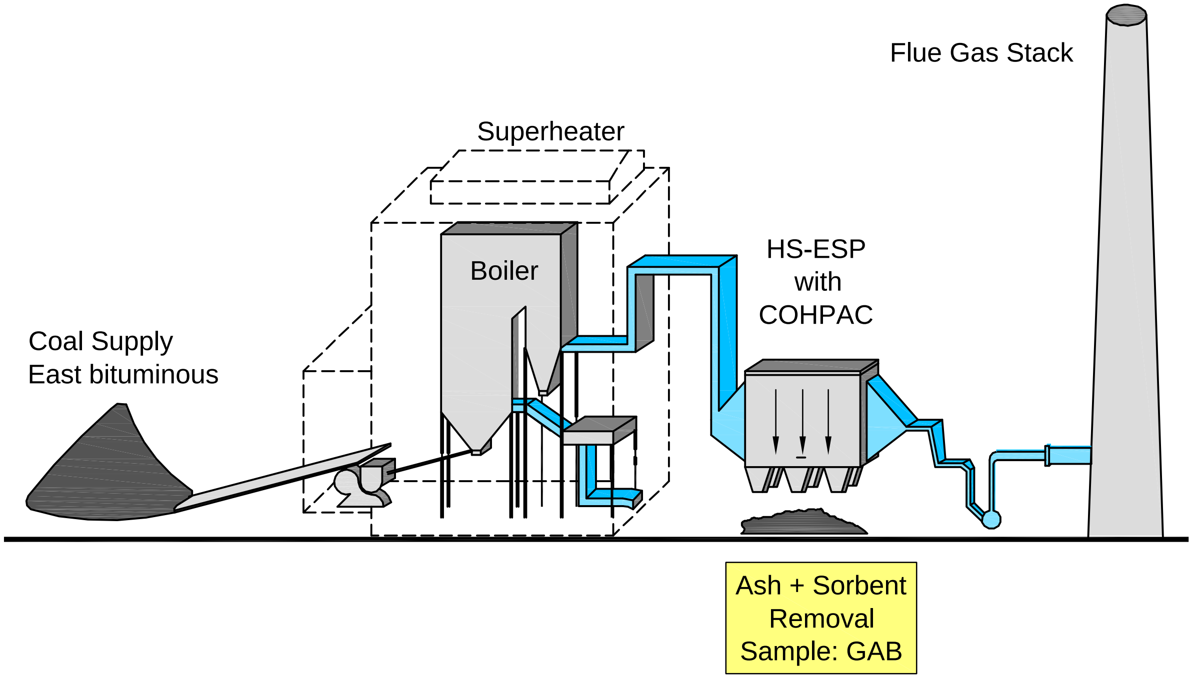
SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: B SCR off



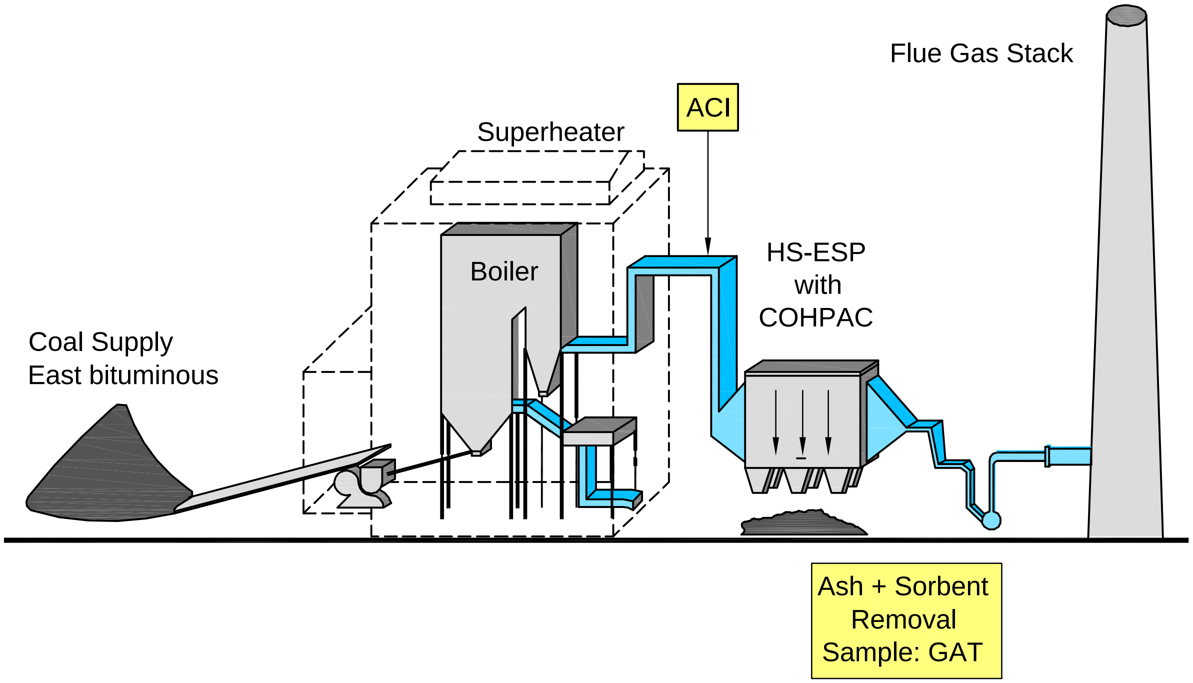
SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: C



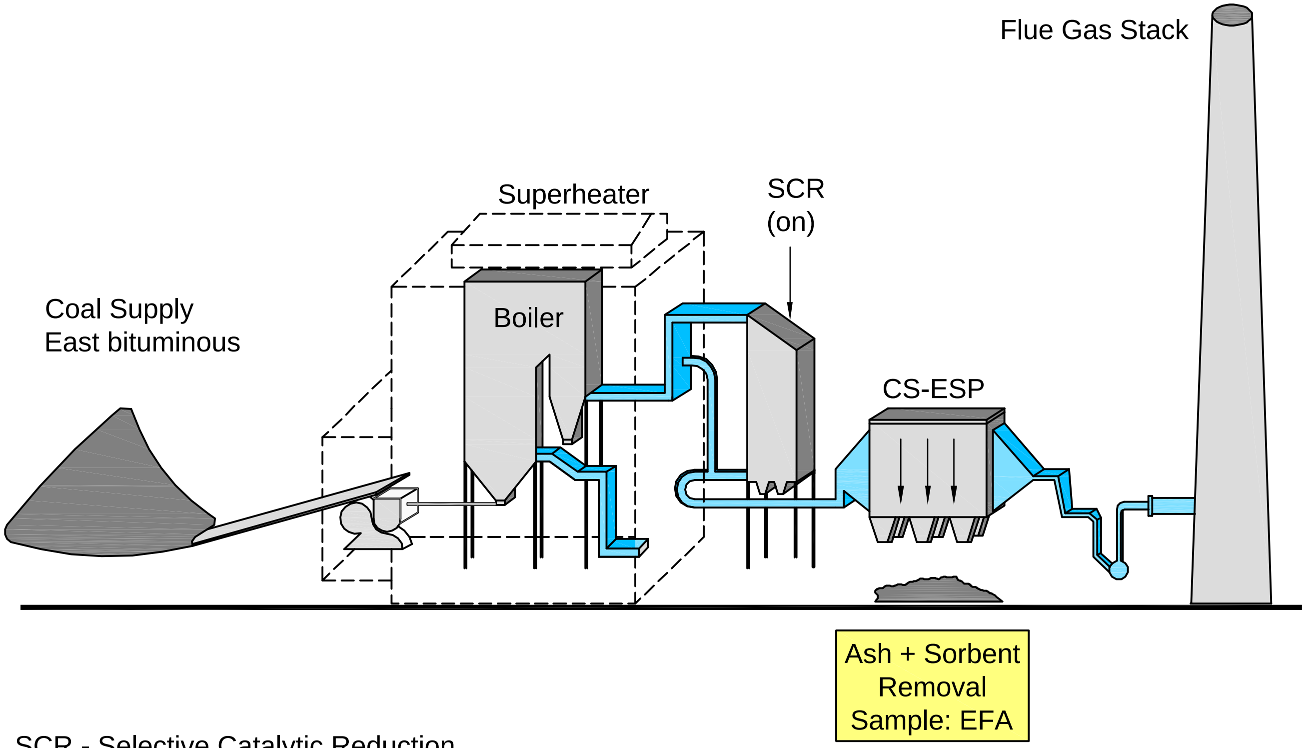
HC-ESP - Hot Side-Electrostatic Precipitator
COHPAC - Compact Hybrid Particulate Collector

Facility: C with ACI



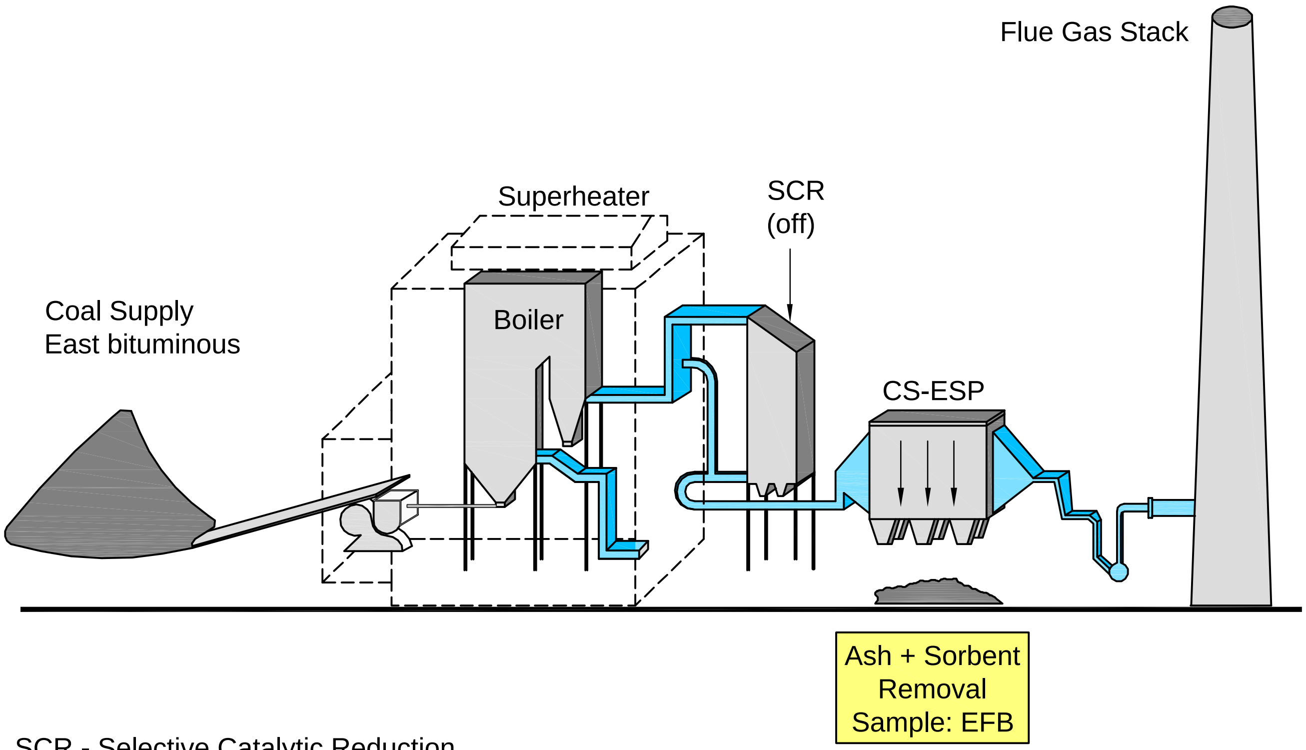
ACI - Activated carbon Injector
HS-ESP - Hot Side-Electrostatic Precipitator
COHPAC - Compact Hybrid Particulate Collector

Facility: E SCR on



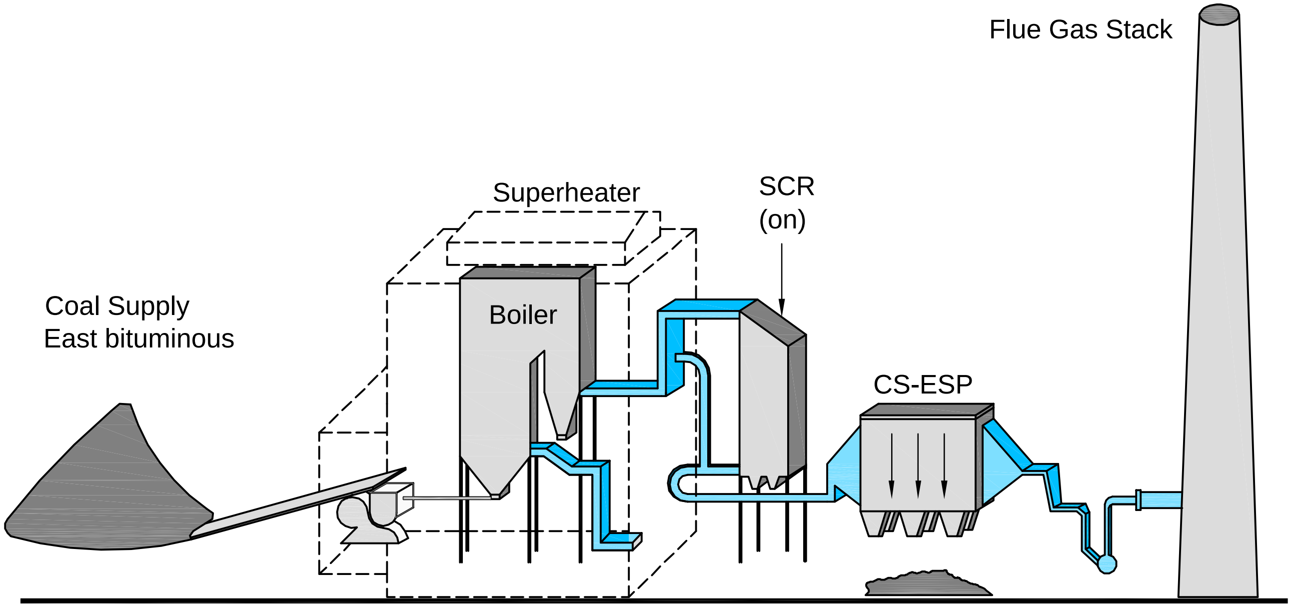
SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

Facility: E SCR off



SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

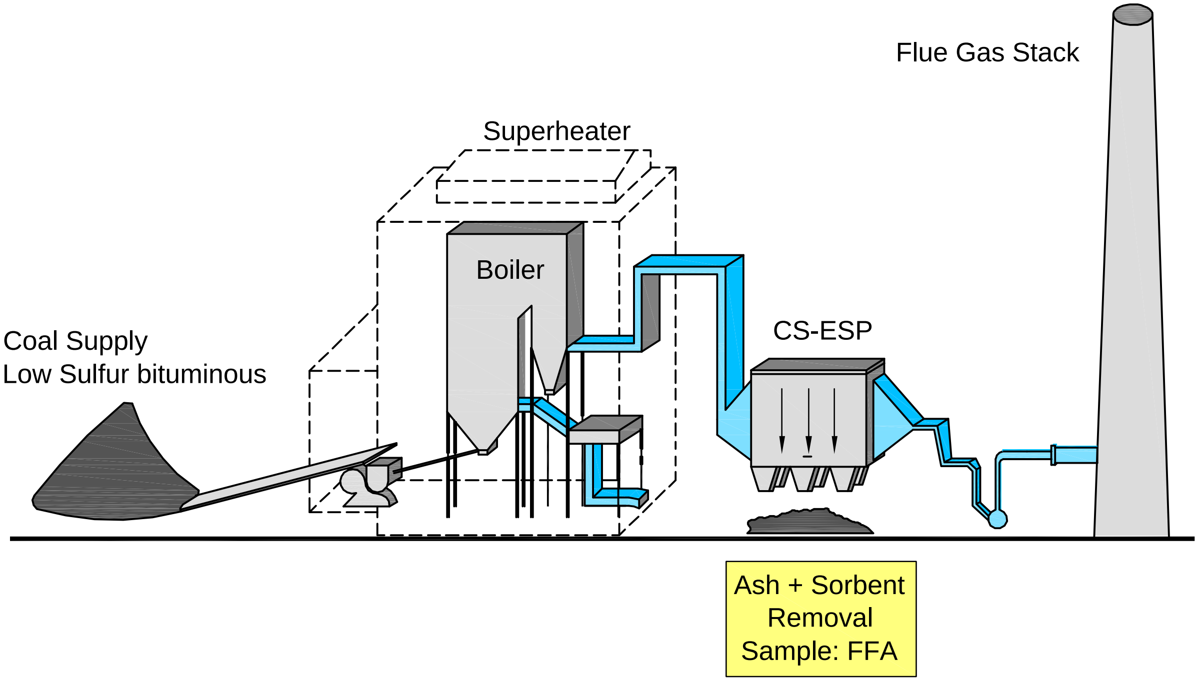
Facility: E SCR on



Ash + Sorbent
Removal
Sample: EFC

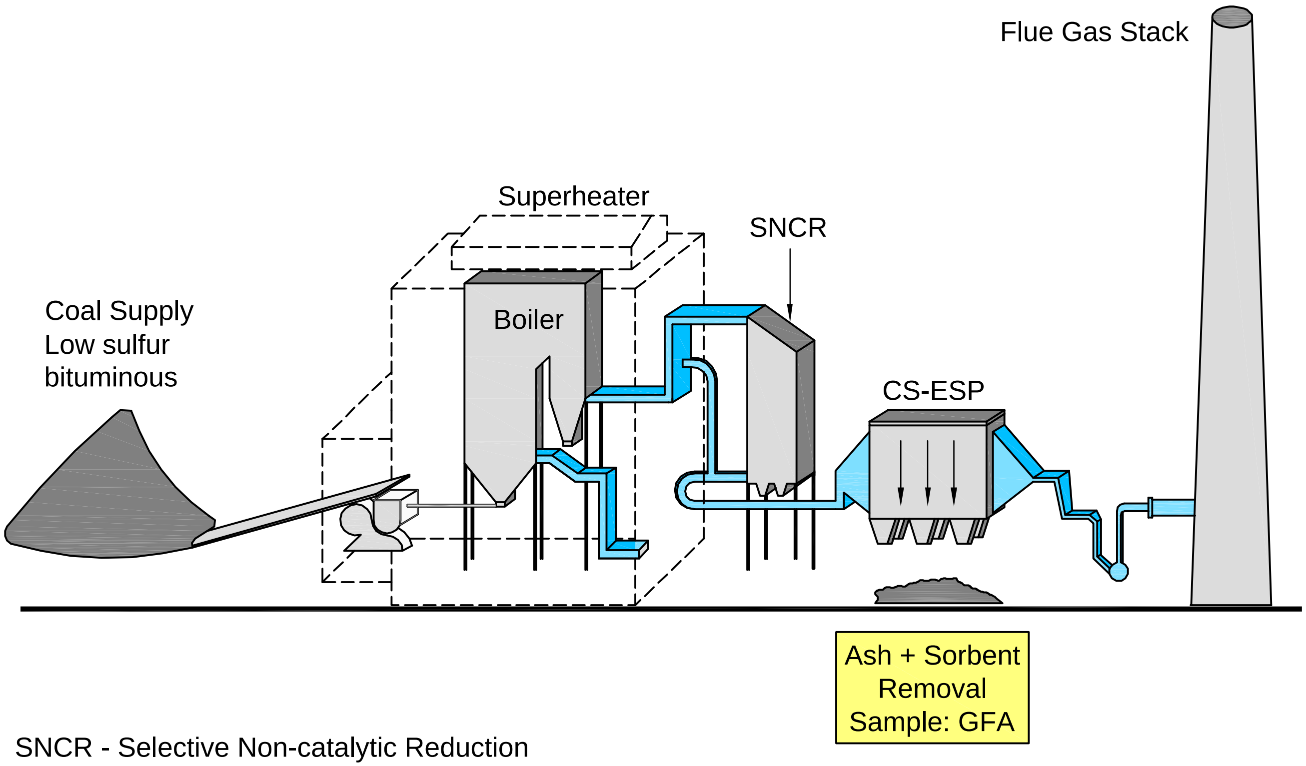
SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

Facility: F



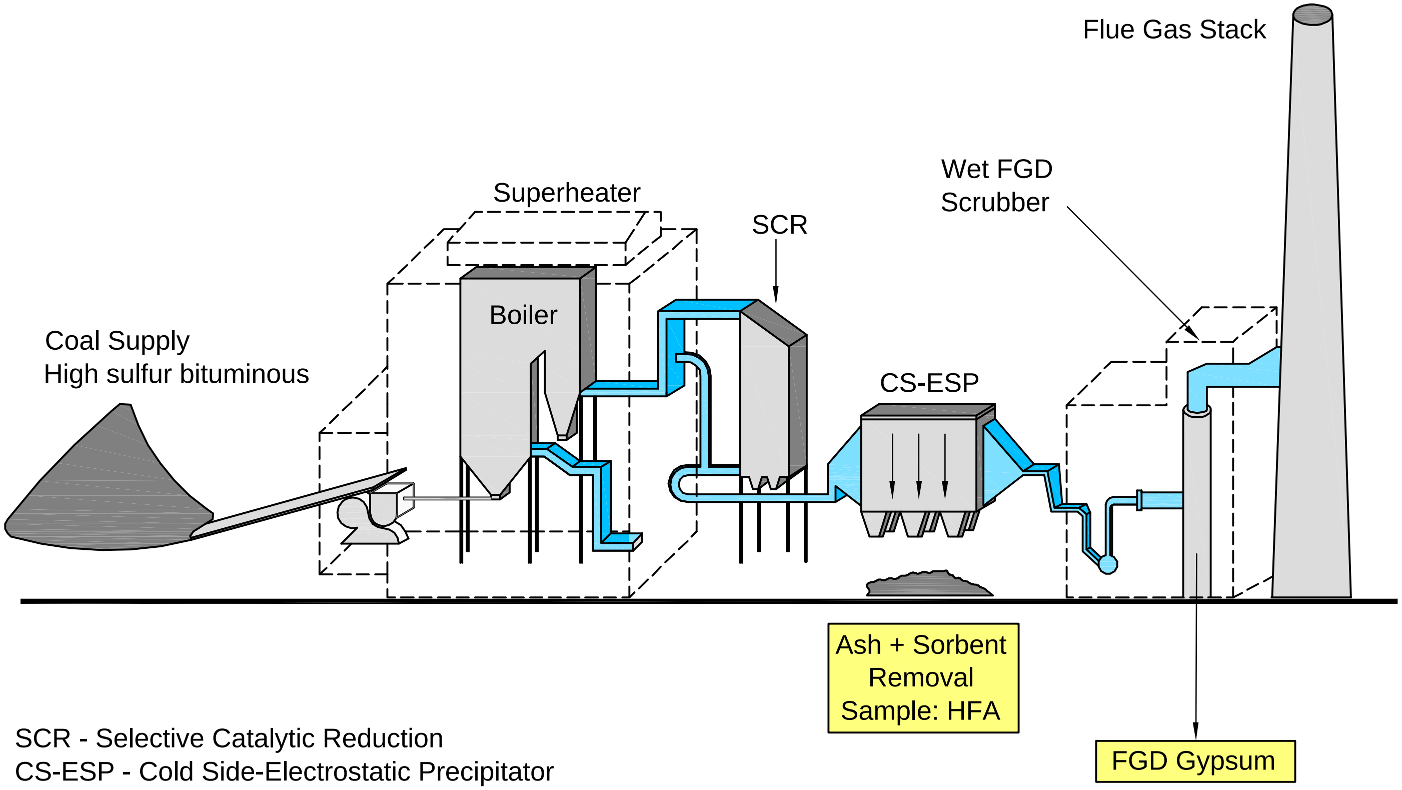
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: G



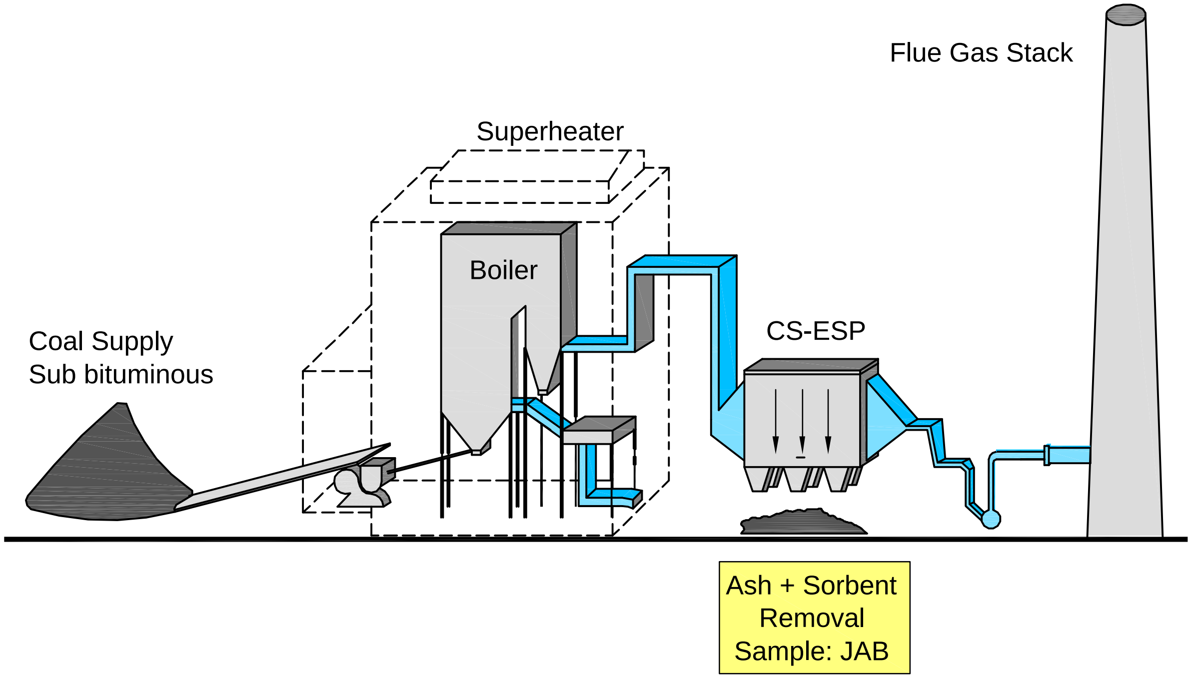
SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: H



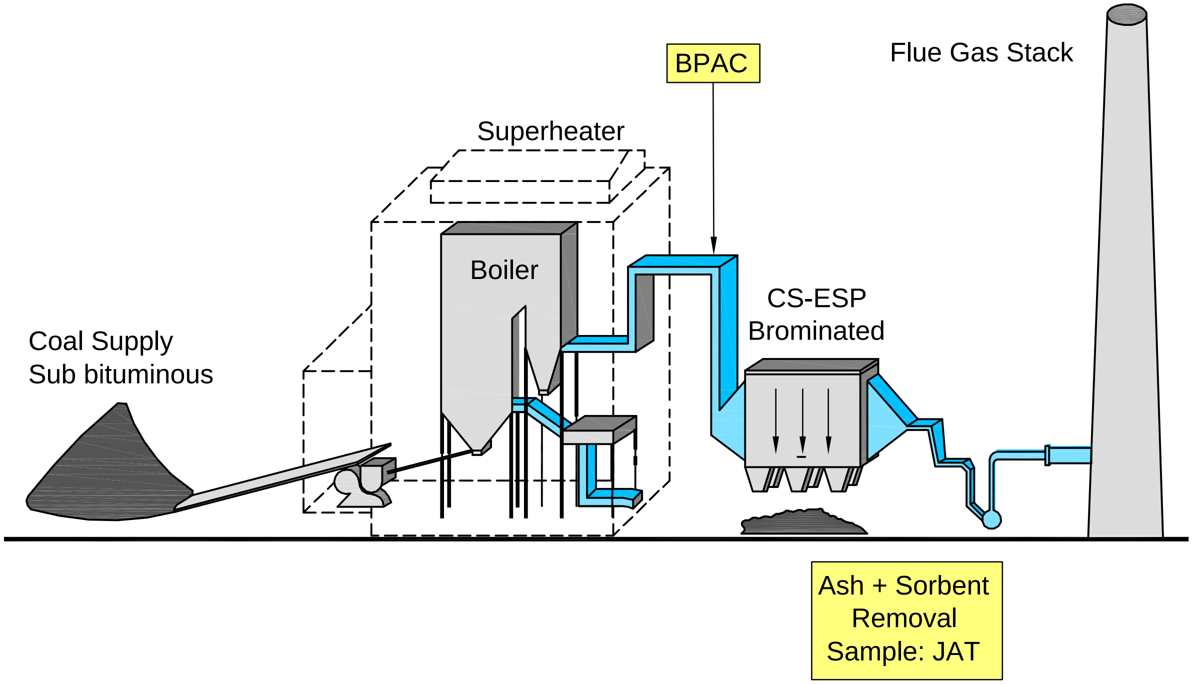
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: J



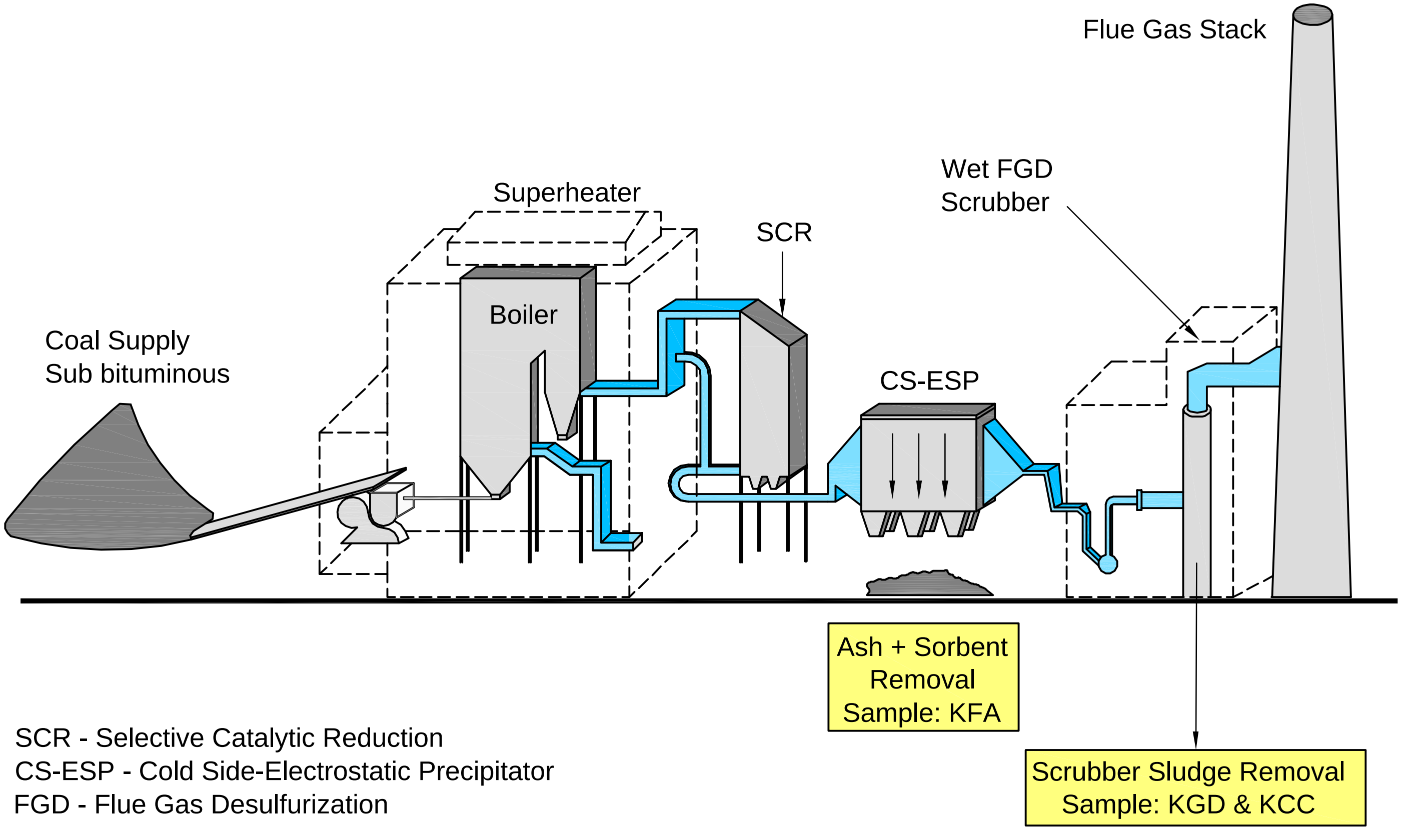
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: J with BPAC



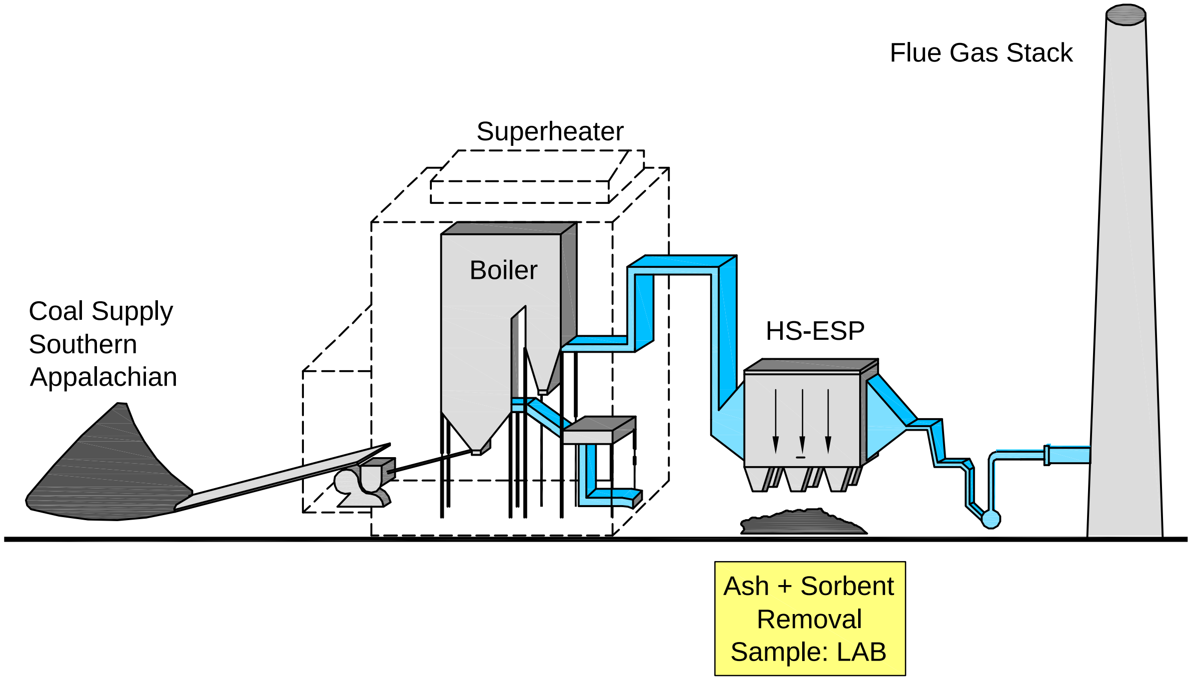
BPAC - Biominated Powder Activated Carbon
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: K



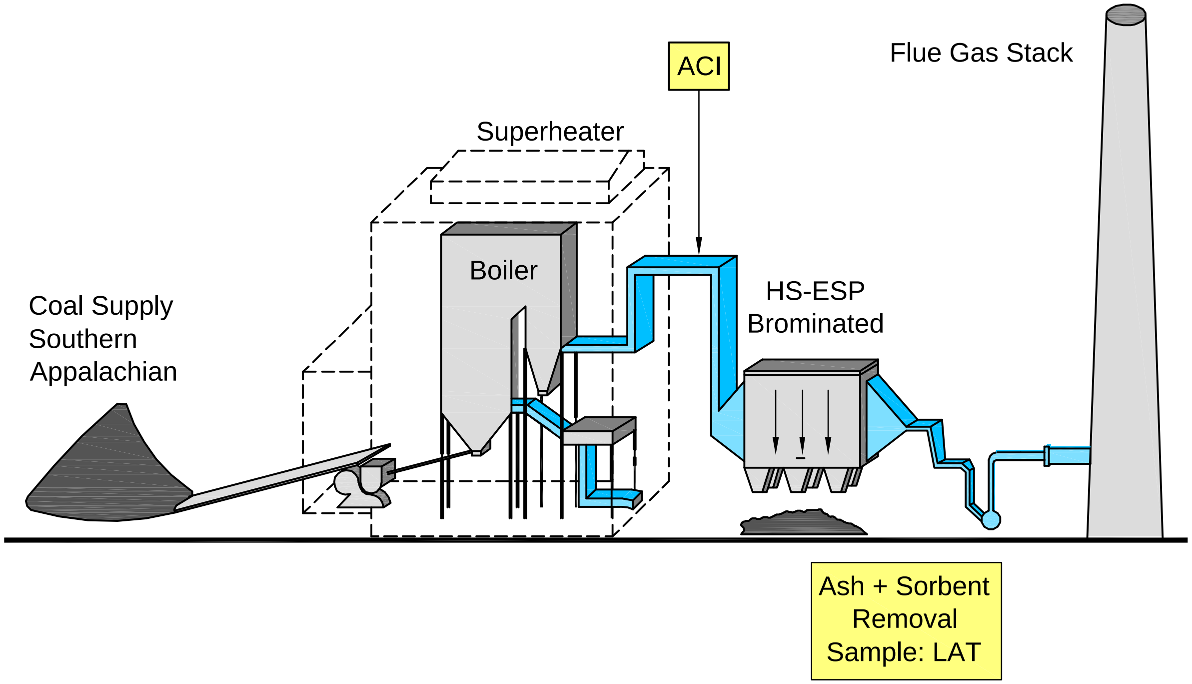
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: L



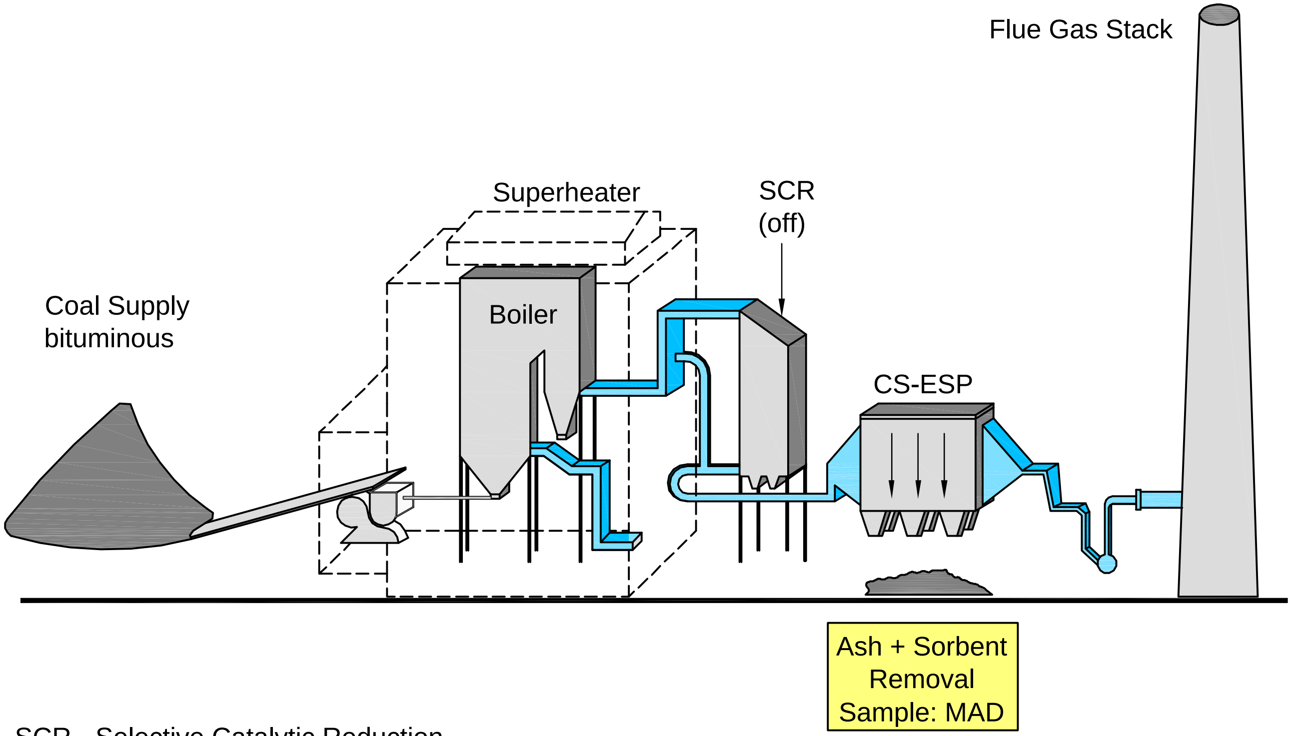
HS-ESP - Hot Side-Electrostatic Precipitator

Facility: L with ACI



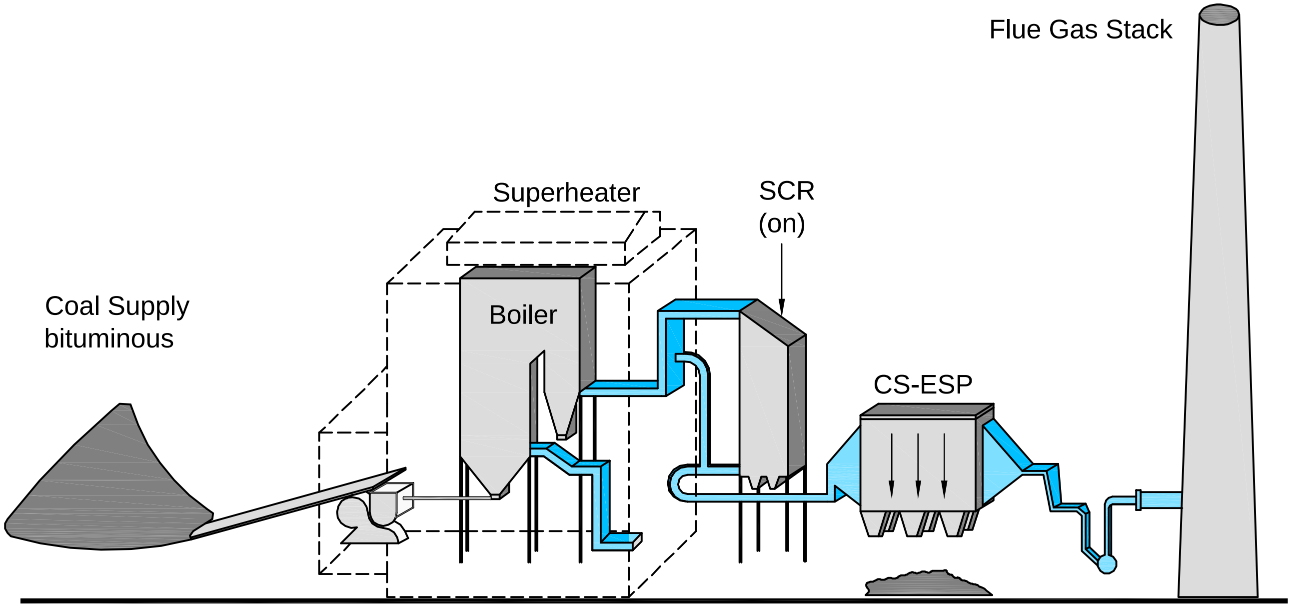
ACI - Activated Carbon Injector
HS-ESP - Hot Side-Electrostatic Precipitator

Facility: M SCR off



SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator

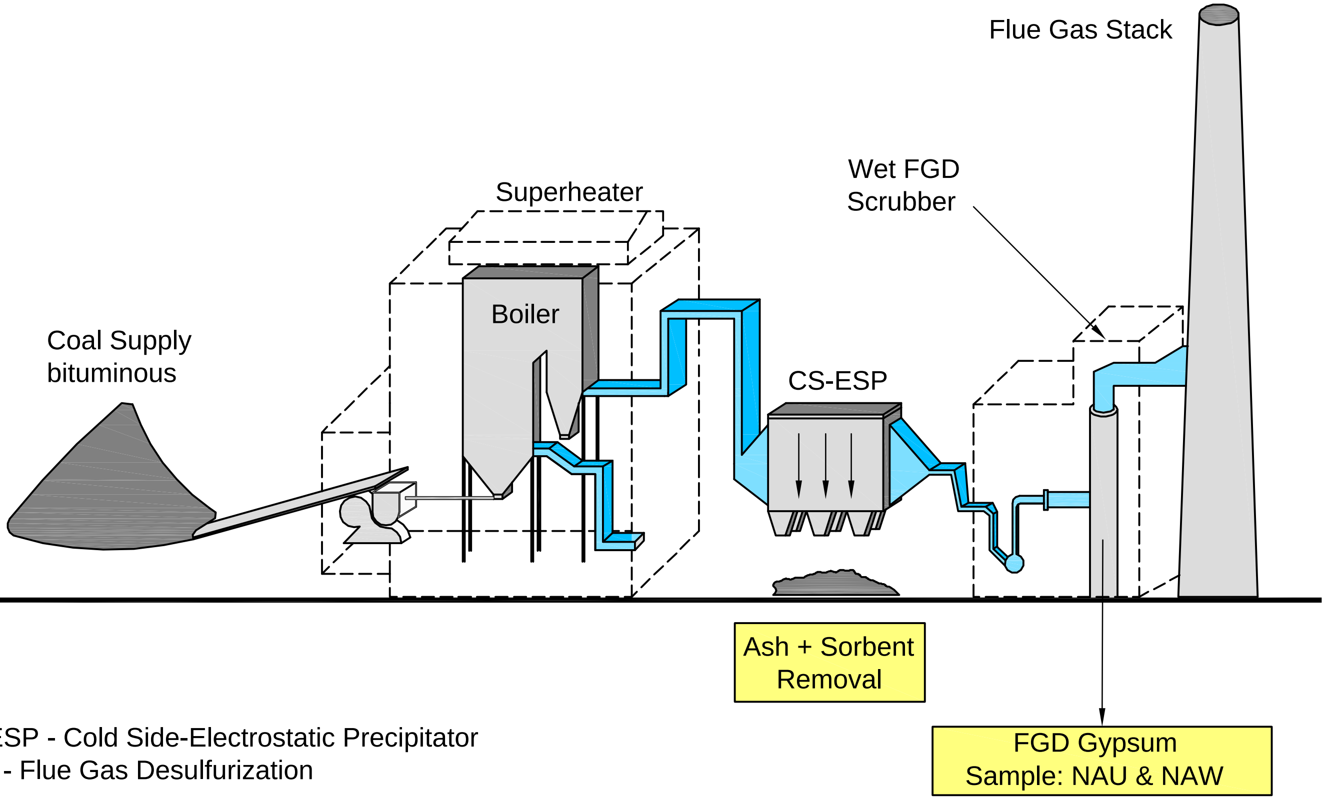
Facility: M SCR on



Ash + Sorbent Removal
Sample: MAS

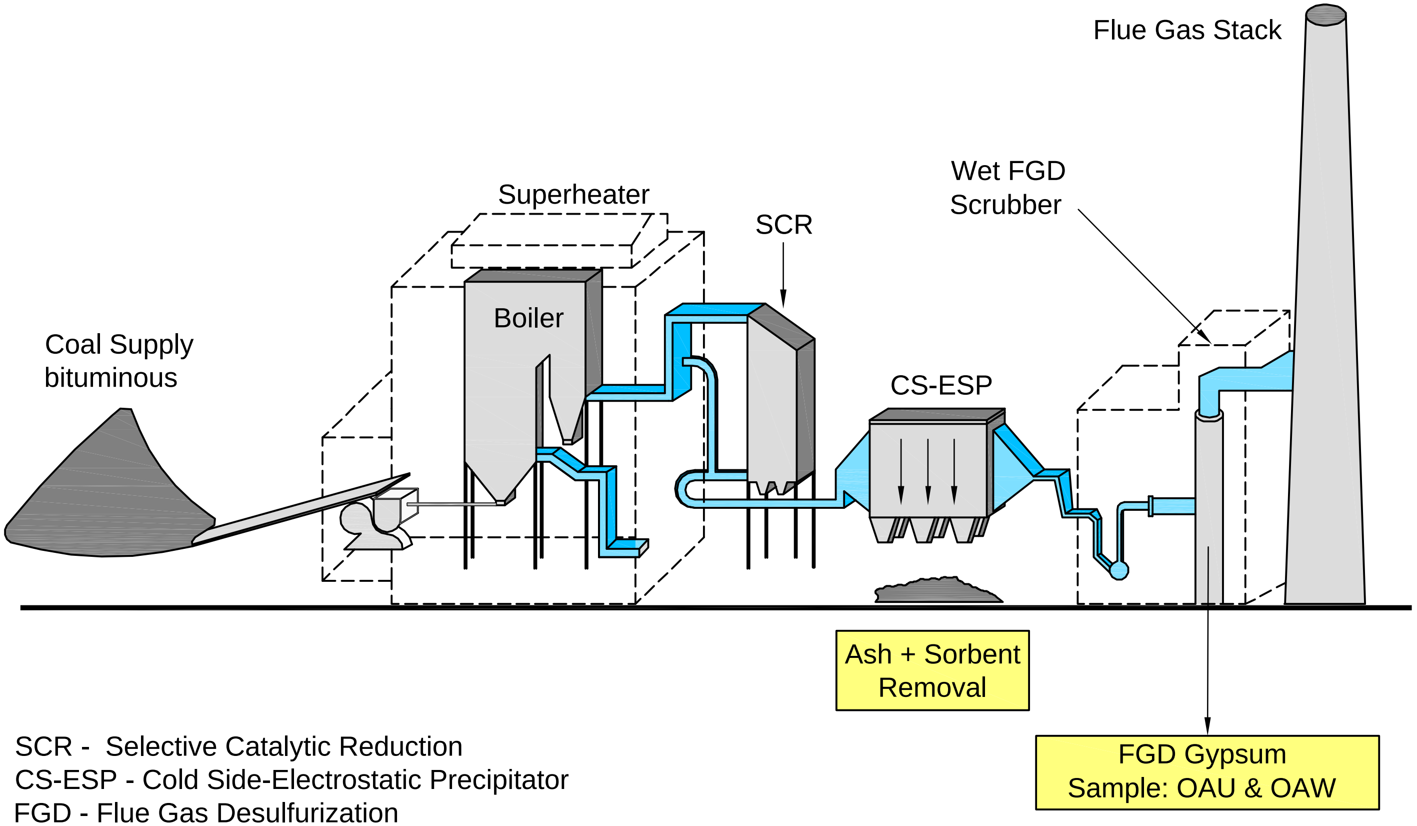
SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: N



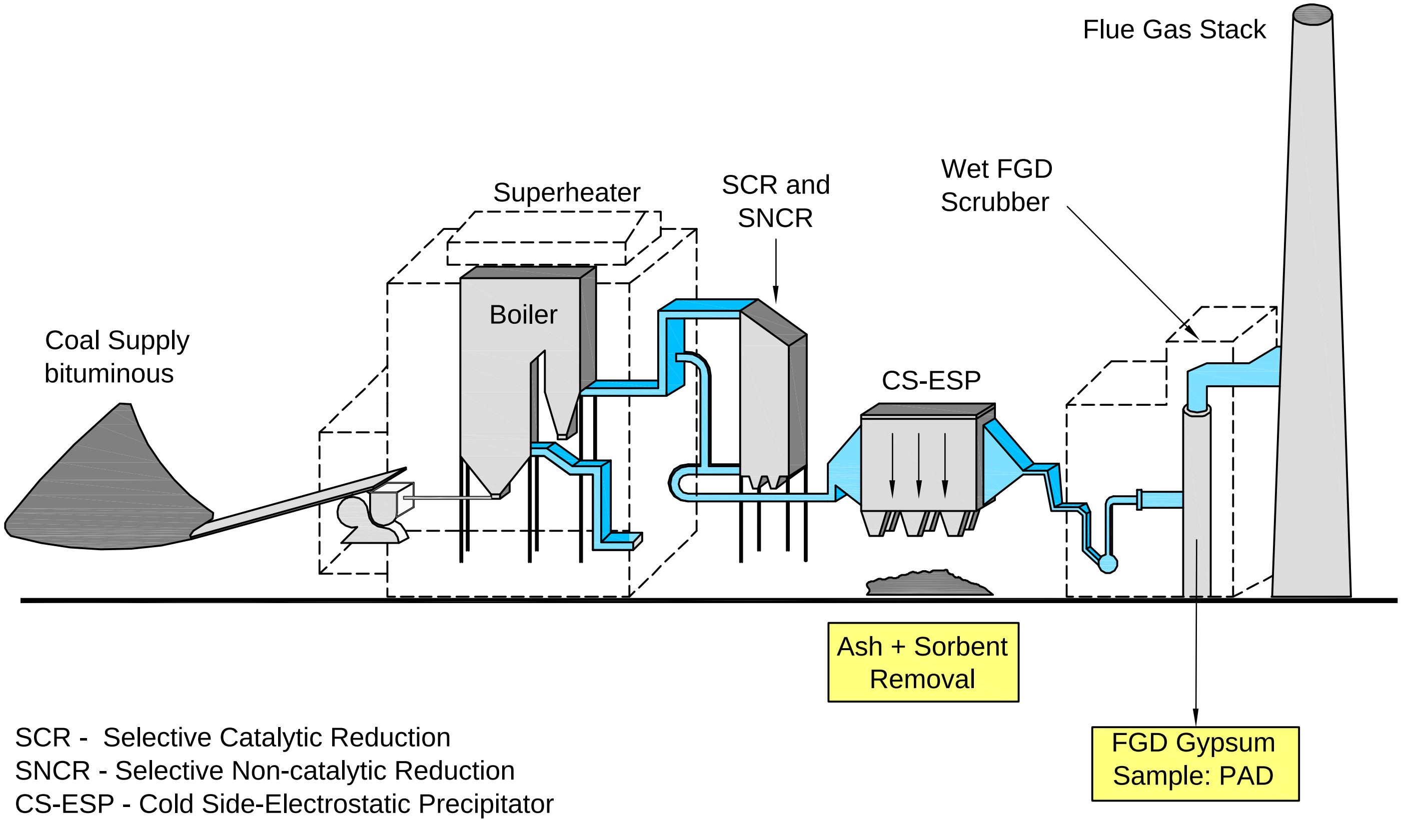
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: O



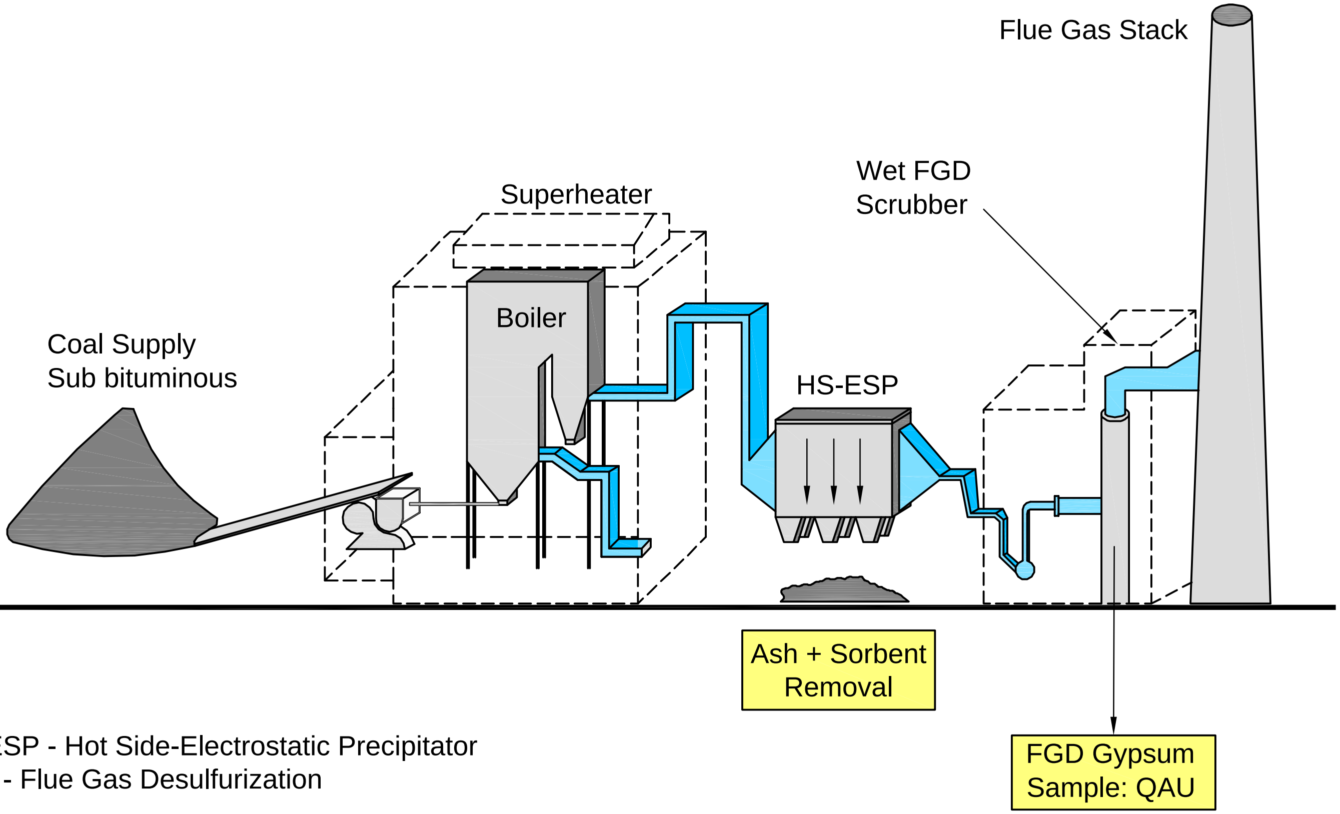
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: P



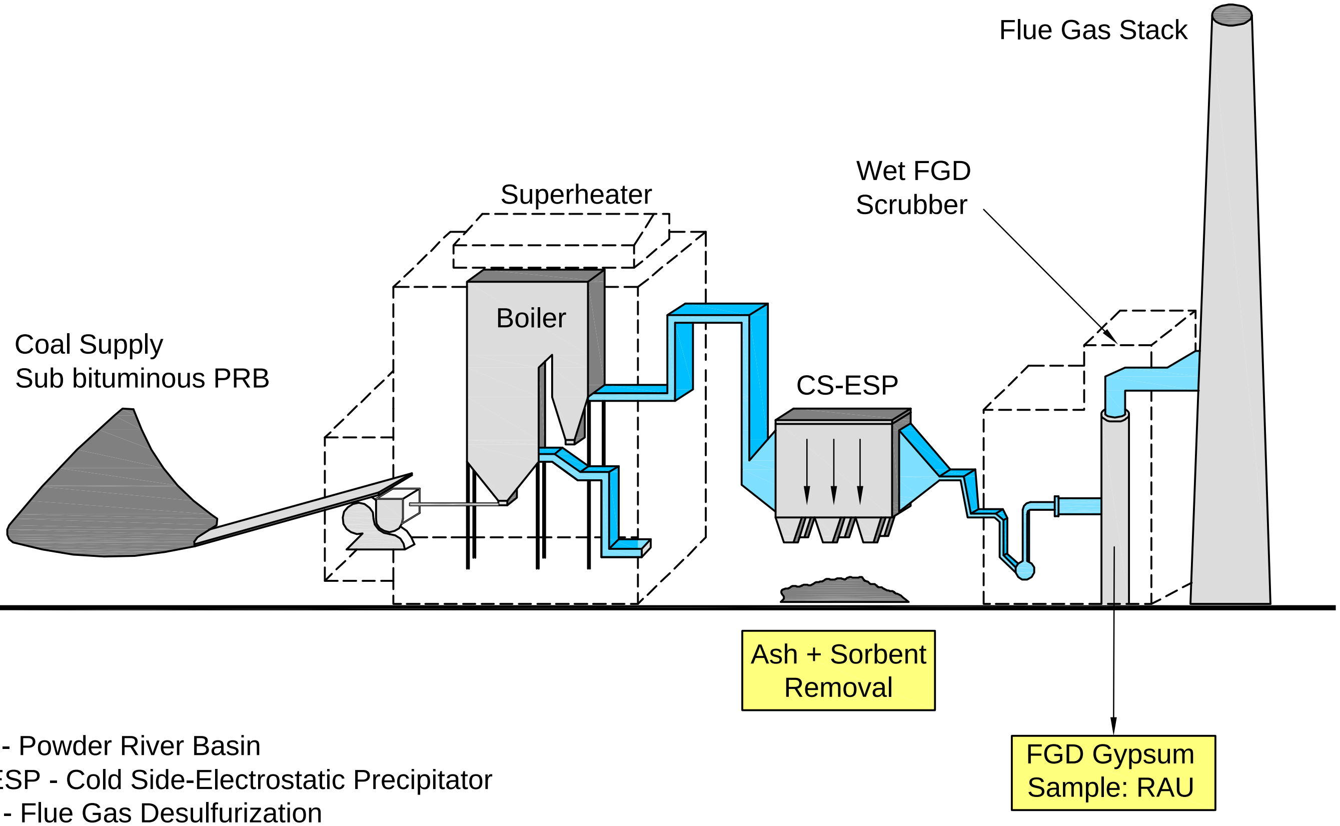
SCR - Selective Catalytic Reduction
SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Q



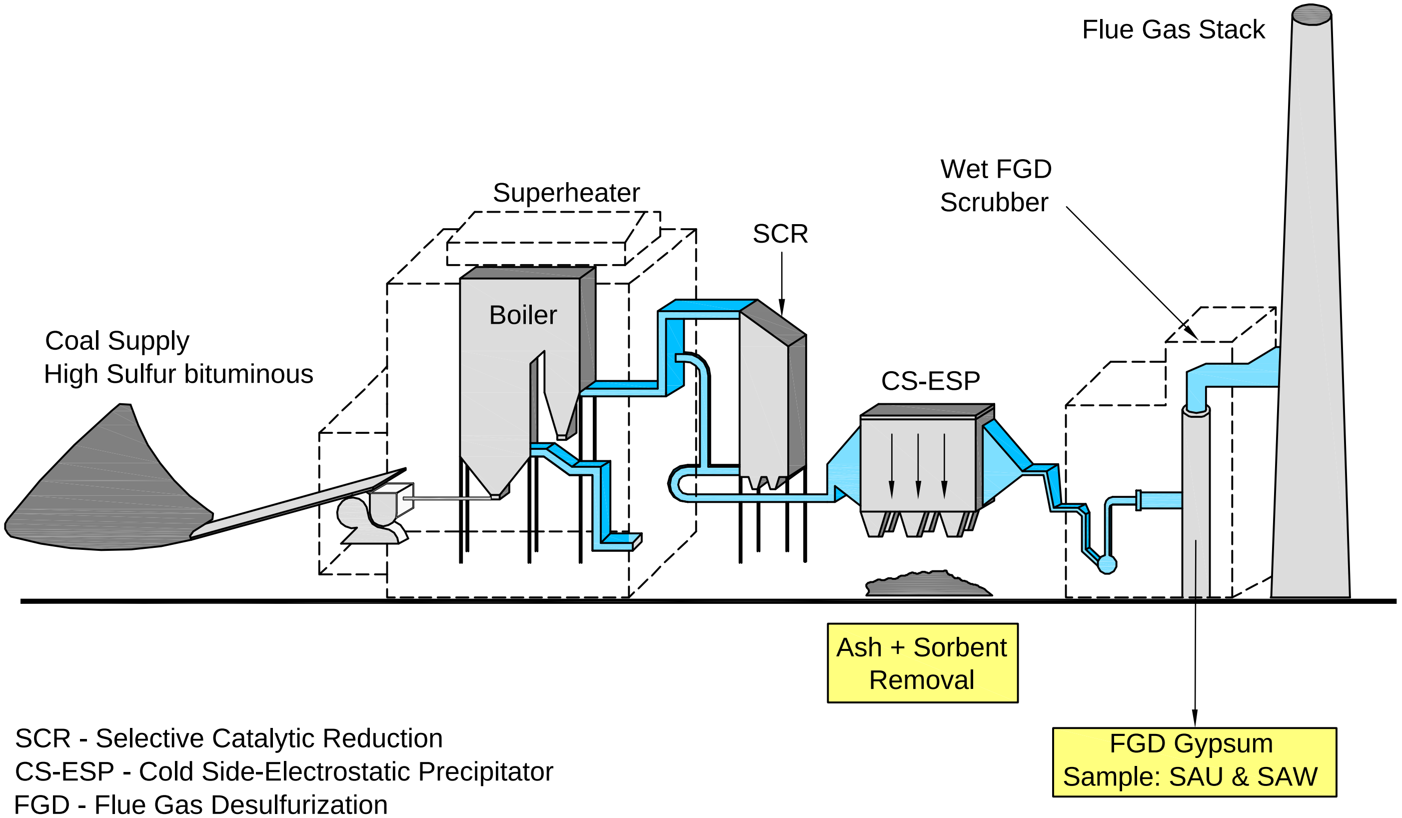
HS-ESP - Hot Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: R



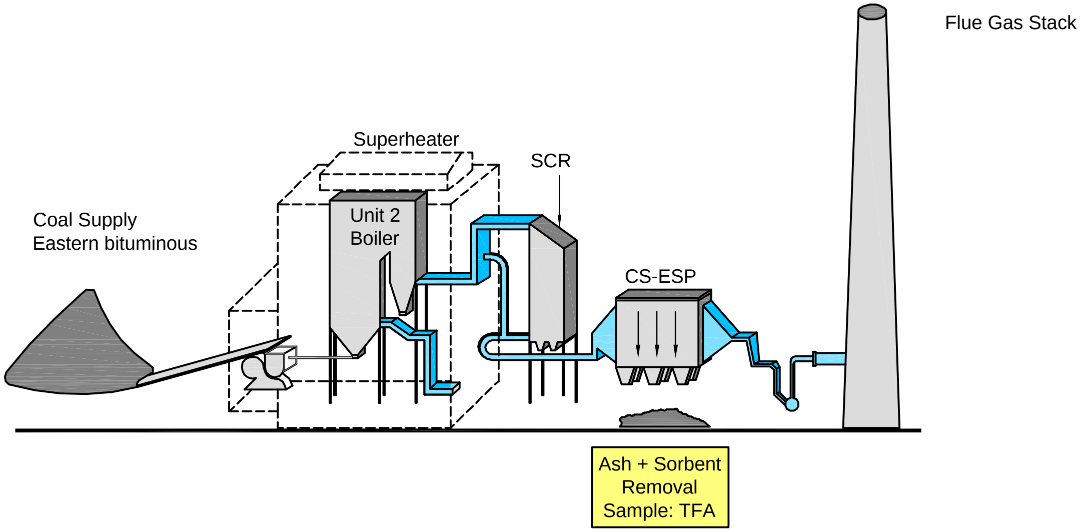
PRB - Powder River Basin
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: S

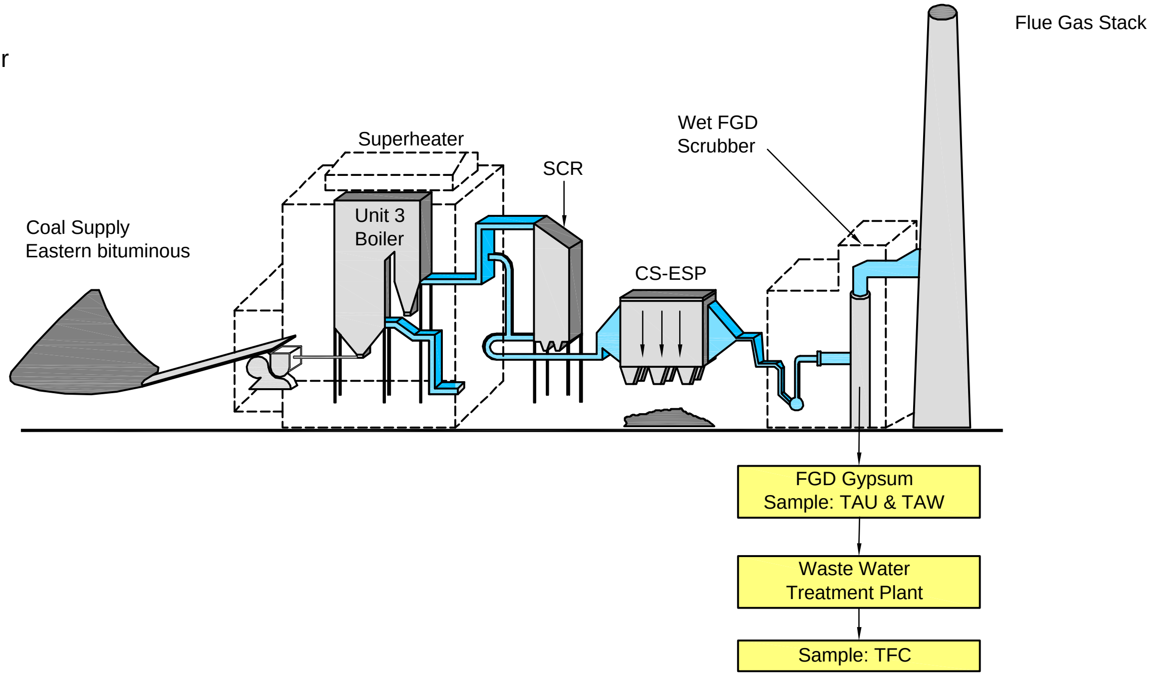


SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

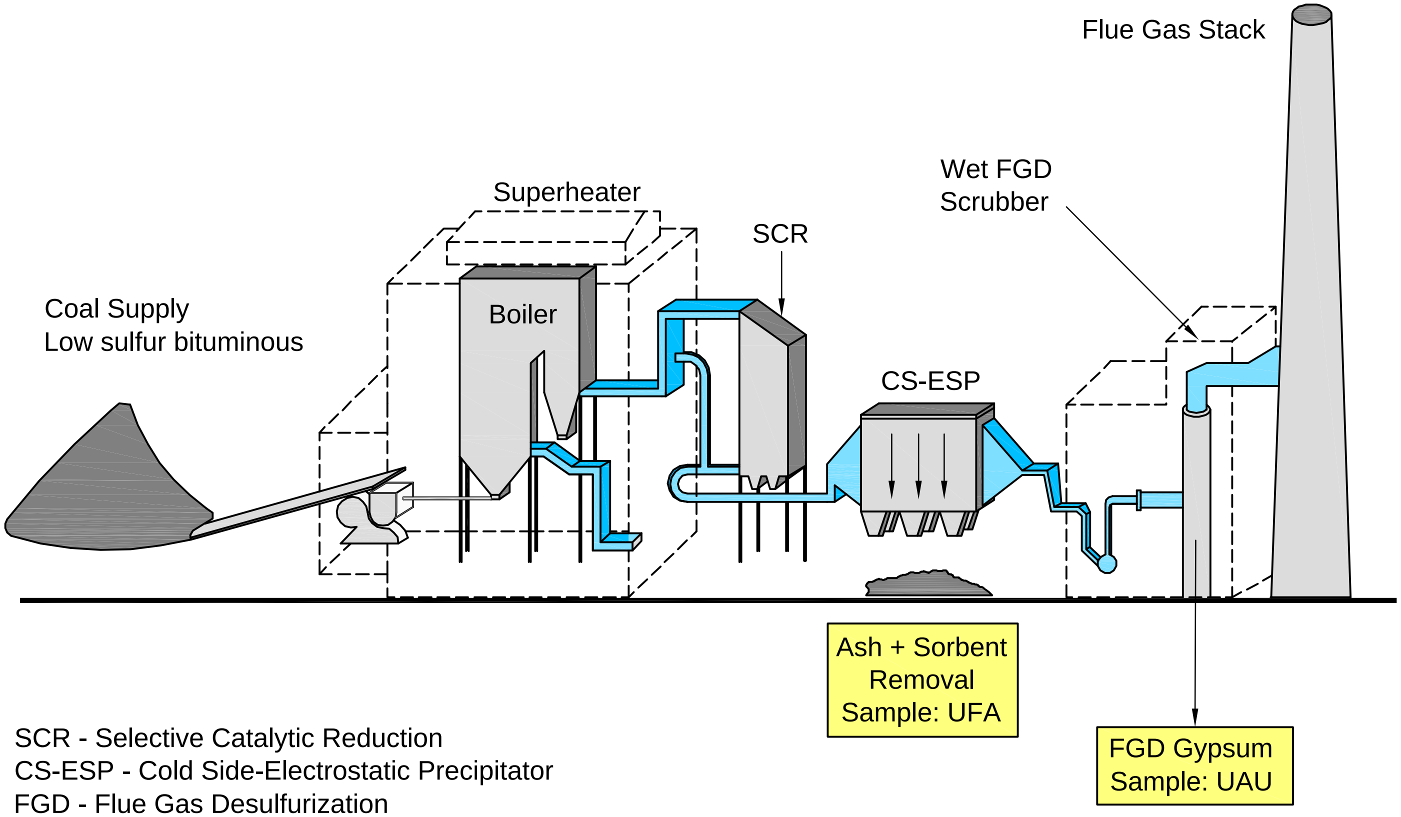
Facility: T



SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

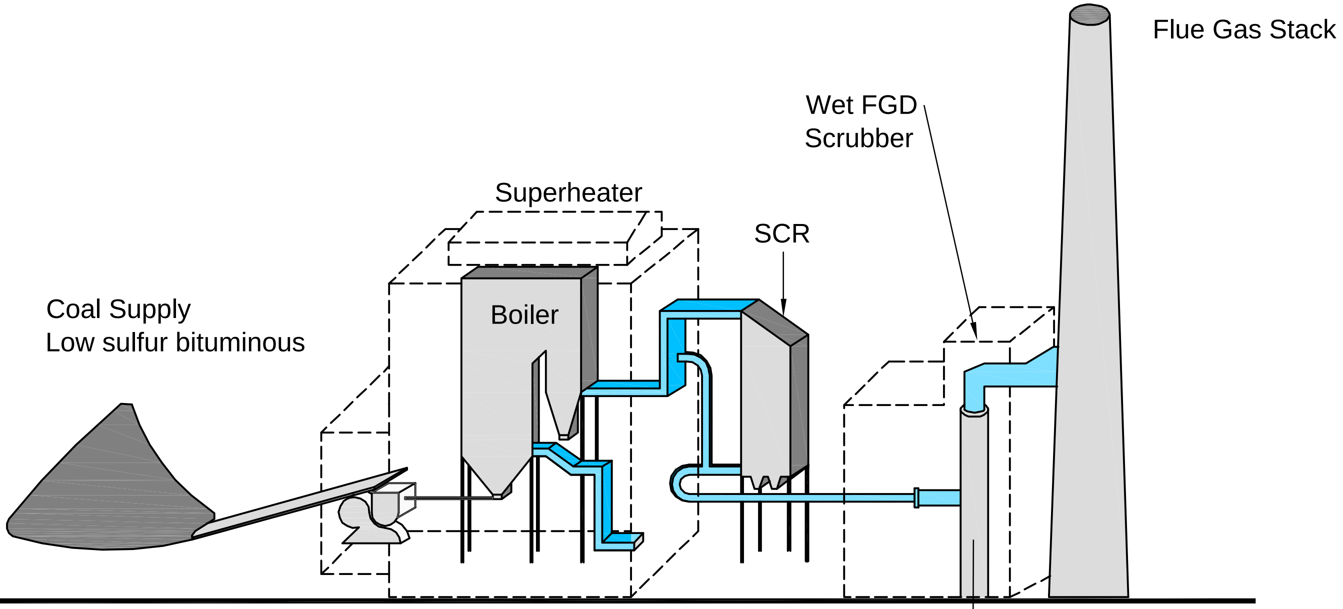


Facility: U Unit 7



SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

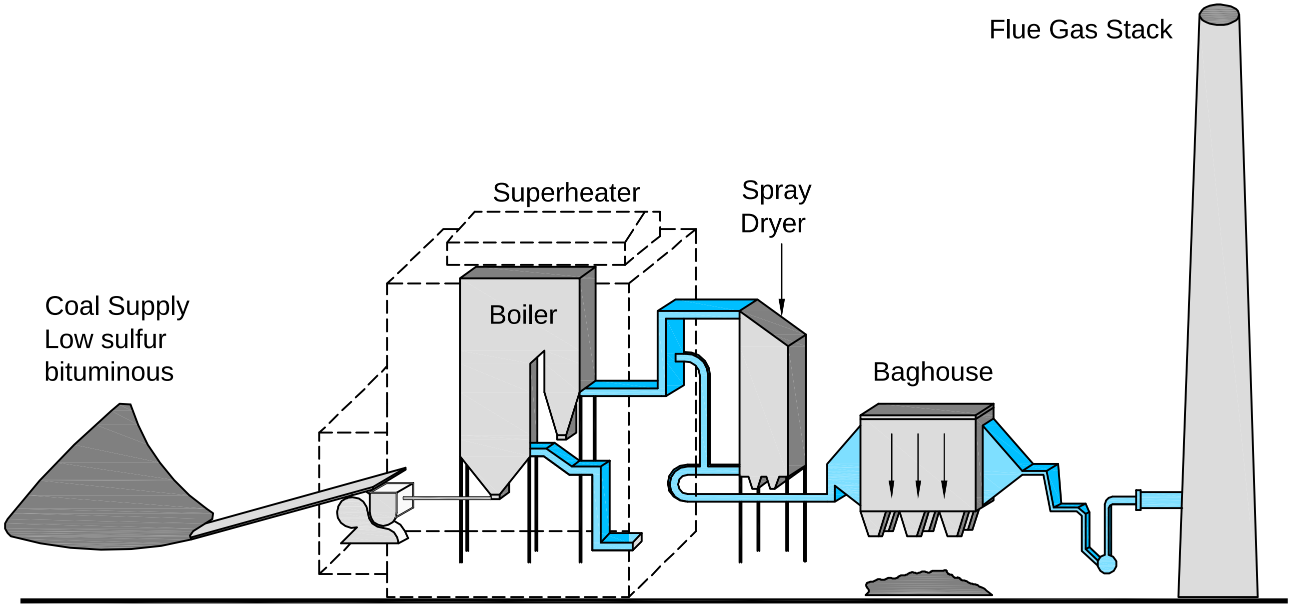
Facility: U Unit 8



FGD Gypsum
Sample: UGF

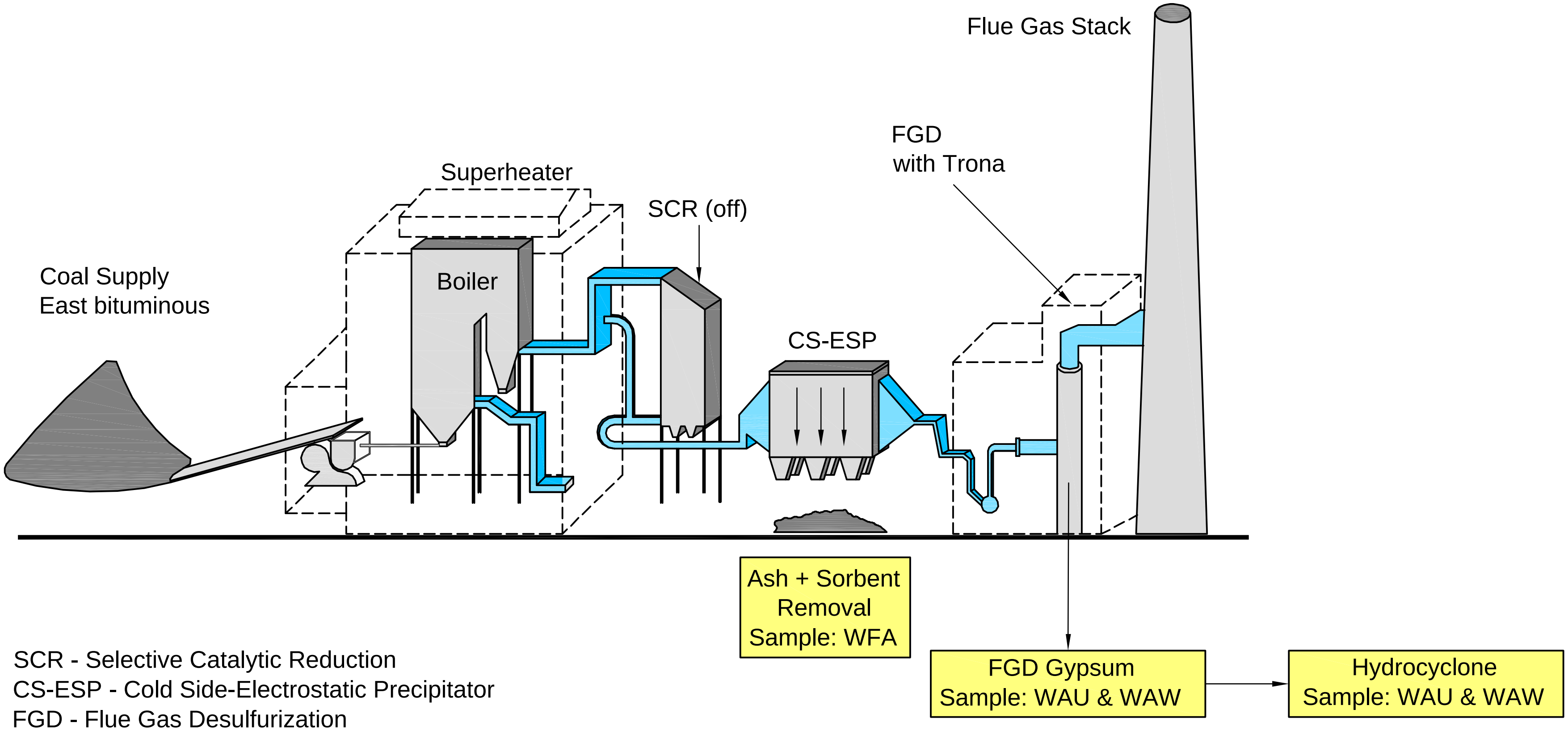
SCR - Selective Catalytic Reduction
FGD - Flue Gas Desulfurization

Facility: V



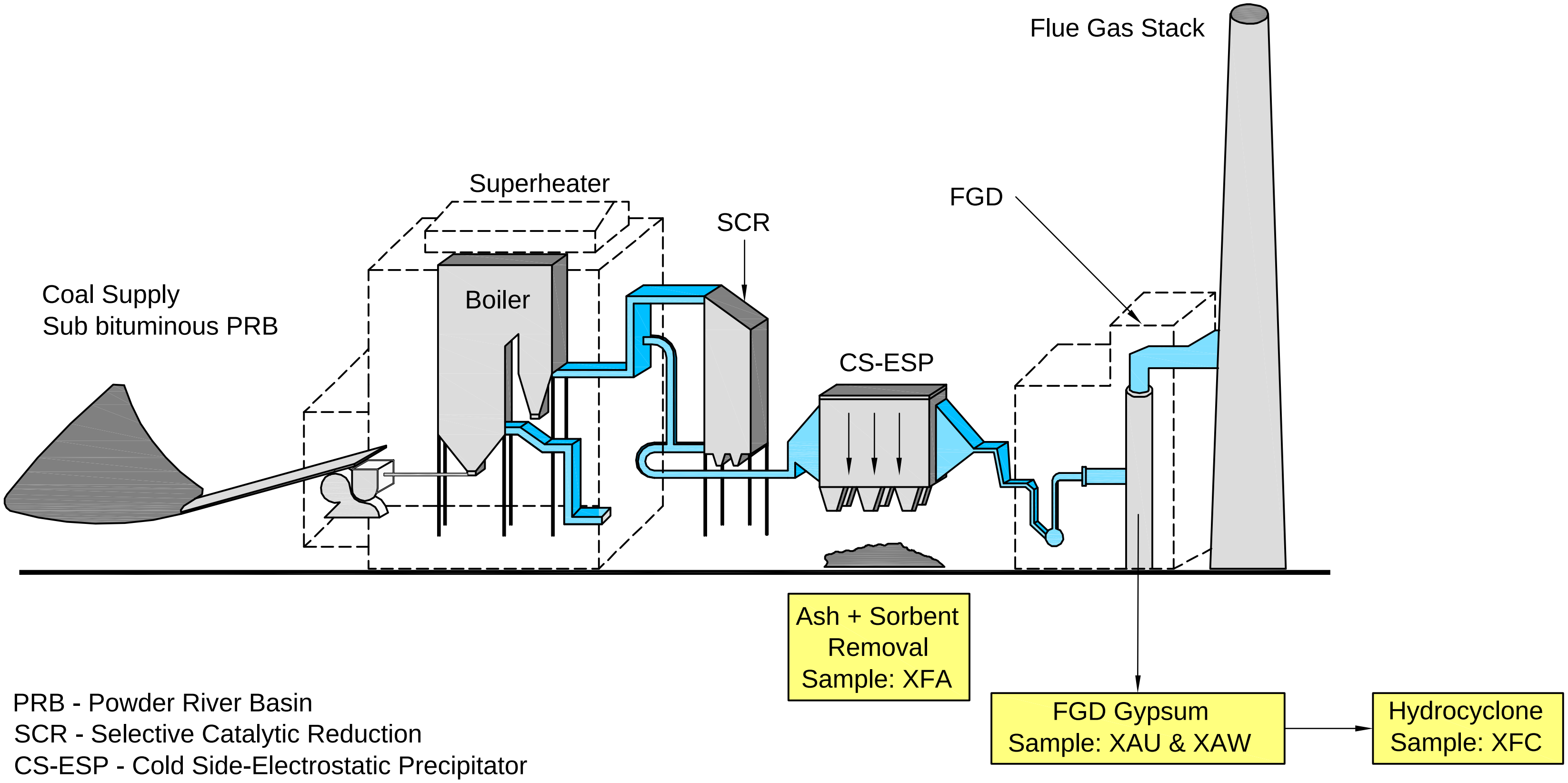
Ash + Sorbent
Removal
Sample: VSD

Facility: W



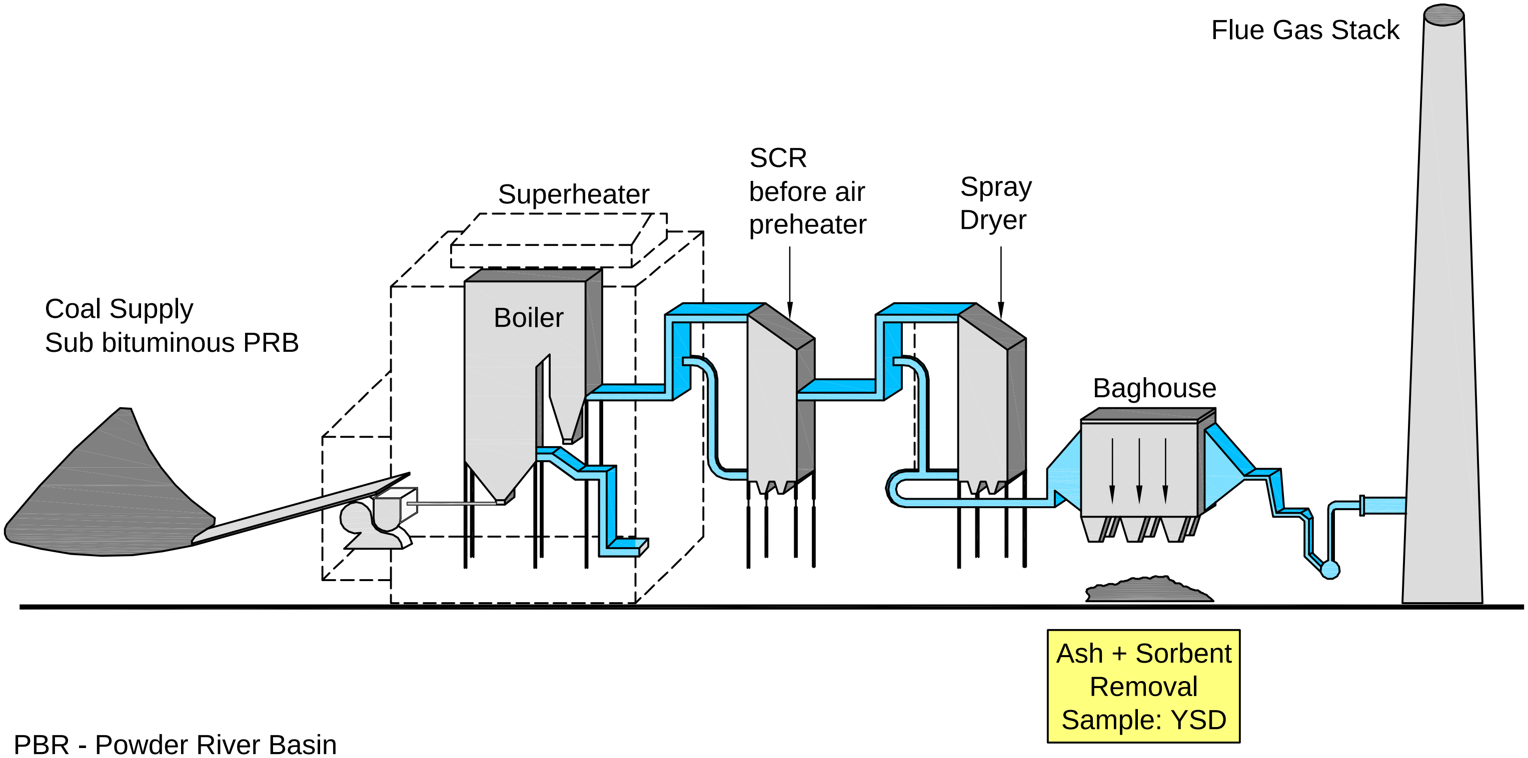
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: X



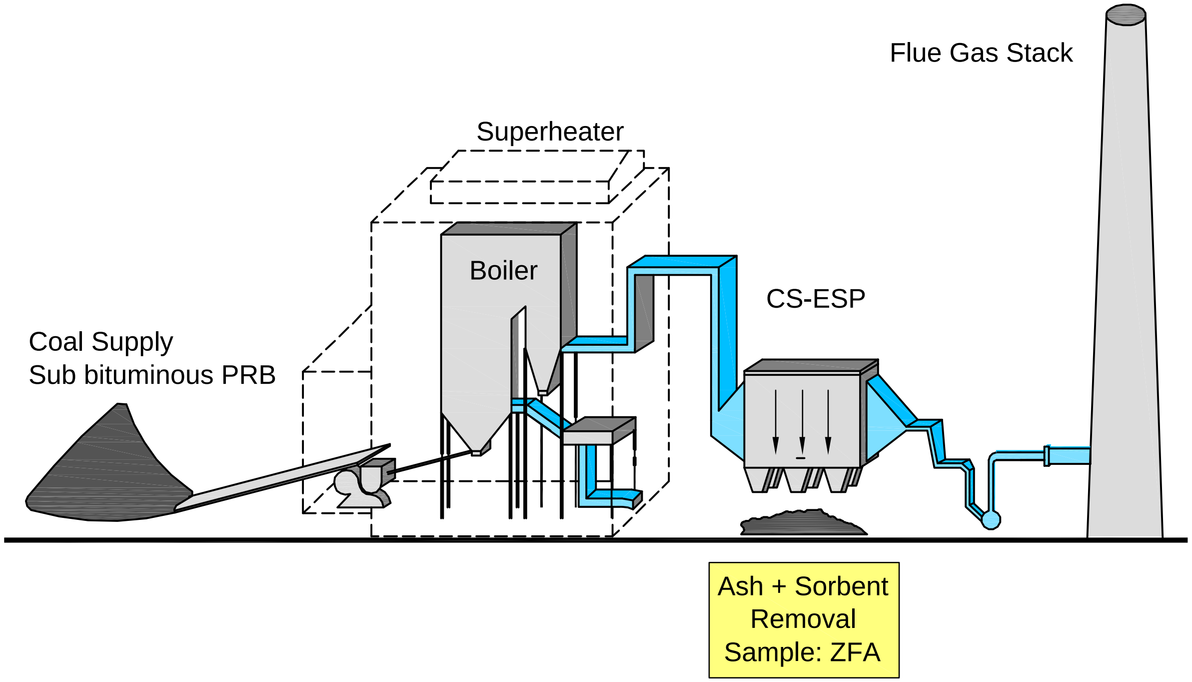
PRB - Powder River Basin
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Y



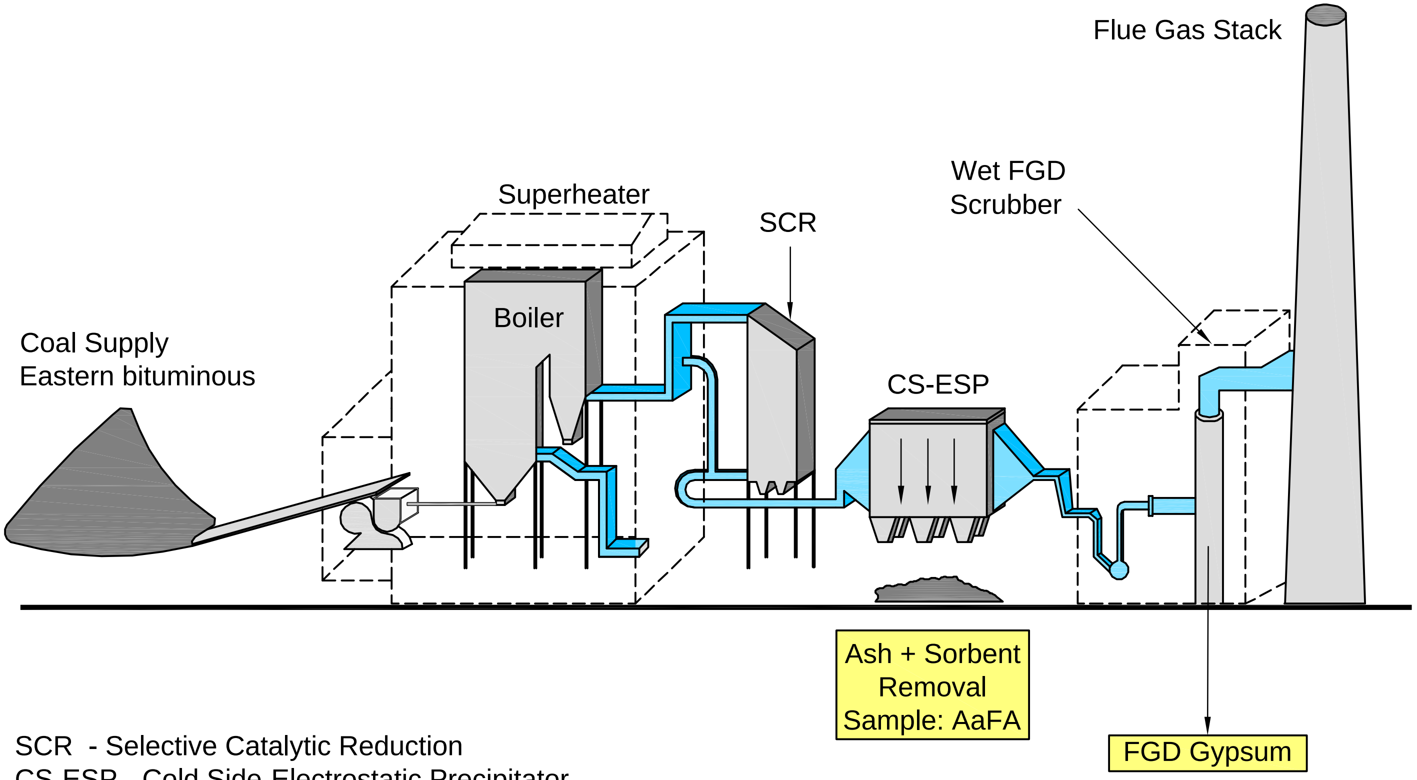
PBR - Powder River Basin
SCR - Selective Catalytic Reduction

Facility: Z



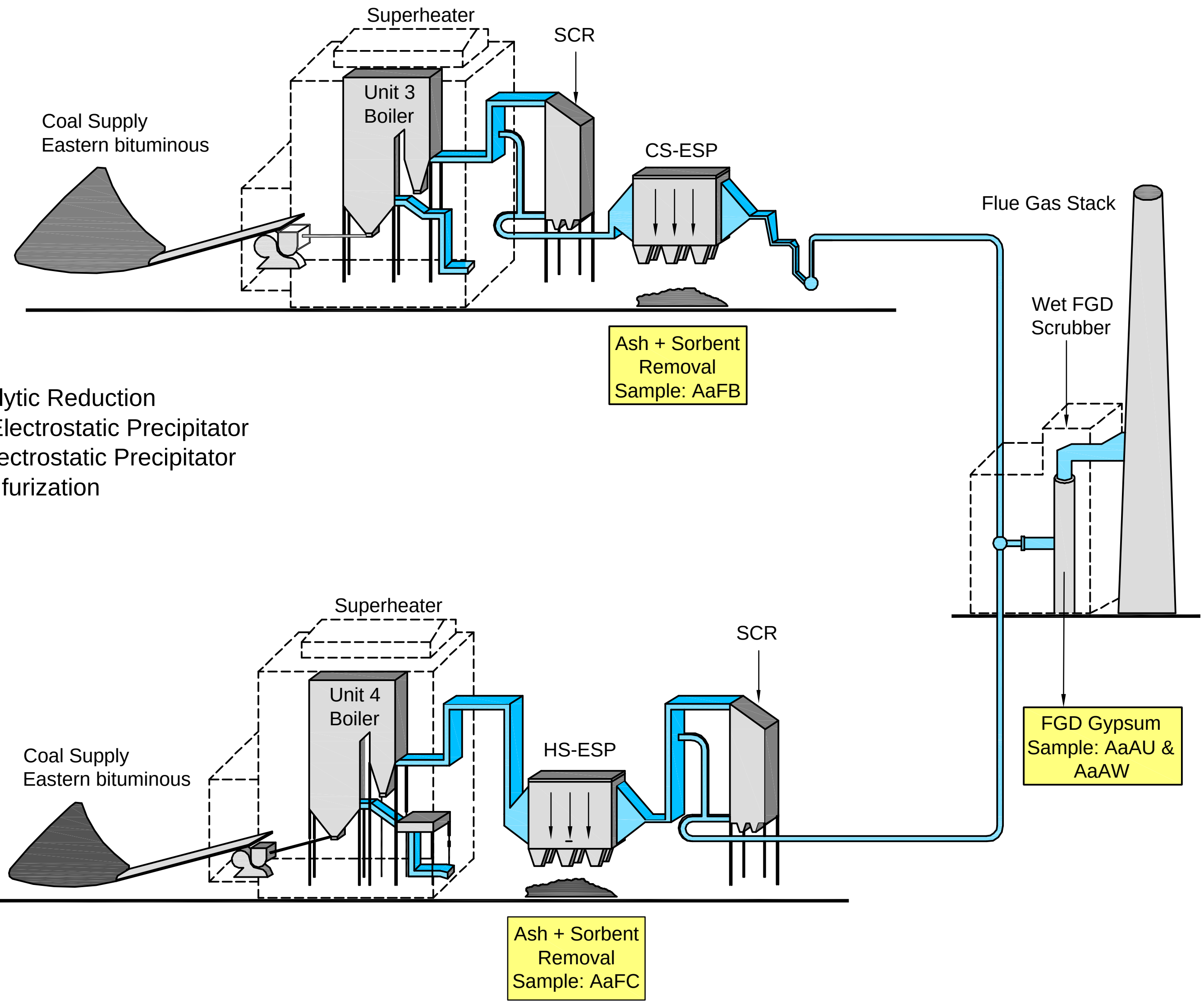
PRB - Powder River Basin
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Aa Unit 1



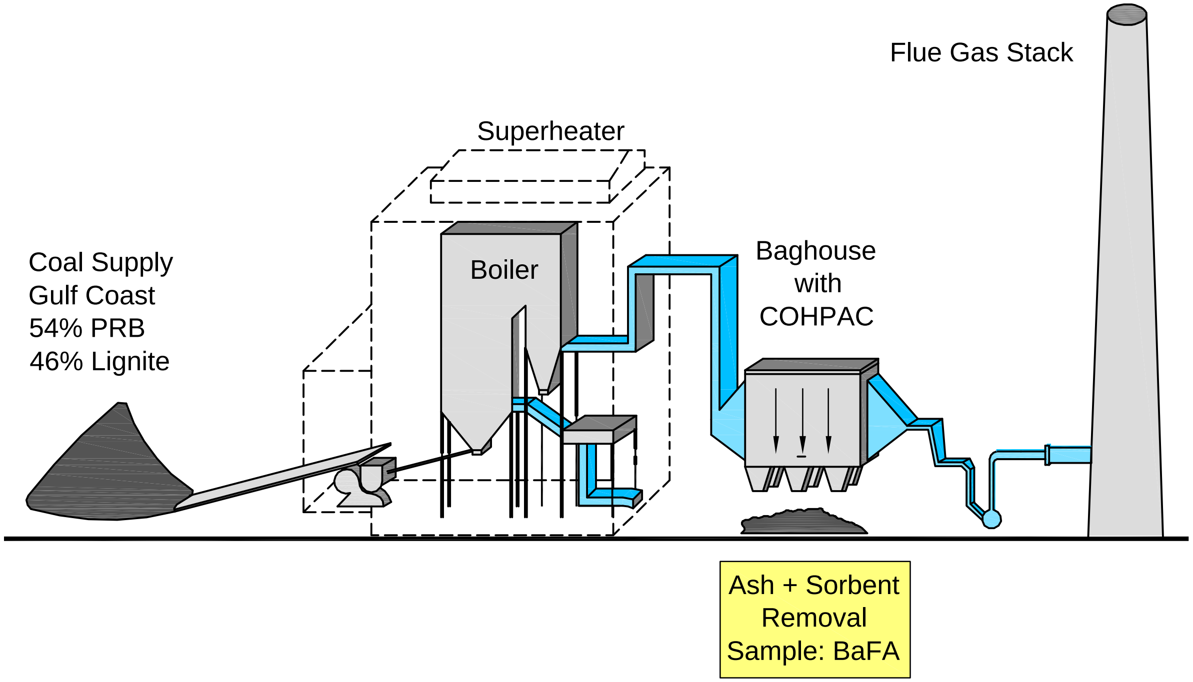
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Aa Unit 3 & 4



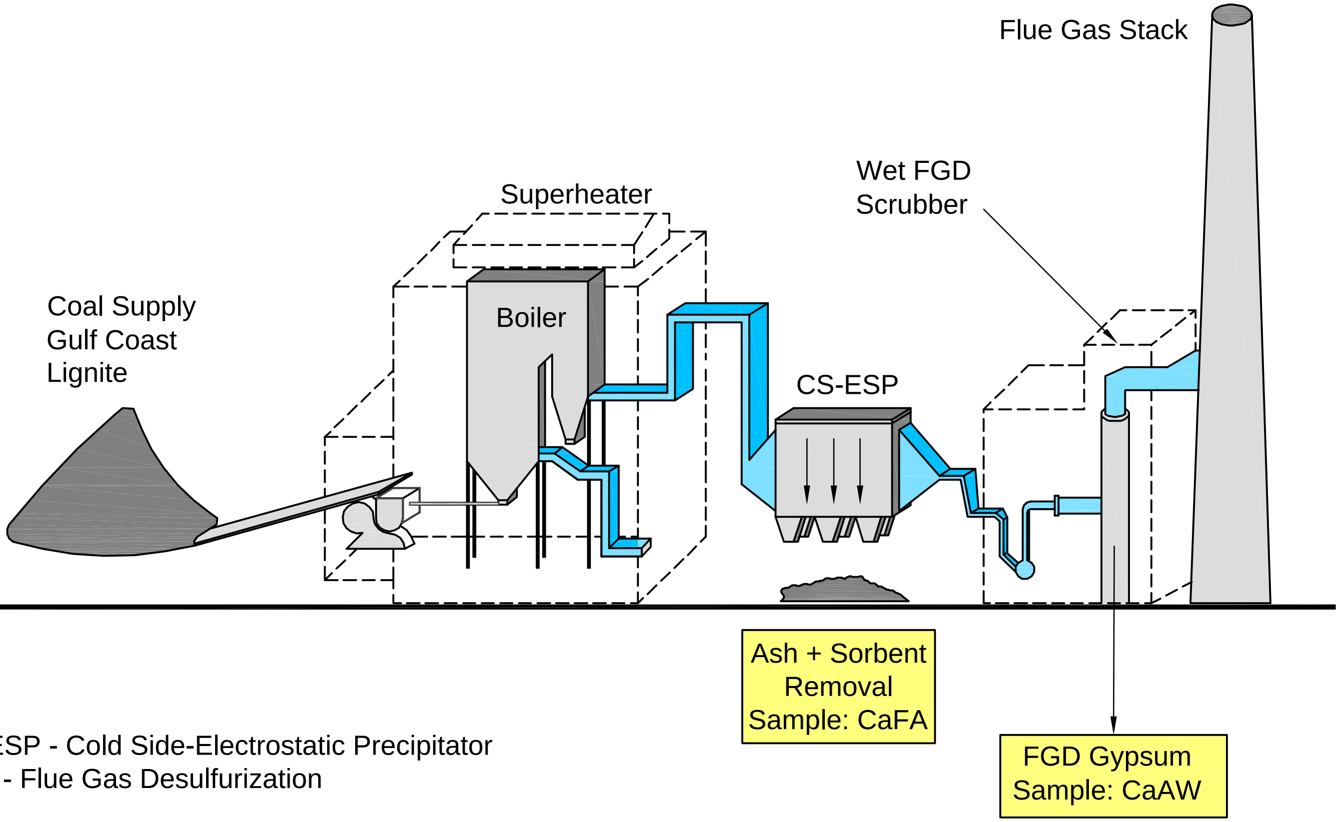
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
HS-ESP - Hot Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Ba



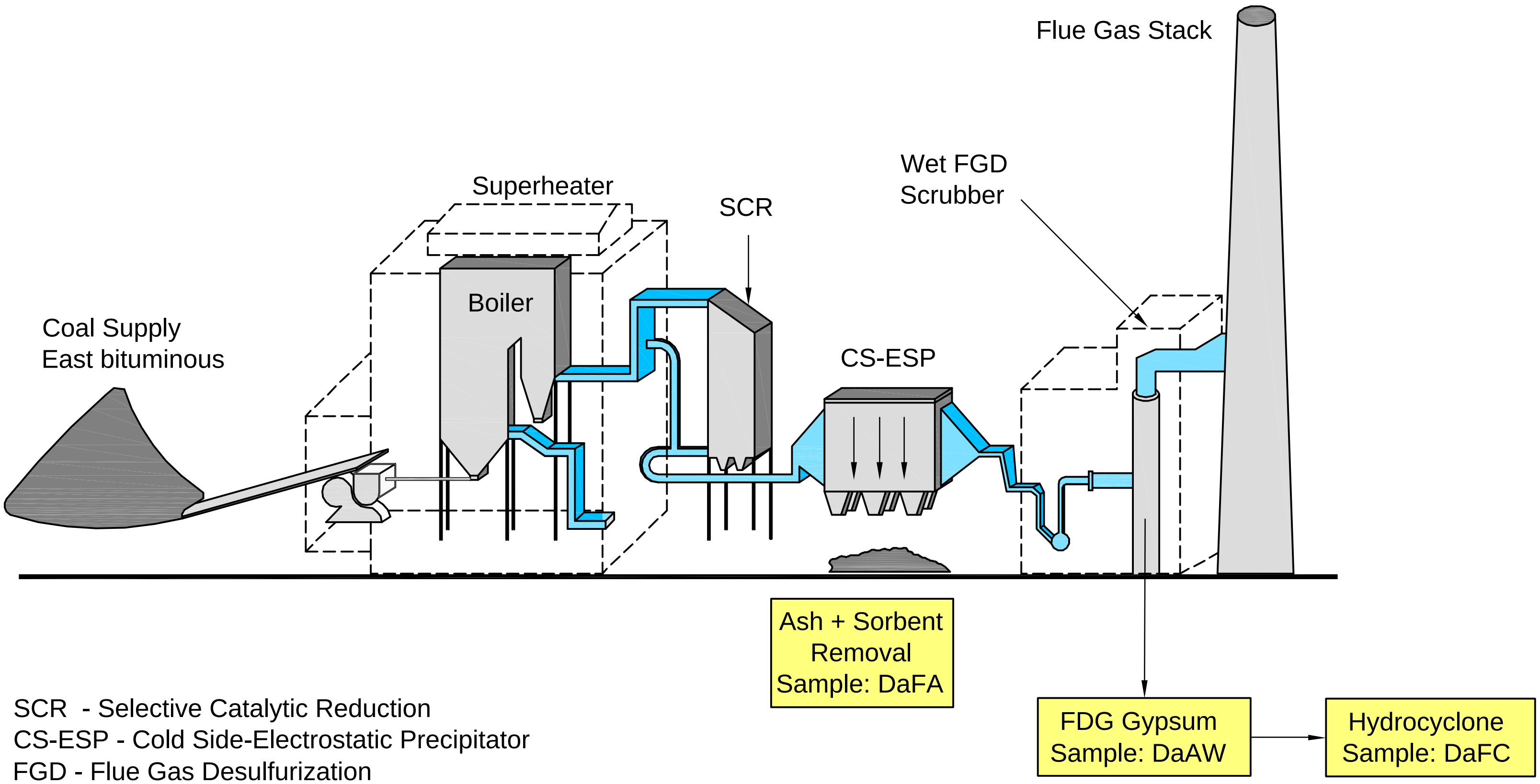
PRB - Powder River Basin
COHPAC - Compact Hybrid Particulate Collector

Facility: Ca



CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Da



SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Appendix B

Quality Assurance Project Plan for the Characterization of Coal Combustion Residues

12/2/2009
Peter Kariher
ARCADIS U.S., Inc
Work Assignment Leader
Date

12/2/2009
Laura Beach Nessley
ARCADIS U.S., Inc.
Quality Assurance Officer
Date

Susan Thorneloe 12/2/2009
Susan Thorneloe
U.S. Environmental Protection Agency
Work Assignment Manager
Date

12/2/09
Andy Miller
U.S. Environmental Protection Agency
Acting Chief, Atmospheric Protection Branch
Date

Robert S. Wright 12/2/09
Robert Wright
U.S. Environmental Protection Agency
Quality Assurance Representative
Date

QAPP for the Characterization of Coal Combustion Residues

Quality Assurance Project Plan
Category III / Technology Development
Final

Prepared for:
Susan Thorneloe
U.S. Environmental Protection Agency
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division
Atmospheric Protection Branch
Research Triangle Park, NC 27711

Prepared by:
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Our Ref.:
RN990270.0007

Date:
December 2009

List of Tables

List of Figures

Distribution List

Copies of this plan and all revisions will be initially sent to the following individuals. It is the responsibility of the U.S. Environmental Protection Agency (EPA) Work Assignment Manager and of the ARCADIS, U.S., Inc. (ARCADIS) Work Assignment Leader to make copies of the plan available to all field personnel.

Susan Thorneloe, EPA Work Assignment Manager. Office of Research and Development, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Research Triangle Park, NC.

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Peter Kariher, ARCADIS Work Assignment Leader. Research Triangle Park, NC.

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1. Project Objectives and Organization

1.1 Purpose

The addition of flue-gas desulfurization (FGD) systems, selective catalytic reduction, and activated carbon injection to capture mercury and other pollutants will shift mercury and other pollutants from the stack gas to fly ash, FGD gypsum, and other air pollution control residues. The Air Pollution Prevention and Control Division (APPCD) of EPA's Office of Research and Development (ORD) is conducting research to evaluate potential leaching and cross media transfers of mercury and other constituents of potential concern (COPCs) resulting from the management of coal combustion residues (CCRs) resulting from wider use of state-of-the art air pollution control technology. This research was cited as a priority in EPA's Mercury Roadmap (http://www.epa.gov/mercury/roadmap.htm) to ensure that one environmental problem is not being traded for another. The objective is to understand the fate of mercury and other COPCs and ensure that emissions being controlled in the flue gas at power plants are not later being released depending upon how the CCRs are managed. The questions to be addressed through this research include:

- What are the changes to CCRs resulting from application of control technology at coal-fired power plants including changes in pH, metals content, and other parameters that may influence environmental release?
- For CCRs that are land disposed, the questions to be addressed include:
    - Will any of these changes result in an increase in the potential for leaching of mercury (Hg) and other metals such as arsenic (As), selenium (Se), lead (Pb), cadmium (Cd), cobalt (Co), aluminum (Al), barium (Ba), boron (B), molybdenum (Mo), antimony (Sb), thallium (Tl), and chromium (Cr) from disposal of CCRs in impoundments, monofills, agriculture amendment, minefills, or other beneficial use scenarios?
    - What is the fate of Hg and other metals from CCRs that are land disposed?
- For CCRs that are used in commercial applications, the questions to be addressed include:
    - Will any of the changes to CCRs from application of control technologies at coal-fired power plants impact their use in commercial applications?
    - What is the fate of Hg and other metals in CCRs when used in commercial applications?
    - What is the extent of Hg, As, Pb, Se, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr release during high temperature manufacturing processes used to produce cement clinkers, asphalt, and wallboard?

- Are Hg and other pollutants such as As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr present in CCRs that are used in commercial applications such as highway construction or beneficial use scenarios subject to conditions that would result in their release to the environment?

EPA's Air Pollution Prevention and Control Division (APPCD) through an on-site laboratory support contract with ARCADIS is to conduct a comprehensive study on the fate of mercury (Hg), arsenic (As), selenium (Se), lead (Pb), cadmium (Cd), cobalt (Co), aluminum (Al), barium (Ba), boron (B), molybdenum (Mo), antimony (Sb), thallium (Tl), and chromium (Cr) in CCRs. This research will be conducted in three tasks. Task I will focus on updating the QAPP to clearly define the project scope and procedures. Task II will focus on completing the report on evaluating the potential release of Hg and other heavy metals from a cement kiln operation, asphalt production, and wallboard production using synthetic gypsum. Task III will cover the evaluation of the potential of CCRs to leach Hg and other heavy metals during disposal or beneficial use scenarios. The scope of this QAPP covers Task I through Task III.

1.2 Project Objectives

US EPA's Office of Resource Conservation and Recovery (ORCR) formerly the Office of Solid Waste (OSW) has been asked to provide general guidance on appropriate testing to evaluate the release potential of Hg and other metallic contaminants (As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr) from CCRs via leaching, run-off, and volatilization when the CCRs are disposed in landfills and incorporated into commercial products using high/low temperature commercial processes. This evaluation in projected disposal and reuse situations (different waste management scenarios; see Section 1.1) will both help assess the likely suitability of new or modified wastes for reuse, and ensure that Hg, As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr removed from stack emissions are not subsequently released to the environment in significant amounts as a result of CCR reuse or disposal practices.

The primary objective of this project is to generate a comprehensive database that will enable ORCR to (1) evaluate changes in CCRs resulting from the implementation of different Hg control technologies (see Section 3.3), and (2) assess environmental releases of these toxic metals during CCR management practices including land disposal and commercial applications. OSW will be using the results to determine needs in regard to future policies for managing CCRs whose characteristics are changing as a result of the MACT under development for coal fired power plants. US EPA's Office of Air and Radiation (OAR) will be using the data to determine the potential for cross-media impacts and potential changes to disposal and reuse practices which impact the economics of potential regulations for coal-fired power plants. The data will also be used to address questions raised by Congress and others regarding establishing the net benefit of potential requirements for reducing emissions from coal-fired power plants.

Data on the chemical stability of these metals (leaching tests) will be generated using the EPA/OSW recommended methods (see Reply to comments on EPA/OSW's Proposed Approach to Environmental

Assessment of CCRs Discussed March 5, 2002 - Appendix A) developed by Dr. David Kosson, Dr. Andrew Garrabrants, and Dr. Florence Sanchez of Vanderbilt University titled *An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials* (Kosson et al., 2002, Environmental Engineering Science, Volume 19, Number 3). The ability of these EPA/OSW methods to assess leaching of the metals of interest will be further demonstrated with the use of a NIST standard reference material (SRM) with certified amounts of trace metals. Using this comprehensive database, EPA/ORCR will determine the feasibility of the application of the above methods to CCRs and they will assess the environmental impacts of different types of CCRs' waste management practices.

2. Project Organization

The organizational chart for this project is shown in Figure 2-1. The roles and responsibilities of the project personnel are discussed in the following paragraphs. In addition, contact information is also provided.

EPA Work Assignment Manager, Susan Thorneloe: The EPA WA Manager is responsible for communicating the scope of work, data quality objectives and deliverables required for this work assignment. The EPA WA Manager is also responsible for providing ARCADIS with the various types of CCRs to be characterized.

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E-mail: thorneloe.susan@epamail.epa.gov

EPA QA Representative, Robert Wright: The EPA QA Representative will be responsible for reviewing and approving this QAPP. This project has been assigned a QA category III and may be audited by EPA QA. Mr. Wright is responsible for coordinating any EPA audits.

Phone (919) 541-4502
E-mail: wright.bob@epamail.epa.gov

ARCADIS Work Assignment Leader, Peter Kariher: The ARCADIS WA Leader is responsible for preparing project deliverables and managing the work assignment. He will ensure the project meets scheduled milestones and stays within budgetary constraints agreed upon by EPA. The WA Leader is also responsible for communicating any delays in scheduling or changes in cost to the EPA WA Manager as soon as possible.

Phone (919) 541-5740
E-mail: peter.kariher@arcadis-us.com

ARCADIS Inorganic Laboratory Manager, Peter Kariher. In addition to being the WA Leader, Peter Kariher is also responsible for the operation of EPA's in-house Inorganic Laboratory. Mr. Kariher will review and validate all analytical data reports and ensure that the leaching studies are performed properly. He will also operate the mercury analyzer and ion chromatograph. For the leaching studies and mercury and metals analyses, Mr. Kariher will be supported by one technician: John Foley.

Mr. Kariher will perform SW-846 Method 3052 digestion of solid CCR and SRM samples and also be responsible for mercury analysis of samples by CVAA. John Foley will perform the leaching tests. Mr. Kariher will submit the remaining Method 3052 digestates to the subcontract analytical laboratory, Test America-Savannah for ICP/MS analysis of the other target metals. Mr. Kariher will also be responsible for assisting Drs. Kosson and Sanchez in the development of appropriate QA/QC procedures for the leaching assessment methods.

Phone (919) 541-5740
E-mail: peter.kariher@arcadis-us.com

Test America-Savannah Analytical Manager, Kathryn Smith: Ms. Smith will review and validate the ICP/MS results for total content digest samples and report them to Mr. Kariher.

Phone (912) 354-7858
E-mail: kathye.smith@testamericainc.com

ARCADIS Designated QA Officer, Laura Nessley: The ARCADIS QA Manager, Laura Nessley, has been assigned QA responsibilities for this work assignment. Ms. Nessley will be responsible for reviewing this QAPP prior to submission to EPA QA for review. Ms. Nessley will also ensure the QAPP is implemented by project personnel by performing internal assessments. All QA/QC related problems will be reported directly to the ARCADIS WAL, Peter Kariher.

Phone: (919) 544-4535
E-mail: libby.nessley@arcadis-us.com

Vanderbilt University, Methods Development, Professors David Kosson and Florence Sanchez: Dr. Kosson in cooperation with Dr. Florence Sanchez developed the leachability methods being evaluated on this project. They will be available to consult regarding method optimization and development of QA/QC procedures for possible promulgation in the SW-846 methods. Dr. Kosson, Dr. Sanchez, and Ms. Rossane Delapp will also assist in report writing and determining non-mercury metals concentrations in the leachates, and development of the LeachXS Lite analytical database for sample data viewing and reporting.

Dr. David Kosson
Phone: (615) 322-1064
E-mail: David.Kosson@vanderbilt.edu

Dr. Florence Sanchez
Phone: (615) 322-5135
E-mail: Florence.Sanchez@vanderbilt.edu

Ms. Rossane Delapp
Phone: (615) 322-1064
E-mail: rossane.c.delapp@vanderbilt.edu

Eastern Research Group (ERG), Analytical Manager, Laura Van Enwyck: Ms. Van Enwyck will review and validate the hexavalent chromium and total chromium results generated by the ERG lab for the liquid leachate digest samples and report them to Mr. Kariher.

Phone (919) 468-7930
E-mail: Laura.VanEnwyck@erg.com

ARCADIS Project Manager, Johannes Lee: The ARCADIS Project Manager, Johannes Lee, has been assigned financial, contractual and managerial responsibilities for this work assignment. Mr. Lee will be responsible for communications with the EPA project officer, the oversight of financial status, and fulfilling contractual requirements.

Phone: (919) 544-4535
E-mail: johannes.lee@arcadis-us.com

ARCADIS Safety Officer, Jerry Revis: The ARCADIS Safety Officer, Jerry Revis, has been assigned the safety supervisor responsibilities for this work assignment. Mr. Revis will be responsible for reviewing safety plans, performing periodic safety inspections, communicating with the EPA safety office, and oversight of safety operations.

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E-mail: jerry.revis@arcadis-us.com

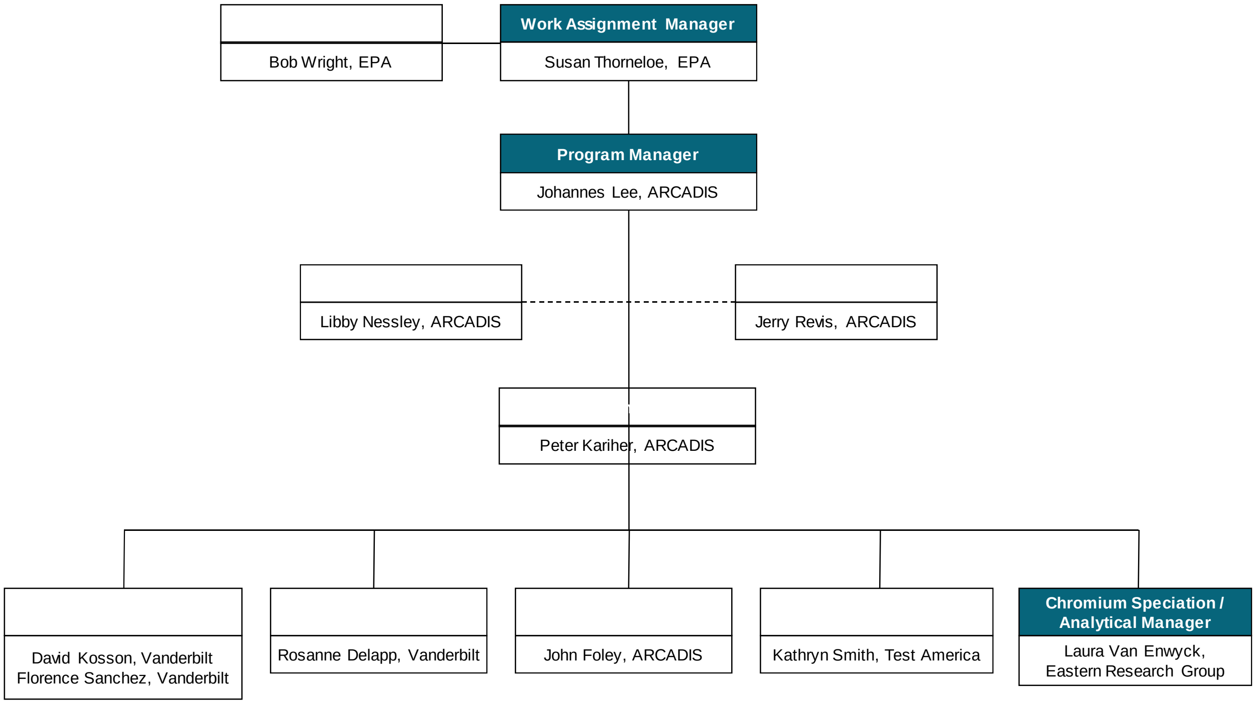

Figure 2-1. **Project Organizational Chart**

3. Experimental Approach

3.1 Task I: QAPP Development

The purpose of this task is to edit and modify the existing QAPP developed during WA 4-26 (EPA Contract # EP-C-04-023) to comply with the requirements of the NRMRL QA requirements and definitions and describe the most up to date record of analytical QA/QC activities.

3.2 Task II: Thermal Stability

This task covers the work to be performed to modify, edit, and complete the report on the thermal stability studies titled "Thermal Stability of Mercury and Other Metals in Coal Combustion Residues Used in the Production of Cement Clinker, Asphalt, and Wallboard". This report focuses on the determination of air emissions of Hg, As, Se, and Pb from the production of cement clinker, asphalt, and wallboard using CCRs.

3.3 Task III: Application of Leaching Framework to Evaluate Leaching Potential of Mercury-Enriched Coal Combustion Residues and Cement Kiln Dust

This task will investigate the fate of Hg, As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr during CCR management practice of land disposal. Using the recently proposed test methods developed by Kosson et al. in coordination with ORCR, leaching studies were first conducted on a reference fly ash. The reference fly ash is a high quantity fly ash that has been characterized by ICP/MS and CVAA analyses. The ICP/MS and CVAA analyses will be checked using the NIST SRM 1633b. NIST SRM 1633b is a bituminous coal fly ash that is fully described in Section 4.2.2. The results obtained from the reference fly ash leaching studies were used to evaluate the performance of the method. Using a known standard in place of the CCR material will also allow optimization of the proposed test methods. The quality control procedures regarding the reference fly ash tests are described in Section 6.0.

Two reports have been published to date. The first report titled, "Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control" (EPA, 2006a) studied the leaching behavior of fly ash with and without the use of mercury sorbents. The second report titled, "Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control" (EPA, 2008) reported the leaching behavior of fly ash, scrubber sludge, and FGD gypsum.

The third CCR report is currently being drafted and should be complete by the end of November 2009. This third report will supersede the first and second reports, and will report the leaching behaviors for over 70 materials evaluated using the new leaching procedures.

The fourth report will present a probabilistic assessment of beneficial use scenarios and provide groundwater model inputs to predict leaching behaviors of Hg and other metals from CCRs.

The group is has developed five leaching methods for consideration for inclusion into SW-846. These methods are currently in the ORCR analytical measurements group for review. These leaching methods are derived from published research procedures and methodologies (Kosson et al, 2002) used to evaluate potential leaching of solid waste through integration of results from a pH-dependence test, a liquid-to-solid ratio (L/S) test, a mass-transport leaching test, a column test, and an abbreviated pH-L/S test. Two of these methods to be used for the leach testing have are included in the appendix. Preliminary Version[1] of Method 1313 - Liquid-Solid Partitioning as a Function of Extract pH for Constituents in Solid Materials Using a Parallel Extraction Procedure is also referred to in this document as the SR002.1 testing. The Preliminary Version of Method 1316 - Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio for Constituents in Solid Materials Using a Parallel Batch Extraction Procedure is also referred in this document as the SR003.1 testing.

The group is also working on the development of a Decision Support Tool (DST) to view and report the data from our testing and allow users of the methods to input their information to compare with our samples. The DST will be important to modelers, regulators, state and local governments, and the risk assessment parties to understand how the leaching function can change due to varying conditions or application. This product is being produced in collaboration with Vanderbilt University and the Energy Research Centre of the Netherlands.

Estimates of the extent of release of the metals of concern during management scenarios that include percolation through the CCRs or infiltration flow around the CCRs (e.g., when compacted to low permeability or otherwise expected to behave as a monolithic material) will be determined. These data will be used to determine the risk of land disposal of the different CCRs. Mass balances for each metal will be determined using the chemical characterization data obtained in Task III to compare total content to CCR leachability. For some metals with higher solubilities, the total content may correlate to total release. Utilization of mass balance as a QA/QC tool is described in section 6. Details of this QA/QC procedure are outlined in section 6. In addition to testing of the CCRs as generated, CCRs as used in commercial products will be examined. Only commercial uses for which there is a potential for release of Hg during leaching will be considered. One commercial use of CCRs that may be of concern for Hg leaching is cement-based materials (i.e., concrete/grout, waste stabilization, road base/subbase). A generic cement-based product made from samples representative of the major coal fly ash categories will be examined. A second commercial use of CCRs that may be of concern is incorporation in gypsum board. In this case leaching of Hg after disposal is

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[1] Preliminary Version denotes that the associated method has not been endorsed by SW-846, but is under consideration for inclusion in SW-846. Preliminary methods have been submitted to USEPA Office of Resource Conservation and Recovery and are currently under review for development of interlaboratory validation studies to develop precision and bias information.

of concern. This task will consider the potential for Hg leaching after disposal from a representative gypsum board product.

A summary of materials for testing that will be carried out on the coal combustion residues is presented in Table 3-1.

Table 3-1. Summary of Materials for Testing under Task III to be Performed for Detailed Characterization of CCRs

Facility Code	Coal Rank	NO_X Control	Particulate Control	Lime or Mg Lime	Oxidation	Fly Ash	Spray Dryer Ash	Gyp-U	Gyp-W	Gyp + FA	SCS	FSS	FSSL	Filter Cake
Brayton Point	East-Bit	None	CS-ESP	None	None	BPB								
Brayton Point	East-Bit	None	ACI+CS-ESP	None	None	BPT								
Peasant Prairie	PRB	None	CS-ESP	None	None	PPB								
Peasant Prairie	PRB	None	ACI+CS-ESP	None	None	PPT								
Salem Harbor	Low sulfur East-Bit	SNCR	CS-ESP	None	None	SHB								
Salem Harbor	Low sulfur East-Bit	SNCR	ACI+ CS-ESP	None	None	SHT								
A	East-Bit	SNCR-BP (off)	Fabric Filter	Limestone	Natural	CFA					CGD	CCC		
A	East-Bit	SNCR (on)	Fabric Filter	Limestone	Natural	AFA					AGD	ACC		
B	East-Bit	SCR-BP (on)	CS-ESP	Mg Lime	Natural	BFA					BGD		BCC	
B	East-Bit	SCR (off)	CS-ESP	Mg Lime	Natural	DFA					DGD		DCC	
C	Low sulfur Bit	None	HS-ESP with COHPAC	None	None	GAB								
C	Low sulfur Bit	None	ACI + HS-ESP with COHPAC	None	None	GAT								
E	East-Bit	SCR (on and off)	CS-ESP	None	None	EFA EFB EFC								
F	Low sulfur Bit	None	CS-ESP	None	None	FFA								
G	Low sulfur Bit	SNCR on	CS-ESP	None	None	GFA								
H	High sulfur Bit	SCR	CS-ESP	Limestone	Forced	HFA								
J	Sub-Bit	None	CS-ESP	None	None	JAB								

Facility Code	Coal Rank	NO_X Control	Particulate Control	Lime or Mg Lime	Oxidation	Fly Ash	Spray Dryer Ash	Gyp-U	Gyp-W	Gyp + FA	SCS	FSS	FSSL	Filter Cake
J	Sub-Bit	None	Brominated ACI + CS-ESP	None	None	JAT								
K	Bituminous	SCR	CS-ESP	Mg Lime	Natural	KFA					KGD		KCC	
L	Southern Appalachian	SOFA	HS-ESP	None	None	LAB								
L	Southern Appalachian	SOFA	Brominated ACI + HS-ESP	None	None	LAT								
M	High sulfur Bit	SCR-BP (off)	CS-ESP	Limestone	Inhibited								MAD	
M	High Sulfur Bit	SCR (on)	CS-ESP	Limestone	Inhibited								MAS	
N	Bit	None	CS-ESP	Limestone	Forced			NAU	NAW					
O	Bit	SCR	CS-ESP	Limestone	Forced			OAU	OAW					
P	Bit	SCR & SNCR	CS-ESP	Limestone	Forced			PAD						
Q	Sub-Bit	None	HS-ESP	Limestone	Forced			QAU						
R	Sub-Bit PRB	None	CS-ESP	Wet Limestone	Forced			RAU						
S	High Sulfur Bit	SCR	CS-ESP	Limestone	Forced			SAU	SAW					
T	East-Bit Class F	SCR	CS-ESP	Lime	Forced	TFA		TAU	TAW					TFC
U	Low sulfur Bit	SCR	ESP	Limestone	Forced	UFA				UGF				
V	Sub-Bit PRB	SCR	Spray Dryer / Baghouse	slaked lime	None		VSD UAU							
W	East-Bit	SCR off	ESP	Limestone Trona	Forced	WFA		WAU	WAW					WFC
X	Sub-Bit PRB	SCR	ESP	Limestone	Forced	XFA		XAU	XAW					XFC
Y	Sub-Bit PRB	SCR before air preheater	Baghouse	Slaked Lime / Spray Dryer Adsorber	Natural		YSD							

Facility Code	Coal Rank	NO$_X$ Control	Particulate Control	Lime or Mg Lime	Oxidation	Fly Ash	Spray Dryer Ash	Gyp-U	Gyp-W	Gyp + FA	SCS	FSS	FSSL	Filter Cake
Z	Sub-Bit PRB	None	ESP	None	None	ZFA ZFB (totals only)								
Aa	East-Bit	SCR	ESP	Limestone	Forced	AaFA AaFB AaFC		AaAU	AaAW					
Ba	Sub-Bit PRB / Lignite		CS- ESP COHPAC baghouse Ammonia injection before the esp for flue gas conditioning	None	None	BaFA								
Ca	Gulf Coast Lignite	Low nox burner	CS ESP	Wet Limestone	Forced	CaFA			CaAW					
Da	East-Bit	SCR	ESP	Limestone	Forced	DaFA			DaAW					DaFC

ACI = activated carbon injection

CS-ESP = cold-side electrostatic precipitator

HS-ESP = hot-side electrostatic precipitator

SCR = selective catalytic reduction

SNCR = selective non-catalytic reduction

SOFA = secondary over-fired air

COHPAC = compact hybrid particulate collector

East-Bit = eastern bituminous

PRB = Powder River Basin

Gyp-U = unwashed gypsum

Gyp-W = washed gypsum

SCS = scrubber sludge

FSS = fixated scrubber sludge

FSSL = fixated scrubber sludge with lime

4. Sampling Procedures

The following subsections describe the sampling procedures to be used for each task. Whenever possible, standard methods will be followed. In some cases, draft methods may be evaluated and implemented. Each method to be used will be cited and any deviations from the methods will be documented.

4.1 Sample Custody Procedures

The following types of samples will be generated during these tests:

1. “As-received” CCR samples before and after application of Hg control technologies, SRM and reference fly ash samples (solid samples), and treated CCR samples as used in commercial applications. Part of the procedure is a coning and quartering to homogenize the sample well. A particle size reduction may also be performed is material size is greater than 2 cm. A plastic sieve with 2 cm square holes is attached to the coning and quartering apparatus to perform the particle size reduction.

2. Post –leaching and post-thermal desorption CCR, reference fly ash samples and treated CCR samples (solid samples)

3. Leachate samples (liquid samples) for Hg and other metals analysis

Each sample generated will be analyzed in-house or by outside laboratories and chain-of-custody procedures will be required. CCRs will be logged as they are received by the ARCADIS WAL, Mr. Peter Kariher. Information regarding where each CCR originated and any other descriptive information available will be recorded in a dedicated laboratory notebook by Mr. Kariher. A 200 g grab sample of the homogenized material will be taken from each “as-received” CCR and processed for physical and chemical characterization. All samples will be properly contained and identified with a unique sample ID and sample label. Sample labels at a minimum will contain the sample ID, date sampled, and initials of the analyst responsible for preparing the sample. Chain-of-custody forms will be generated for all samples prior to transfer for analysis.

Handling of CCR samples for the leaching tests (Task III) is described in detail by the leaching procedure provided by its developers. This procedure is included in Appendix A.

4.2 CCR, and Reference Fly Ash Samples

As mentioned, the focus of this program is to obtain information on the leachability and stability of Hg, As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr in CCRs. Chemical modifications are being implemented in wet scrubbers to enhance the Hg capture. The scrubber sludge from these facilities will be impacted by these new control technologies. The scrubber sludge samples from these facilities will be included in this test program.

The facility descriptions will include information on the history/origin of each CCR sample, facility process description, CCR type, sampling location, sampling time and method, coal type, operating condition, and sample storage condition. Section 4.1 describes the sampling custody procedure.

4.2.1 Physical and Chemical Characterization Samples

“As received” CCR will be well mixed prior to taking samples for physical characterization. Mixing of the sub-samples collected at the site will be done using a riffle splitter. To ensure a good homogeneity of the final composite sample that will be used for the study, the first two composite samples exiting the splitter will be reintroduced at the top of the splitter. This procedure should be repeated at least 6 times. At the end, the two resulting homogeneous composite samples will be combined in the same bucket and stored until laboratory testing. A 200 g representative sample will be taken from the homogenized “as received” CCR and subjected to physical characterization measurements. Samples will also be taken of any CCRs that undergo size-reduction techniques (if size reduction is needed for testing purposes). The reference fly ash samples will be processed in the same manner as the CCRs. They will be tracked by lot number and will not require size-reduction.

4.2.2 Leaching Study Samples

CCRs used for leaching studies may undergo size reduction to acquire an adequate sample for testing. The size reduction method is outlined in the leaching test methods (see Appendix A). If “as-received” CCRs are altered in any way prior to leaching studies, a representative sample will be submitted for physical and chemical characterization. SRM samples will not require size reduction. The NIST 1633B SRM is a bituminous coal fly ash that has been sieved through a nominal sieve opening of 90 μm and blended to assure homogeneity. The certified values for the constituent elements are given in Table 4-1. The reference fly ash will also be certified using ICP/MS and CVAA.

Table 4-1. NIST 1633B SRM Certified Values

Element	Concentration (mg/kg)
Arsenic	136.2 ± 2.6
Barium	709 ± 27
Cadmium	0.784 ± 0.006
Chromium	198.2 ± 4.7
Copper	112.8 ± 2.6
Lead	68.2 ± 1.1
Manganese	131.8 ± 1.7
Mercury	0.141 ± 0.019
Nickel	120.6 ± 1.8
Selenium	10.26 ± 0.17
Strontium	1041 ± 14
Thorium	25.7 ± 1.3
Uranium	8.79 ± 0.36
Vanadium	295.7 ± 3.6

4.3 Leachate Collection

The proposed test methods described in the publication titled *An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials* (Kosson et al., 2002a) will be used to conduct leaching studies. This publication along with the referenced procedures is provided in Appendix A. There are three tiers to this test method:

- Tier 1) Screening based assessment (availability)
- Tier 2) Equilibrium-based assessment over a range of pH and Liquid/solid (L/S) ratios
- Tier 3) Mass transfer based assessment

The Tier 1 screening test provides an indication of the maximum potential for release under the limits of anticipated environmental conditions expressed on a mg contaminant leached per kg waste basis. Tier 2 defines the release potential as a function of liquid-to-solid (L/S) ratio and pH. Tier 3 uses information on L/S equilibrium in conjunction with mass transfer rate information. As mentioned previously, prior to testing CCR, a reference fly ash will be used to demonstrate the effectiveness of the proposed test methods. Procedures for each tier are discussed in the following subsections.

If needed, prior to tier testing, the “as-received” CCR will be size reduced using the procedure PS001.1 Particle Size Reduction to minimize mass transfer rate limitation through larger particles. The pH will be then tested using the method pH001.0 pH Titration Pretest. These methods can be found in the Leaching Test Methods (Appendix A).

4.3.1 Tier 1 Screening Tests

Test Method AV002.1 Availability at pH 7.5 with EDTA (found in the Leaching Test Methods in Appendix A) will be used to perform the screening test. This method measures availability in relation to the release of anions at an endpoint pH of 7.5±0.5 and cations under enhanced liquid-phase solubility due to complexation with the chelating agent. Constituent availability is determined by a single challenge of an aliquot of the reference fly ash or size reduced CCR material to dilute acid or base in DI water with the chelating agent, ethylenediaminetetraacetic acid (EDTA). Extracts are tumbled end-over-end at 28±2 rpm at room temperature for a contact time of 24 hours. At the end of the 24-hour period, the leachate pH value of the extraction is measured. The retained extract is filtered through a 0.45 μm polypropylene filtration membrane and the sample is stored at 4°C until analysis.

The results from this test are used to determine the maximum quantity, or the fraction of the total constituent content, of inorganic constituents (Hg, As, Se, Pb, and Cd) in a solid matrix that potentially can be released from the solid material in the presence of a strong chelating agent. The chelated availability, or mobile fraction, can be considered (1) the thermodynamic driving force for mass transport through the solid material, or (2) the potential long-term constituent release. Also, a mass balance based on the total constituent concentration provides the fraction of a constituent that may be chemically bound, or immobile in geologically stable mineral phases.

4.3.2 Tier 2 Solubility and Release as a Function of pH and L/S Ratio

Test Method SR002.1 Alkalinity, Solubility and Release as a Function of pH is the method to be used for Tier 2 pH Screening. This procedure is included in the leaching test methods (Appendix A). The original protocol consisted of 11 parallel extractions of particle size reduced material at a liquid-to-solid ratio of 10 mL extractant per gram of dry sample. An acid or base addition schedule is formulated for 11 extracts with final solution pH values between 3 and 12, through addition of aliquots of HNO_3 or KOH as needed. The exact pH schedule is adjusted based on the nature of the CCR; however, the range of pH values must include the natural pH of the matrix, which may extend the pH domain. The extraction schedule and the range of tested pHs are outlined in the developers’ leaching test plan *Method 1313* - Liquid-Solid Partitioning as a Function of Extract pH for Constituents in Solid Materials Using a Parallel Extraction Procedure (see Appendix A).

This method was modified from the original 11 extracts to a more concise leaching procedure using the criteria found in Table 4-2. Replicates for the leach testing were also reduced to allow a greater number of samples to be analyzed after trends were seen in the first and second reports. The single replicate was due to resource constraints and availability of adequate replication in the remaining datasets to provide comparative interpretation.

To develop a more concise test than the 11 position SR002.1 test, a 9-point test was developed to provide leaching data for pH points of particular rationale. Table 4-2 presents the final pH points for the concise SR002.1 testing.

Table 4-2. Final Extract pH Targets

pH Target	Rationale
Will Vary*	Natural pH at LS 10 mL/g-dry (no acid/base addition)
2.0±0.5	Provides estimates of total or available COPC content
4.0±0.5	Lower pH limit of typical management scenario
5.5±0.5	Typical lower range of industrial waste landfills
7.0±0.5	Neutral pH region; high release of oxyanions
8.0±0.5	Endpoint pH of carbonated alkaline materials
9.0±0.5	Minimum of LSP curve for many cationic and amphoteric COPCs
12.0±0.5	Maximum in alkaline range for LSP curves of amphoteric COPCs
13.0±0.5	Upper bound (field conditions) for amphoteric COPCs
10.5±0.5	Substitution if natural pH falls within range of a mandatory target

*This is the pH of the material as received with only deionized water added (i.e., no acid or base addition).

If large particles are present in the CCR material, the material being evaluated is particle size reduced to 2 mm by sieving to remove any large pebbles present. A mortar and pestle may be used to break up clumps of material. A 40 g dry sample of the reference fly ash or size reduced CCR is used for these tests. Using the schedule, equivalents of acid or base are added to a combination of deionized water and the reference fly ash or particle size reduced CCR. The final liquid-to-solid (L/S) ratio is 10 mL extractant per gram of sample, which includes DI water, the added acid or base, and the amount of moisture that is inherent to the waste matrix as determined by moisture content analysis. The 11 extractions are tumbled in an end-over-end fashion at 28 rpm for a contact time of 24 hrs. Following gross separation of the solid and liquid phases by centrifuging for 15 minutes, leachate pH measurements are recorded and the phases are separated by pressure filtration through 0.45 μm polypropylene filtration membranes. Analytical samples of the leachates are collected and preserved as appropriate for chemical analysis. For metal analysis, leachates are preserved by acidification with HNO_3 to a pH <2 and stored at 4 °C until analysis. For anion analysis by IC, un-preserved leachates are stored at 4°C until analysis. Mercury samples are prepared with 87 mL of leachate, 3 mL of nitric, 5 mL of 5% KMnO4, and 5 mL of 10% hydroxylamine hydrochloride (NH_2OH HCl) to clear the solution before analysis.

Test method SR003.1 Solubility and Release as a Function of L/S Ratio is the method to be used for Tier 2 L/S ratio screening. This method is also referred to as the *Method 1316* - Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio for Constituents in Solid Materials Using a Parallel Batch Extraction Procedure is included in the leaching test methods (Appendix A). The protocol consists of five parallel batch extractions over a range of L/S ratios (0.5, 1, 2, 5, and 10 mL/g dry material) using the particle size reduced CCR and DI water as the extractant. Extractions are conducted at room temperature in leak-proof vessels that are tumbled at 28±2 rpm for 24 hours. Solid and liquid phases are separated by centrifuging for 15 minutes, and then pH and conductivity measurements are taken. The liquid is further separated by pressure filtration using a 0.45 μm polypropylene filter membrane. Leachates are collected for each of the 5 L/S ratios and preserved as appropriate for chemical analysis. For metal analysis, leachates are preserved by acidification with HNO_3 to a pH <2 and stored at 4 °C until analysis. For anion analysis by IC, leachates are stored at 4 °C until analysis. The change to single replicates was also changed for the SR003.1 sampling due to resource constraints and availability of adequate replication in the remaining datasets to provide comparative interpretation.

5. Testing and Measurement Protocols

Whenever possible, standard methods will be used to perform required measurements. Standard methods are cited in each applicable section. Where standard methods are not available, operating procedures will be written to describe activities. In situations where method development is ongoing, activities and method changes will be thoroughly documented in dedicated laboratory notebooks.

5.1 Physical Characterization

5.1.1 Surface Area and Pore Size Distribution

A Quantachrome Autosorb-1 C-M/S chemisorption mass-spectrometer Surface Area Analyzer will be used to perform Brunauer, Emmett, and Teller (BET) method surface area, pore volume, and pore size distribution analysis on each as-received and size reduced CCR. The BET will be operated according to ASTM Method D-6556-09 (ASTM 2009). A 200 mg sample is degassed at 200 °C for at least one hour in the sample preparation manifold. Samples are then moved to the analysis manifold, which has a known volume. Total gas volume in the analysis manifold and sample tube is calculated from the pressure change after release of an N_2 gas from the analysis manifold known volume. Report forms are automatically generated after each completed analysis. The instrument uses successive dosings of N_2 while measuring pressure. Standards of known surface area are run with each batch of samples as a QC check. Detailed instructions for the operation of this instrument are included in the Mercury Facility Manual.

5.1.2 pH and Conductivity

pH and conductivity will be measured on all aqueous extracts. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability is dependent upon the presence of ions; on their total concentration, mobility, and variance; and on the temperature of the measurement.

pH of the leachates will be measured using a combined pH electrode. A 2-point calibration will be done using National Institute of Science and Technology (NIST) traceable pH buffer solutions. The pH meter will be accurate and reproducible to 0.1 pH units with a range of 0 to 14.

Conductivity of the leachates will be measured using a standard conductivity probe. The conductivity probe will be calibrated using appropriate standard conductivity solutions for the conductivity range of concern. Conductivity meters are typically accurate to ±1% and have a precision of ±1%. The procedure to measure pH and conductivity will be as follows:

Following a gross separation of the solid and liquid phases by centrifugation or settling, a minimum volume of the supernatant to measure the solution pH and conductivity will be taken and poured in a test tube. The remaining liquid will be separated by pressure filtration and filtrates will be appropriately labeled, preserved, and stored for subsequent chemical analysis.

5.1.3 Moisture Content and Loss on Ignition (LOI)

Moisture content of the “as received” CCR, the reference fly ash and SRM samples will be determined using ASTM D 2216-05 (ASTM 2005). This procedure supersedes the method indicated in the leaching procedure (see Appendix A). This method, however, is not applicable to the materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water), since this material slowly dehydrates at the standard drying temperature (110°C). This slow dehydration results in the formation of another compound (calcium sulfate hemihydrate) which is not normally present in natural material. The ASTM method allows cooling at 60 °C to prevent the conversion and will be used to determine the moisture content of materials containing gypsum.

Loss on ignition (LOI) is performed by placing dried samples in a furnace at 750 °C for 1 hour and measuring the mass lost during the combustion using ASTM D7348-08 (ASTM 2008).

5.2 Chemical Characterization

5.2.1 Dissolved Organic Carbon / Dissolved Inorganic Carbon (DOC/DIC) and Elemental Carbon / Organic Carbon (EC/OC)

Analyses of total dissolved organic carbon and dissolved inorganic carbon are performed on a Shimadzu model TOC-V CPH/CPN combustion catalytic oxidation NDIR analyzer. Five-point calibration curves, for both inorganic (IC) and non-purgeable organic carbon (NPOC) analyses, are generated for an analytical range between 5 ppm and 100 ppm and are accepted with a correlation coefficient of at least 0.995. Reagent grade potassium hydrogen phthalate is used as the NPOC standard and sodium hydrogen carbonate is used as the IC standard. An analytical blank and check standard at approximately 10 ppm are run every 10 samples. The standard is required to be within 15% of the specified value. A new calibration curve is generated if the check standard measurement does not meet specification. A volume of approximately 16 mL of undiluted sample is loaded for analysis. Inorganic carbon analysis is performed first for the analytical blank and standard and then the samples. Total carbon (non-purgeable organic carbon) analysis follows with addition of 2M hydrochloric acid to a pH of 2 and a sparge gas flow rate of 50 mL/min. Method detection limit (MDL) and minimum level of quantification (MLQ) are shown in Table 5-1.

Table 5-1. MDL and MLQ of Total Organic Carbon Analyzer

	MDL (ppm)	MLQ (ppm)
IC	0.07	0.20
NPOC	0.09	0.20

Elemental carbon and organic carbon are determined using a Sunset Laboratory Carbon Aerosol Analysis Lab Instrument in EPA RTP Laboratory E-581A. This method is defined in NIOSH Method 5040 (CDC 2003). This equipment uses a furnace to heat the sample and combust the carbon to carbon dioxide. The carbon dioxide is reduced to methane and a FID is used to quantify the carbon emitted as the sample is heated from ambient to 870 °C over four heating steps. Samples are prepared by weighing 3 grams of the CCR into a 500 mL Nalgene high-density polyethylene bottle. A 37 mm tarred pre-baked quartz filter is loaded into a 2.5 µm particulate sampler and attached to the bottle. The particulate sampler is connected to a vacuum source and a rotometer to control the flow at 4 liters per minute. The CCR material is aspirated onto the quartz filter for 5 minutes and the filter is reweighed to determine the mass loading. Duplicate filters are prepared for each material. Three analyses are performed on each filter. Blank filters are provided to determine background levels.

5.2.2 Mercury (CVAA)

Mercury analysis of each extract and leachate will be carried out by Cold Vapor Atomic Absorption (CVAA) Spectrometry according to EPA SW-846 Method 7470A Mercury in Liquid Waste (EPA 1994). Samples are treated with potassium permanganate to reduce possible sulfide interferences. A Perkin Elmer FIMS 100 Flow Injection Mercury System is the instrument to be used for this analysis. The instrument is calibrated with known standards ranging from 0.25 to 10 μg/L mercury. The detection limit for mercury in aqueous samples is 0.05 μg/L.

5.2.3 Mercury by Thermal Decomposition and Cold Vapor Atomic Adsorption (TD-CVAA) Method 7473

Mercury analysis of the solid materials will be carried out by thermal decomposition cold vapor atomic adsorption (TC/CVAA) according the EPA SW-846 Method 7473 (EPA 1998).

The Lumex RA-915+ Mercury Analyzer is a portable instrument capable of measuring mercury concentrations in air, liquids, and solids. Developed for use by the Russian Navy to detect elemental mercury leaks on submarines (mercury is used as ballast), the analyzer is capable of measuring 1 ng/m3. The instrument contains an internal sample pump, multi-pass optical cell and Zeeman Effect atomic adsorption detector tuned to a wavelength of 253.7 nm for the detection of mercury. The Zeeman effect atomic adsorption (AA) detector modulates the frequency of the source to eliminate matrix effects from air samples and enhance the detector sensitivity for mercury. An optional RP-91C high temperature (>750 °C) furnace can be used to convert any mercury species to elemental mercury for post combustion detection of total mercury in the solids. Since the detector can only measure elemental mercury directly, this technique is based on the thermal decomposition properties of mercury, as only elemental mercury can exist at these high temperatures. Under high temperatures, any oxidized mercury compounds are converted to elemental mercury.

To perform a mercury analysis on a solid sample, the solid of known mass is weighed into a quartz or stainless steel combustion boat. The combustion boat is then inserted into the furnace combustion chamber and as the elemental mercury is evolved from the sample, the detector measures the mass of mercury. The mass of mercury is directly proportional to the area under the peak, similar to the quantitation principle used in gas chromatography. By dividing the mass of mercury by the mass of sample introduced to the instrument, a mercury concentration can be derived. For wet samples, a moisture measurement of the solid must be determined to correct the mercury content to a dry basis.

5.2.4 Other Metals (ICP)

Analysis for As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr will be performed on a ICP-MS using EPA SW-846 Method 6020A (EPA 2007d). Metals and estimated instrument detection limits are listed in the method. The ICP will be profiled and calibrated for the target compounds and specific instrument detection limits will be determined. Mixed calibration standards will be prepared at least 5 levels. Each target compound will also be analyzed separately to determine possible spectral interference or the presence of impurities. Two types of blanks will be run with each batch of samples. A calibration blank is used to establish the analytical curve and the method blank is used to identify possible contamination from varying amounts of the acids used in the sample processing. Additional daily QC checks include an Initial Calibration Verification (ICV) and a Continuing Calibration Verification (CCV). The ICV is prepared by combining target elements from a standard source different than that of the calibration standard and at a concentration within the linear working range of the instrument. The CCV is prepared in the same acid matrix using the same standards used for calibration at a concentration near the mid-point of the calibration curve. A calibration blank and a CCV or ICV are analyzed after every tenth sample and at the end of each batch of samples. The CCV and ICV results must verify that the instrument is within 10% of the initial calibration with an RSD < 5% from replicate integrations. Procedures to incorporate the analysis of a MS/MSD for these CCR samples will be evaluated.

These analyses will be performed at two different ICP-MS facilities. The first facility is Test America Laboratories in Savannah, Ga. This laboratory uses an Agilent ICP-MS with octopole reaction system (ORS) and will measure the metal species for the total content. The second facility is Vanderbilt University (Department of Civil and Environmental Engineering). This laboratory uses a Perkin Elmer model ELAN DRC II or a Varian inductively couple plasma optical emission spectroscopy (ICP-OES). Vanderbilt

University is responsible for measuring the metals content in the leachates. Standard analysis mode is used for Pb and DRC mode is used for analysis of As and Se.

5.2.4.1 ICP-OES Analyses

Analysis of the inductively coupled plasma optical emission spectroscopy (ICP-OES) aqueous samples by SW-846 Method 6010A (EPA 2007c) from laboratory leaching tests will be carried out at Vanderbilt University (Department of Civil and Environmental Engineering) using a Varian ICP Model 720-ES. Five-point standard curves will be used for an analytical range between approximately 0.1 mg/L and 25 mg/L for trace metals. Seven-point standard curves will be used for an analytical range between approximately 0.1 mg/L and 500 mg/L for minerals. Analytical blanks and analytical check standards at approximately 0.5 mg/L will be run every 10 to 20 samples and required to be within 15% of the specified value. Initially, analyses were performed on undiluted samples to minimize total dissolved loading to the instrument. If the maximum calibration is exceeded, samples for analysis will be diluted gravimetrically to within the targeted analytical range using 1% v/v Optima grade nitric acid (Fisher Scientific). Yttrium at 10 mg/L will be used as the internal standard. Analytical matrix spikes will be completed for three test positions from one of the replicate extracts from SR002.1. For each analytical matrix spike, a volume of 500 µL of a 10 mg/L standard solution will be added to 5 mL of sample aliquot. Table 5-2 provides the method detection limit (MDL) and minimum level of quantification (ML) for each element to be analyzed. Analyte concentrations measured that are less than the ML and greater than the MDL will be reported as estimated value using the instrument response. Table 5-3 indicates the switch from ICP-MS to ICP-OES for specific elements and samples.

Table 5-2. Method Detection Limits (MDLs) and Minimum Level of Quantification (ML) for ICP-OES Analysis on Liquid Samples*

Symbol	Units	MDL	ML
Al	µg/L	1.00	3.18
Sb	µg/L	8.00	25.4
As	µg/L	15.0	47.7
Ba	µg/L	1.00	3.18
Be	µg/L	5.00	15.9
B	µg/L	1.00	3.18
Cd	µg/L	6.00	19.1
Ca	µg/L	3.50	11.1
Cr	µg/L	1.00	3.18
Co	µg/L	1.00	3.18
Cu	µg/L	4.1	13.0
Fe	µg/L	2.90	9.22
Pb	µg/L	7.00	22.3
Li	µg/L	6.00	19.1
Mg	µg/L	1.00	3.18
Mn	µg/L	3.60	11.4
Mo	µg/L	1.00	3.18
Ni	µg/L	2.20	7.00
K	µg/L	1.50	4.77
P	µg/L	6.2	19.7
Se	µg/L	17.0	54.1
Si	µg/L	2.80	8.90
Ag	µg/L	18.00	57.2
Na	µg/L	3.50	11.1
Sr	µg/L	1.00	3.18
S	µg/L	8.30	26.4
Tl	µg/L	5.00	15.9
Sn	µg/L	17.0	54.1
Ti	µg/L	6.40	20.3
V	µg/L	1.30	4.13
Zn	µg/L	2.50	7.95
Zr	µg/L	2.70	8.59

* All elements indicated in Table 5.2 will be analyzed, however, only elements indicated in bold are reported as part of the leaching studies. The elements that were included in the leaching studies were selected based on input from EPA program offices due to potential concern for human health and the environment.

Table 5-3. ICP Instrument Used for Each Element*

Symbol	Instrument	Used	Switch Date
Al		ICP-OES	Report 3 Samples
Sb	ICP-MS	ICP-OES*	Only SR3 Rpt 1 Samples*
As	ICP-MS		
Ba	ICP-MS		
Be	ICP-MS		
B		ICP-OES	Report 1 and 3 Samples
Cd	ICP-MS		
Ca		ICP-OES	Report 3 Samples
Cr	ICP-MS		
Co	ICP-MS		
Cu	ICP-MS		
Fe		ICP-OES	Report 3 Samples
Pb	ICP-MS		
Mg		ICP-OES	Report 3 Samples
Mn	ICP-MS		
Mo	ICP-MS	ICP-OES*	Only Rpt 1 Samples*
Ni	ICP-MS		
K		ICP-OES	Report 3 Samples
Re	ICP-MS		
Se	ICP-MS		
Si		ICP-OES	Report 3 Samples
Na		ICP-OES	Report 3 Samples
Sr		ICP-OES	Report 3 Samples
Tl	ICP-MS	ICP-OES*	Only SR3 Rpt 1 Samples*
Sn	ICP-MS		
Ti		ICP-OES	Report 3 Samples
U	ICP-MS		
V	ICP-MS		
Zn	ICP-MS		

* Report 3 samples will be analyzed on the ICP-OES for the indicated elements. These elements would require multiple dilutions on the ICP-MS. Measurements for the same elements on Facility T samples (TFA, TFC, TAW, and TAU) were also completed on the ICP-MS for comparison. Results were within 15% for concentrations above 100 µg/L and within 25% for concentrations below 100 µg/L. Bold-faced elements are metals that are included in the leaching studies.

5.2.4.2 ICP-MS Analyses

ICP-MS analyses by SW-846 Method 6020A (EPA 2007d) of aqueous samples from laboratory leaching tests will be carried out at Vanderbilt University (Department of Civil and Environmental Engineering) using a Perkin Elmer model ELAN DRC II in both standard and dynamic reaction chamber (DRC) modes. Standard chamber analysis mode will be used for all analytes except for As and Se, which are run in DRC mode with 0.5 mL/min of oxygen as the reaction gas. Seven-point standard curves will be analyzed with an analytical range between approximately 0.5 µg/L and 500 µg/L and will be completed before each analysis. Analytical blanks and analytical check standards at approximately 50 µg/L will be run every 10 to 20 samples and required to be within 15% of the specified value. Samples for analysis will be diluted gravimetrically to within the targeted analytical range using 1% v/v Optima grade nitric acid (Fisher Scientific). Initially, analyses for 10:1 dilutions will be performed to minimize total dissolved loading to the instrument. Additional dilutions at 100:1 and 1000:1 will be analyzed if the calibration range is exceeded with the 10:1 dilution. 50 µL of a 10 mg/L internal standard consisting of indium (In) (for mass range below 150) and bismuth (Bi) (for mass range over 150) will be added to 10 mL of sample aliquot prior to analysis. Analytical matrix spikes will be completed for one of each of the replicate extracts from SR002.1. For each analytical matrix spike, a volume between 10 µL and 100 µL of a 10 mg/L standard solution will be added to 10 mL of sample aliquot. Table 5-4 provides the element to be analyzed, method detection limit (MDL) and minimum level of quantification (ML). Analyte concentrations measured that are less than the ML and greater than the MDL are reported as estimated value using the instrument response. The values will reflect the initial 10:1 dilution used for samples from laboratory leaching tests.

Table 5-4. Method Detection Limits (MDLs) and Minimum Level of Quantification (ML) for ICP-MS Analysis on Liquid Samples*

Symbol	Units	MDL	ML
Al	µg/L	0.96	3.06
Sb	µg/L	0.08	0.25
As	µg/L	0.64	2.04
Ba	µg/L	0.57	1.82
Be	µg/L	0.64	2.03
B	µg/L	0.65	2.06
Cd	µg/L	0.17	0.54
Ca	µg/L	1.02	3.24
Cr	µg/L	0.50	1.58
Co	µg/L	0.41	1.32
Cu	µg/L	0.70	2.23
Fe	µg/L	0.94	3.00
Pb	µg/L	0.23	0.73
Mg	µg/L	0.57	1.83
Mn	µg/L	0.34	1.09
Mo	µg/L	0.76	2.41
Ni	µg/L	0.73	2.31
K	µg/L	1.38	4.38
Re	µg/L	0.24	0.77
Se	µg/L	0.52	1.65
Si	µg/L	1.56	4.97
Na	µg/L	0.74	2.35
Sr	µg/L	0.52	1.66
Tl	µg/L	0.51	1.61
Sn	µg/L	0.70	2.22
Ti	µg/L	0.52	1.66
U	µg/L	0.30	0.95
V	µg/L	0.31	0.98
Zn	µg/L	0.92	2.94
Zr	µg/L	0.47	1.48

* All elements indicated in Table 5-4 will be analyzed. However, only elements indicated in bold are reported as part of the leaching studies. The elements that were included in the leaching studies were selected based on input from EPA program offices due to potential concern for human health and the environment.

5.2.5 Anions Analysis by IC

Aqueous concentrations of anions (fluoride, chloride, nitrate, sulfate, sulfides, carbonate and phosphate) will be determined using ion chromatography (IC). Standard USEPA guideline SW-846 Method 9056A (EPA 2007b) will be used. These analyses are performed using a Dionex HPLC system and a conductivity detector. Equipment used in the instrument includes an ATC-3 anion trap column, AS-11G 4-mm guard column, and a AS-11 analytical column. The system uses a sodium hydroxide gradient elution at 1 mL/min to resolve the peaks.

5.2.6 X-Ray Fluorescence (XRF) and Neutron Activation Analysis (NAA)

X-Ray Fluorescence Spectrometry is used in the USEPA RTP, NC laboratories to analyze these samples for the determination of total content for the major elements. A Philips model PW 2404 wavelength dispersive instrument, equipped with a PW 2540 VRC sample changer, is used for these analyses. The manufacturer’s software suite, “SuperQ”, is used to operate the instrument, collect the data, and perform quantification.

The instrument was calibrated using a manufacturer-supplied set of calibration standards at the time of installation of the software plus a new X-ray tube. On a monthly basis, manufacturer-supplied drift correction standards are used to create an updated drift correction factor for each potential analytical line. On a monthly basis, a dedicated suite of QC samples are analyzed before and after the drift correction procedure. This data is used to update and maintain the instrument’s QC charts. This has been described in previous memos.

The software suite’s “Measure and Analyze” program collects and stores the sample data. This program has two basic modes of operation, “scan” and “channels”. The scan mode is used to collect the bulk of the data. It operates in a stepwise scanning mode and uses the manufacturer supplied “IQ+” program to define operating parameters. IQ+ scans the available wavelength range using a series of 10 sub-scans that vary in terms of detector, radiant power, collimator crystal, and wavelength. While the instrument incorporates a sample rotation capability, this is not used by IQ+ since the time spent at any one wavelength is only a fraction of the pellet rotation time.

The channel mode is typically reserved for trace work. In this mode, the instrument moves to a specific wavelength and goniometer position and collects data for defined periods of time. These data collection periods are typically long enough to make use of the sample rotation function worth while. Other instrument operation parameters, such as tube power and crystal, are taken from the scan function parameters. The data collected in the channel mode is then incorporated into the sample’s data file. The intent is to improve detection limits for certain trace elements that are often of interest at a small cost in analytical time.

Quantification is performed post-data collection using the program, “IQ+”. IQ+ is a “first principles” quantification program that includes complex calculations to account for a wide variety of sample-specific parameters. For this reason, sample-specific calibrations are not necessary. This program calculates both peak heights and baseline values. The difference is then used, after adjustment by drift correction factors, for elemental quantification versus the calibration data. Interelement effects are possible and the software includes a library of such parameters. Data from secondary lines may be used for quantification where interelement effects are significant or the primary peak is overloading the DAQ. Where the difference between the calculated peak height and baseline are of low quality, the program will not identify a peak and will not report results. IQ+ permits the inclusion of data from other sources by manual entry. Carbon is an example of this for these samples. Entry of other source data for elements indeterminable by XRF improves the mass balance.

Neutron activation analysis (NAA) is an established analytical technique with elemental analysis applications. This method will be used to confirm the presence of hexavalent chromium species in the CCR solids. NAA is different from AA or inductively coupled plasma mass spectrometry (ICP-MS) because it is based on nuclear instead of electronic properties. Neutron activation analysis is a sensitive multi-element analytical method for the accurate and precise determination of elemental concentrations in unknown materials. Sensitivities are sufficient to measure certain elements at the nanogram level and below, although the method is well suited for the determination of major and minor elemental components as well. The method is based on the detection and measurement of characteristic gamma rays emitted from radioactive isotopes produced in the sample upon irradiation with neutrons. Depending on the source of the neutrons, their energies and the treatment of the samples, the technique takes on several differing forms. It is generally referred to as INAA (instrumental neutron activation analysis) for the purely instrumental version of the technique. RNAA (radiochemical neutron activation analysis) is the acronym used if radiochemistry is used to separate the isotope of interest before counting. FNAA (fast neutron activation analysis) is the form of the technique if higher energy neutrons, usually from an accelerator based neutron generator, are used.

5.2.7 XRF Detection Limits

Table 5-5 presents detection limit data in two forms, which are not mutually exclusive. The reporting limit is built into the software and reflects the manufacturer’s willingness to report low-level data. Data listed under “detection limit” are based upon the short-term reproducibility of replicate analyses and are sample matrix specific. These calculations are likely to report higher detection limits for macro elements than what would be calculated where the same element is present at trace levels. In this data set, calcium is a likely example of this.

Table 5-5. XRF Reporting and Detection Limits

Analyte	Reporting Limit, µg/g	Detection Limit %, 2σ (wt. %)
Al	20	0.016
As	20	0.038
Ba	20	0.0084
Br	20	0.02
Ca	20	0.1
Cd	20	0.064
Ce	20	0.022
Cl	20	0.0046
Co	20	0.0024
Cr	20	0.0028
Cu	20	0.0014
F	20	0.082
Fe	20	0.034
Ga	20	0.0016
Ge	20	0.0014
K	20	0.0048
La	20	0.0054
Mg	20	0.01
Mn	20	0.0032
Mo	20	0.0026
Na	20	0.0076
Nb	20	0.0018
Ni	20	0.0048
Pb	20	0.0034
Px	20	0.004
Rb	20	0.0016
Sc	20	0.0016
Se	20	0.0018
Si	20	0.092
Sr	20	0.0016
Sx	20	0.05
Ti	20	0.003
V	20	0.0038
W	20	0.0036
Y	20	0.0018
Zn	20	0.0014
Zr	20	0.0024

5.2.8 Hexavalent Chromium Determination in CCR Extracts

Fly ash samples will be leached at three different pH values in duplicate using the SR002.1 leaching procedure for the determination of hexavalent (Cr^{6+}) and total chromium concentrations. The pH target values for the leachates are defined as 7-7.5, 10.5-11, and the natural CCR pH. The extracts will be split into three samples for analysis by Eastern Research Group (ERG) and Vanderbilt University. ERG will receive one unpreserved and one nitric acid preserved sample. Vanderbilt University will receive one nitric acid preserved sample. Samples will be preserved by adding 97 mL of leachate with 3 mL concentrated nitric acid.

Hexavalent chromium concentrations of the un-preserved CCR leachate extracts will be determined using ion-chromatography. This procedure was modified from the EPA Urban Air Toxics Monitoring Programs (UATMP) Hexavalent Chromium method developed by Eastern Research Group (ERG), Research Triangle Park NC, for the determination of Cr^{6+} in air by analyzing the liquid extracts from sodium bicarbonate impregnated cellulose filters using SOPs developed for the UATMP (EPA 2007a). The analytical system uses a ion chromatography with a guard column, an analytical column, a post-column deriviatization module, and a UV/VIS detector. In the analysis procedure, Cr^{6+} exists as chromate due to the near neutral pH of the eluent. After separation through the column, the Cr^{6+} complexes with 1,5-diphenylcarbohydrazide (DPC) to allow detection at 530 nm (EPA, 2006b). This method had a reporting limit (RL) of 0.03 ng/mL in liquids.

The total chromium species for the nitric acid preserved samples will be analyzed by ERG and Vanderbilt University using inductively-coupled plasma / mass spectroscopy (ICP/MS) found in SW-846 Method 6020A (2007d).

6. QA/QC Checks

6.1 Data Quality Indicator Goals

Data quality indicator goals for critical measurements in terms of accuracy, precision and completeness are shown in Table 6-1.

Table 6-1. Data Quality Indicator Goals

Measurement	Method	Accuracy	Precision	Completeness
As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr Concentration	ICP-MS/6020	10%	10%	>90%
Hg Concentration	CVAA/7470A/7473	10%	10%	>90%
Anions, Sulfate, Carbonates, Chlorides	IC/SW-846 9056A	10%	10%	>90%
pH, conductivity, ORP	Electrode	2%	2%	100%
Carbon Content	DIC/DOC EC/OC	10%	10%	>90%
Surface Area BET	ASTM D6556-09	5%	5%	>90%
Loss on Ignition (LOI)	ASTM D7348-08	2%	2%	100%
Moisture	ASTM D2216-05	1%	10%	100%

Accuracy will be determined by calculating the percent bias from a known standard. Precision will be calculated as relative percent difference (RPD) between duplicate values and relative standard deviation (RSD) for parameters that have more than two replicates. Completeness is defined as the percentage of measurements that meet DQI goals of the total number measurements taken.

Mass balance calculations will also be used as a data quality indicator for total content determination and for thermal stability testing. Different mass balance recovery methods will be examined. The reference fly ash sample will be used to develop and validate an appropriate mass balance recovery method. Mass balance will be determined by using the metals concentrations determined by analysis of the “as-received” reference fly ash as the total. Results from successive leaching samples and analysis of any solid residues will be combined to determine recoveries.

One approach that will be considered is the use of either total digestion (Method 3052B) or Neutron Activation Analysis (NAA) for the analysis of solid residues.

The mass balance recovery will only be performed on 3 pH points and one low L/S ratio. Uncertainty analysis will be considered for each mass balance. The selection of the target pH values will be dependent on the natural pH of the material. If the natural pH is <5, then natural pH, 7 and 9 will be selected as the target pH values. If the natural pH ranges between 5 and 9, then 5, 7 and 9 will be selected as the target pH values, and if the natural pH is >9, then 5, 7 and natural pH will selected as the target pH values. In addition, an extraction at the natural pH of the material and an L/S ratio of 1mL/g will be carried out. At least 4 replicates per extract will be run. In the case where the mass balance will be performed using total digestion or NAA, at least 3 representative samples per residue will be analyzed.

6.2 QC Sample Types

Types of QC samples used in this project will include blanks, spiked samples, replicates, and mass balance tests on the reference fly ash and the SRM. For physical characterization testing, duplicate samples of the CCR, reference fly ash and SRM will be processed through each analysis. Duplicates must agree within ±10% to be considered acceptable. For the leaching studies, an objective of this project is to determine the appropriate types of QC samples to incorporate in the proposed leaching methods. This will be accomplished by subjecting the reference fly ash to the leaching procedure and determining the metals' mass balances by analyzing the leaching solution and the post-leachate solids. Initially, mass balances of 70-130% will be considered as an acceptable QC of the leaching procedure. Further statistical analysis on available data will be performed to narrow down the range of acceptable mass balances. This method development will be thoroughly documented in a dedicated laboratory notebook. Leaching of the reference fly ash samples may also be used as method controls during testing of CCR samples. For the fixed-bed reactor testing, one in every five tests will be run in duplicate. Duplicate results from the reactor testing are expected to agree within 20% to be considered valid. Identical to the leaching procedure, the use of the reference fly ash as a baseline QC sample will also be implemented during TPD tests (initial mass balances of 70-130%). Required QC samples for metals and mercury sampling trains are detailed in EPA Method 29 (EPA 1996c) and the Ontario Hydro Methods (ASTM 2002). QC samples required for ICP, CVAA, IC analysis are detailed in SW-846 Methods 6020A (EPA 2007d), 7470A (EPA 1994), and 9056A (EPA 2007b) respectively.

7. Data Reduction, Validation, and Reporting

Chemical (ICP, CVAA, TGA, XRF, IC, NAA) and physical (surface area, pore size distribution and density) characterization data are reduced and reports are generated automatically by the instrument software. The primary analyst will review 100% of the report for completeness and to ensure that quality control checks meet established criteria. If QC checks do not meet acceptance criteria, sample analysis must be repeated. A secondary review will be performed by the Inorganic Laboratory Manager to validate the analytical report. If appropriate, certain chemical characterization data will be compared to the XRF and NAA analyses. In addition, the designated QA Officer will review at least 10% of the raw data for completeness. Analytical data will be summarized in periodic reports to the ARCADIS WAL. The procedures for reduction, validation and reporting of the leaching experiments (Task III) are outlined in Appendix A. ARCADIS WAL is responsible for the implementation of these procedures. ARCADIS and Vanderbilt University will be responsible for publishing results and reports. QA/QC activities will be mentioned in any published materials. A data quality report will be provided in the final report of this investigation.

Data generated for the leachate analysis and total composition are entered into a standard Excel spreadsheet to ease uploading into the Vanderbilt metals database from the ICP-MS and other analyses. This data along with QA/QC information can be viewed using the “LeachXS Lite” software program developed by Vanderbilt University and the Energy Research Centre of the Netherlands. This software tool will allow future users to view the metals leaching information based on sample type, facility configuration, or CCR coal type. This data viewer and database program will be available to the public on-line when complete.

8. Assessments

Assessments and audits are an integral part of a quality system. This project is assigned a QA Category III and, while desirable, does not require planned technical systems and performance evaluation audits. EPA will determine external or third-party audit activities. Internal assessments will be performed by project personnel to ensure acquired data meet data quality indicator goals established in Section 6.

There are currently no planned performance evaluation audits but Table 8-1 lists the measurement parameters and expected ranges should EPA determine a PEA should be provided.

Table 8-1. PEA Parameters and Ranges

Analyte or Measurement	Method	Expected Range
As, Se, Pb, Cd, Co, Al, Ba, B, Mo, Sb, Tl, and Cr	ICP-MS/3052/6020A	1-100 µg/mL
Hg	CVAA/7470A	0.25 to 10 ug/L
pH	Electrode	0-14

In addition to the internal TSA, the ARCADIS Designated QA Officer will perform an internal data quality audit on at least 10% of the reported data. Reported results will be verified by performing calculations using raw data and information recorded in laboratory notebooks.

9. Appendices

Vanderbilt Leaching Procedures

PRELIMINARY VERSION[2] OF METHOD 1313

LIQUID-SOLID PARTITIONING AS A FUNCTION OF EXTRACT pH FOR CONSTITUENTS IN SOLID MATERIALS USING A PARALLEL BATCH EXTRACTION

SW-846 is not intended to be an analytical training manual. Therefore, method procedures are written based on the assumption that they will be performed by analysts who are formally trained in at least the basic principles of chemical analysis and in the use of the subject technology.

In addition, SW-846 methods, with the exception of required method use for the analysis of method-defined parameters, are intended to be guidance methods which contain general information on how to perform an analytical procedure or technique which a laboratory can use as a basic starting point for generating its own detailed Standard Operating Procedure (SOP), either for its own general use or for a specific project application. The performance data included in this method are for guidance purposes only, and are not intended to be and must not be used as absolute quality control (QC) acceptance criteria for purposes of laboratory accreditation.

1.0 SCOPE AND APPLICATION

1.1 This method is designed to provide aqueous extracts representing the liquid-solid partitioning (LSP) curve as a function of pH for inorganic constituents (e.g., metals and radionuclides), semi-volatile organic constituents (e.g., polycyclic aromatic hydrocarbons or PAHs) and non-volatile organic constituents (e.g., dissolved organic carbon) in solid materials. The LSP curve is evaluated as a function of final extract pH at a liquid-to-solid (LS) ratio of 10 mL extractant/g dry sample (g-dry) and conditions that approach liquid-solid chemical equilibrium. This method also yields the acid/base titration and buffering capacity of the tested material at an LS ratio of 10 mL extractant/g-dry sample. The analysis of extracts for dissolved organic carbon and the solid phase for total organic carbon allow for the evaluation of the impact of organic carbon release and the influence of dissolved organic carbon on the LSP of inorganic constituents.

1.2 This method is intended to be used as part of an environmental leaching assessment for the evaluation of disposal, beneficial use, treatment effectiveness and site remediation options.

1.3 This method is suitable for a wide range of solid materials. Examples of solid materials include: industrial wastes, soils, sludges, combustion residues, sediments, stabilized materials, construction materials, and mining wastes.

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[2] Preliminary Version denotes that this method has not been endorsed by EPA but is under consideration for inclusion into SW-846. This method has been derived from published procedures (Kosson et al, 2002) using reviewed and accepted methodologies (USEPA 2006, 2008, 2009). The method has been submitted to the USEPA Office of Resource Conservation and Recovery and is currently under review for development of interlaboratory validation studies to develop precision and bias information.

1.4 This method is a leaching characterization method that is used to provide values for intrinsic material parameters that control leaching of inorganic and some organic species under equilibrium conditions. This test method is intended as a means for obtaining a series of extracts of a solid material (i.e., the eluates), which may be used to estimate the LSP (e.g., solubility and release) of constituents as a function of pH under the laboratory conditions described in the method. Eluate constituent concentrations may be used in conjunction with information regarding environmental management scenarios to estimate the anticipated leaching concentrations, release rate and extent for individual material constituents under the management c evaluated. Eluate constituent concentrations generated by this method may also be used along with geochemical speciation modeling to infer the mineral phases that control the LSP in the pore structure of the solid material.

1.5 This method is not applicable for characterizing the release of volatile organic analytes (e.g., benzene, toluene, xylenes).

1.6 The relationships between eluate concentrations observed from this method and field leachate must be considered in the context of the material being tested and the field scenario being evaluated. This method provides solutions considered indicative of eluate under field conditions, only where the field leaching pH is the same as the final laboratory extract pH and the LSP is controlled by aqueous phase saturation of the constituent of interest.

1.7 The maximum mass of constituent released over the range of method pH conditions ($2 \leq pH \leq 13$) may be considered an estimate of the maximum mass of the constituent leachable under field leaching conditions for intermediate time frames and the domain of the laboratory test pHs.

1.8 The solvents used in this method include dilute solutions of nitric acid (HNO_3) and potassium hydroxide (KOH) in reagent water.

1.9 Analysts are advised to take reasonable measures to ensure that the sample is homogenized to the extent practical, prior to employment of this method. Particle-size reduction may provide additional assurance of sample homogenization and also facilitate achievement of equilibrium during the test procedure. Table 1 of this standard designates a recommended minimum dry mass of sample to be added to each extraction vessel and the associated extraction contact time as a function particle diameter. If the heterogeneity of the sample is suspected as the cause of unacceptable precision in replicate test results or is considered significant based on professional judgment, the sample mass used in the test procedure may be increased to a greater minimum dry mass than that shown in Table 1 with the amount of extractant increased proportionately to maintain the designated LS ratio.

1.10 In the preparation of solid materials for use in this method, particle-size reduction of samples with a large grain size is performed in order to enhance the approach towards LS equilibrium under the designated contact time interval of the extraction process. The extract contact time for samples reduced to a finer maximum particle size will consequently be shorter (see Table 1).

1.11 Prior to employing this method, analysts are advised to consult the base method for each type of procedure that may be employed in the overall analysis (e.g., Methods 9040, 9045, and 9050, and the determinative methods for the target analytes), QC acceptance criteria, calculations, and general guidance. Analysts also should consult the disclaimer statement at the front of the manual and the information in Chapter Two for guidance on the intended flexibility in the choice of methods, apparatus, materials, reagents, and supplies, and on the responsibilities of the analyst for demonstrating that the techniques employed are appropriate for the analytes of interest, in the matrix of interest, and at the concentration levels of concern.

In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is not mandatory in response to Federal testing requirements. The information contained in this method is provided by EPA as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives for the intended application. Guidance on defining data quality objectives can be obtained at http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf

1.12 Use of this method is restricted to use by, or under supervision of, properly experienced and trained personnel. Each analyst must demonstrate the ability to generate acceptable results with this method.

2.0 SUMMARY OF METHOD

This method consists of nine parallel extractions of a particle size-reduced solid material in dilute acid or base and reagent water. A flowchart for performing this method is shown in Figure 1. Particle-size reduction of the material to be tested is performed according to Table 1. A schedule of acid and base additions is formulated from a pre-test titration curve or prior knowledge indicating the required equivalents/g acid or base to be added to the series of extraction vessels so as to yield a series of eluates having specified pH values in the range of 2-13. In addition to the nine test extractions, three method blanks without solid sample are carried through the procedure in order to verify that analyte interferences are not introduced as a consequence of reagent impurities or equipment contamination. The twelve bottles (i.e., nine test positions and three method blanks) are tumbled in an end-over-end fashion for a specified contact time, which depends on the particle size of the sample (see Table 1). At the end of the specified contact interval, the liquid and solid phases are roughly separated via settling or centrifugation. Extract pH and specific conductivity measurements are then made on an aliquot of the liquid phase and the remaining bulk of the eluate is clarified by either pressure or vacuum filtration. Analytical samples of the filtered eluate are collected and preserved as appropriate for the desired chemical analyses. The eluate concentrations of COPCs are determined and reported. In addition, COPC concentrations may be plotted as a function of eluate pH and compared to quality control and assessment limits for the interpretation of method results.

3.0 DEFINITIONS

3.1 COPC — A chemical species of interest, which may or may not be regulated, but may be characteristic of release-controlling properties of the sample geochemistry.

3.2 Release — The dissolution or partitioning of a COPC from the solid phase to the aqueous phase during laboratory testing (or under field conditions). In this method, mass release is expressed in units of mg COPC/kg dry solid material.

3.3 LSP — The distribution of COPCs between the solid and liquid phases at the conclusion of the extraction.

3.4 LS ratio — The fraction of the total liquid volume (including the moisture contained in the “as used” solid sample) to the dry mass equivalent of the solid material. LS ratio is typically expressed in volume units of liquid per dry mass of solid material (mL/g-dry).

3.5 “As-tested” sample — The solid sample at the conditions (e.g., moisture content and particle-size distribution) present at the time of the start of the test procedure. The “as-tested” conditions will differ from the "as-received" sample conditions if particle-size reduction and drying were necessarily performed.

3.6 Dry-mass equivalent — The mass of “as-tested” (i.e., “wet”) sample that equates to the mass of dry solids plus associated moisture, based on the moisture content of the “as-tested” material. The dry-mass equivalent is typically expressed in mass units of the “as-tested” sample (g).

3.7 Refer to the SW-846 chapter of terms and acronyms for potentially applicable definitions.

4.0 INTERFERENCES

4.1 Solvents, reagents, glassware, and other sample processing hardware may yield artifacts and/or interferences to sample analysis. All of these materials must be demonstrated to be free from interferences under the conditions of the analysis by analyzing method blanks. Specific selection of reagents and purification of solvents by distillation in all-glass systems may be necessary. Refer to each method to be used for specific guidance on quality control procedures and to Chapters Three and Four for general guidance on the cleaning of laboratory apparatus prior to use.

4.2 If potassium is a COPC, the use of KOH as a base reagent will interfere with the determination of actual potassium release. In this case, sodium hydroxide (NaOH) of the same grade and normality may be used as a substitute.

5.0 SAFETY

5.1 This method does not address all safety issues associated with its use. The laboratory is responsible for maintaining a safe work environment and a current awareness file of OSHA regulations regarding the safe handling of the chemicals listed in this method. A reference file of material safety data sheets (MSDSs) should be available to all personnel involved in these analyses.

5.2 During preparation of extracts and processing of extracts, some waste materials may generate heat or evolve potentially harmful gases when contacted with acids and bases. Adequate prior knowledge of the material being tested should be used to establish appropriate personal protection and workspace ventilation.

6.0 EQUIPMENT AND SUPPLIES

The mention of trade names or commercial products in this manual is for illustrative purposes only, and does not constitute an EPA endorsement or exclusive recommendation for use. The products and instrument settings cited in SW-846 methods represent those products and setting used during the method development or subsequently evaluated by the Agency. Glassware, reagents, supplies, equipment, and setting other than those listed in this manual may be employed provided that method performance appropriate for the intended application has been demonstrated and documented. This section does not list common laboratory glassware (e.g., beakers and flasks) which nonetheless may be required to perform the method.

6.1 Extraction vessels

6.1.1 Twelve wide-mouth bottles (i.e., nine for test positions plus three for method blanks) constructed of inert material, resistant to high and low pH values and interaction with COPCs as described in the following sections.

6.1.1.1 For the evaluation of inorganic COPC mobility, bottles made of high density polyethylene (HDPE) (e.g., Nalgene #3140-0250 or equivalent), polypropylene (PP), or polyvinyl chloride (PVC) are recommended.

6.1.1.2 For the evaluation of non-volatile organic and mixed organic/inorganic COPC mobility, bottles made of glass or Type 316 stainless steel are recommended. Polytetrafluoroethylene (PTFE) is not recommended for non-volatile organics due to the sorption of species with high hydrophobicity (e.g., PAHs). Borosilicate glass is recommended over other types of glass, especially when inorganic analytes are of concern.

6.1.2 The extraction vessels must be of sufficient volume to accommodate both the solid sample and an extractant volume, based on an LS ratio of 10 ± 0.5 mL extractant/g-dry. The head space in the bottle should be minimized to the extent possible when semi-volatile organics are COPCs. For example, Table 1 indicates that 250-mL volume bottles are recommended when the minimum 20 g-dry mass equivalent is contacted with 200 mL of extractant.

6.1.3 The vessel must have a leak-proof seals that can sustain end-over-end tumbling for the duration of the designated contact time.

6.1.4 If centrifugation is anticipated to be beneficial for initial phase separation, the extraction vessels should be capable of withstanding centrifugation at 4000 ± 100 rpm for a minimum of 10 ± 2 min. Alternately, samples may be extracted in bottles that do not meet this centrifugation specification (e.g., Nalgene I-Chem #311-0250 or equivalent) and the solid-liquid slurries transferred into appropriate centrifugation vessels for phase separation as needed.

6.2 Balance — Capable of 0.01-g resolution for masses less than 500 g.

6.3 Rotary tumbler — Capable of rotating the extraction vessels in an end-over-end fashion at a constant speed of 28 ± 2 rpm (e.g., Analytical Testing, Werrington, PA or equivalent).

6.4 Filtration apparatus — Pressure or vacuum filtration apparatus composed of appropriate materials so as to maximize the collection of extracts and minimize loss of the COPCs (e.g., Nalgene #300-4000 or equivalent) (see Sec. 6.1).

6.5 Filtration membranes — Composed of polypropylene or equivalent material with an effective pore size of 0.45-µm (e.g., Gelman Sciences GH Polypro #66548 from Fisher Scientific or equivalent).

6.6 pH Meter — Laboratory model with the capability for temperature compensation (e.g., Accumet 20, Fisher Scientific or equivalent) and a minimum resolution of 0.1 pH units.

6.7 pH combination electrode — Composed of chemically-resistant materials.

6.8 Conductivity meter — Laboratory model (e.g., Accumet 20, Fisher Scientific or equivalent), with a minimum resolution of 5% of the measured value.

6.9 Conductivity electrodes — Composed of chemically-resistant materials.

6.10 Adjustable-volume pipettor — Oxford Benchmate series or equivalent The necessary delivery range will depend on the buffering capacity of the solid material and acid/base strength used in the test.

6.11 Disposable pipettor tips

6.12 Centrifuge (recommended) — Capable of centrifuging the extraction vessels at a rate of 4000 ± 100 rpm for 10 ± 2 min.

7.0 REAGENTS AND STANDARDS

7.1 Reagent-grade chemicals must be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specification are available. Other grades may be used, provided it is first ascertained that the reagents are of sufficiently high purity to permit use without lessening the accuracy of the determination. Inorganic reagents and extracts should be stored in plastic to prevent interaction of constituents from glass containers.

7.2 Reagent water must be interference free. All references to water in this method refer to reagent water unless otherwise specified.

7.3 Nitric acid (2.0 N), HNO_3 – Trace-metal grade or better, purchased at strength or prepared by diluting concentrated nitric acid with reagent water. Solutions with alternate normality may be used as necessary. In such cases, the amounts of HNO_3 solution added to samples should be adjusted based on the equivalents required in the schedule of acid/base additions (see Sec. 11.3).

7.4 Potassium hydroxide (1.0 N), KOH – ACS grade, purchased at strength or prepared by diluting concentrated potassium hydroxide solution with reagent water, or otherwise by dissolving 56.11 g of solid potassium hydroxide in 1 L of reagent water. Solutions with alternate normality may be used as necessary. In such cases, the amounts of KOH solution added to samples should be adjusted based on the equivalents required in the schedule of acid/base additions (see Sec. 11.3).

7.5 Consult Methods 9040 and 9050 for additional information regarding the preparation of reagents required for pH and specific conductance measurements.

8.0 SAMPLE COLLECTION, PRESERVATION, AND STORAGE

8.1 See the introductory material to Chapter Three “Inorganic Analytes” and Chapter Four “Organic Analytes.”

8.2 All samples should be collected using an appropriate sampling plan.

8.3 All analytical sample containers should be composed of materials that minimize interaction with solution COPCs. For further information, see Chapters Three and Four.

8.4 Preservatives should not be added to samples before extraction.

8.5 Samples can be refrigerated, unless refrigeration results in an irreversible physical change to the sample.

8.6 Analytical samples should be preserved according to the guidance given in the individual determinative methods for the COPCs.

8.7 Extract holding times should be consistent with the aqueous sample holding times specified in the determinative methods for the COPCs.

9.0 QUALITY CONTROL

9.1 Refer to Chapter One for guidance on quality assurance (QA) and quality control (QC) protocols. When inconsistencies exist between QC guidelines, method-specific QC criteria take precedence over both technique-specific criteria and those criteria given in Chapter One, and technique-specific QC criteria take precedence over the criteria in Chapter One. Any effort involving the collection of analytical data should include development of a structured and systematic planning document, such as a Quality Assurance Project Plan (QAPP) or a Sampling and Analysis Plan (SAP), which translates project objectives and specifications into directions for those that will implement the project and assess the results. Each laboratory should maintain a formal quality assurance program. The laboratory should also maintain records to document the quality of the data generated. All data sheets and quality control data should be maintained for reference or inspection.

9.2 In order to demonstrate the purity of reagents and sample contact surfaces, method blanks should be tested at the extremes of the acid and base additions, as well as when only reagent water (no acid or base addition) is used for extraction.

9.3 The analysis of extracts should follow appropriate QC procedures, as specified in the determinative methods for the COPCs. Refer to Chapter One for specific quality control procedures.

9.4 Unless the "as-received" samples are part of a time-dependent (e.g., aging) study, solid materials should be processed and tested within one month of their receipt.

10.0 CALIBRATION AND STANDARDIZATION

10.1 The balance should be calibrated and certified at a minimum annually or in accordance with laboratory policy.

10.2 Prior to measurement of eluate pH, the pH meter should be calibrated using a minimum of two standards that bracket the range of pH measurements. Refer to Methods 9040 and 9045 for additional guidance.

10.3 Prior to measurement of eluate conductivity, the meter should be calibrated using at least one standard at a value greater than the range of conductivity measurements. Refer to Method 9050 for additional guidance.

11.0 PREPARATORY PROCEDURES

A flowchart for the method procedure is presented in Figure 1.

11.1 Particle-size reduction (if required)

11.1.1 In this method, particle-size reduction is used for sample homogenization and to prepare large-grained samples for extraction so that the approach toward liquid-solid equilibrium is enhanced and mass transport through large particles is minimized. A longer extract contact time is required for larger maximum particle-size designations. This method designates three maximum particle sizes and associated contact times (see Table 1). The selection of an appropriate maximum particle size from this table should be based on professional judgment regarding the practical effort required to size-reduce the solid material.

11.1.2 Particle-size reduction of “as received” samples may be achieved through crushing, milling or grinding with equipment made from chemically-inert materials. During the reduction process, care should be taken to minimize the loss of sample and potentially volatile constituents in the sample.

11.1.3 If the moisture content of the “as received” material is greater than 15% (wet basis), air drying or desiccation may be necessary. Oven drying is not recommended for the preparation of test samples due to the potential for mineral alteration and volatility loss. In all cases, the moisture content of the “as received” material should be recorded.

NOTE: If the solid material is susceptible to interaction with the atmosphere (e.g., carbonation, oxidation), drying should be conducted in an inert environment.

11.1.4 When the material appears to be of a relatively uniform particle size, calculate the percentage less than the sieve size as follows:

$$\%\ \text{Passing} = \frac{M_{sieved}}{M_{total}} \times 100\%$$

Where: M_{sieved} = mass of sample passing the sieve (g)
M_{total} = mass of total sample (g) (e.g., M_{sieved} + mass not passing sieve)

11.1.5 The fraction retained by the sieve should be recycled for further particle-size reduction until at least 85% of the initial mass has been reduced below the designated maximum particle size. Calculate and record the final percentage passing the sieve and the designated maximum particle size. For the un-crushable fraction of the "as received" material, record the fraction mass and nature (e.g., rock, metal or glass shards, etc).

11.1.6 Store the size-reduced material in an airtight container in order to prevent contamination via gas exchange with the atmosphere. Store the container in a cool, dark and dry place prior to use.

11.2 Determination of solids and moisture content

11.2.1 In order to provide the dry mass equivalent of the "as-tested" material, the solids content of the subject material should be determined. Often, the moisture content of the solid sample is recorded. In this method, the moisture content is determined and recorded on the basis of the "wet" or "as-tested" sample.

WARNING: The drying oven should be contained in a hood or otherwise properly ventilated. Significant laboratory contamination or inhalation hazards may result when drying heavily contaminated samples. Consult the laboratory safety officer for proper handling procedures prior to drying samples that may contain volatile, hazardous, flammable or explosive materials.

11.2.2 Place a 5–10-g sample of solid material into a pre-tared dish or crucible. Dry the sample to a constant mass at 105 ± 2 °C. Periodically check the sample mass after allowing the sample to cool to room temperature (20 ± 2 °C) in a desiccator.

NOTE: The oven-dried sample is not used for the extraction and should be properly disposed of once the dry mass is determined.

11.2.3 Calculate and report the solids content as follows:

$$SC = \frac{M_{dry}}{M_{test}}$$

Where: SC = solids content (g-dry/g)
M_{dry} = mass of oven-dried sample (g-dry)
M_{test} = mass of "as-tested" sample (g)

11.2.4 Calculate and report the moisture content (wet basis) as follows:

$$MC_{wet} = \frac{M_{test} - M_{dry}}{M_{test}}$$

Where: $MC_{(wet)}$ = moisture content on a wet basis (g_{H_2O}/g)
M_{dry} = mass of oven-dried sample (g-dry)
M_{test} = mass of “as-tested” sample (g)

11.3 Pre-test titration (if required)

In order to conduct the parallel batch test in Sec. 12.0, a schedule of acid and base additions should be formulated from either a pre-test titration or based on prior knowledge of the acid/base titration curve of the sample. This section describes the procedure for obtaining a titration curve of the test material, when sufficient prior knowledge is unavailable.

If the schedule of acid and base additions will be generated from prior knowledge, proceed to Sec. 11.4. If the schedule of acid and base additions is already known, proceed to Sec. 12.0.

Figures 2-4 show example titration curves for a wide variety of solid materials. Table 2 indicates how these materials may be classified as (a) low alkalinity; (b) moderate alkalinity; or (c) high alkalinity in terms of the equivalents of acid required for obtaining final extraction pH values in the range of 2-13.

11.3.1 Predict the classification of the neutralization behavior of the solid material based on professional judgment, preliminary data, or the material examples shown in Table 2 and Figures 2-4.

11.3.2 Conduct a five-point parallel extraction test using 10-g-dry samples of the solid following the pre-test schedule shown in Table 3 for the chosen classification. Perform the extraction procedure in Sec. 12.0, omitting the filtration, method blanks, and analytical sample collection.

11.3.3 Plot the pre-test titration curve (e.g., the extract pH as a function of the equivalents of acid added) considering base equivalents as the negative sign of acid equivalents.

11.3.4 Reiterate the pre-test extraction, if necessary to expand or contract the pre-test titration until the 2-13 pH range can be resolved.

NOTE: Additional pre-test point(s) interpolating or extrapolating from the pre-test schedule may be necessary to provide adequate resolution in the titration curve.

11.3.5 Pre-test titration using provided Microsoft® Excel template

The “Pre-Test” worksheet in the provided Excel template may be used to calculate pre-test extraction formulations and plot the pre-test titration curve. Mandatory input data for the template includes:

a) particle size of the “as tested” material (see Sec. 11.1);
b) solids content of the “as tested” material (see Sec. 11.2); and
c) five acid/base additions based on the predicted response classification of the solid material (see Sec. 11.3).

Enter the eluate pH and plot the pre-test titration curve. Compare the resulting titration curve to the target pH values as designated in Table 4.

11.4 Formulation of acid and base additions schedule

A schedule of acid and base additions is used in the main extraction procedure (Sec. 12.0) to set up nine extractions of the test material plus three method blanks. Based on either prior knowledge of the acid/base titration curve of the sample or the results of the pre-test titration procedure in Sec. 11.3, formulate a schedule of test extractions using the example in Table 4 and the following steps.

11.4.1 Using the extraction parameters in Table 1, identify the recommended minimum dry-mass equivalent associated with the particle size of the "as-tested" sample. Calculate and record the amount of "as tested" material equivalent to the dry-material mass from Table 1 as follows:

$$M_{test} = \frac{M_{dry}}{SC}$$

Where: M_{test} = mass of "as-tested" solid equivalent to the dry-material mass (g)
M_{dry} = mass of dry material specified in the method (g-dry)
SC = solids content of "as-tested" material (g-dry/g)

11.4.2 Label Column A of the schedule table with consecutive numbers for the nine test positions (shown in Table 4 as "TXX" labels) and three method blanks (shown in Table 4 as "BXX" labels).

11.4.3 Select the nine target pH points as shown in Table 5 and enter this data into Column B of the schedule table. One of the nine target pH values should be with no acid or base addition in order to record the natural pH of the material. The target pH points shown in Table 5 allow for substitution of one optional target point if the natural pH of the solid material falls within the tolerance of another designated target pH. For example, if the natural pH is 11.8 and would satisfy the target pH of 12.0 ± 0.5, the optional target point of 10.5 ± 0.5 should be included.

11.4.4 For each test position, determine the equivalents of acid or base required to meet the target pH from the pre-test titration curve (see Sec. 11.3). Enter this data into Column C of the schedule table. Interpolate intermediate acid additions on the pre-test titration curve using linear interpolation or other regression techniques.

NOTE: Linear interpolation will have some inherent error, which may result in an extract pH that falls outside of the target pH tolerance. Additional pre-test points interpolating or extrapolating from the pre-test schedule in Table 3 may be necessary to provide adequate resolution of the titration curve.

11.4.5 Enter the acid volumes in Column D and base volumes in Column E of the schedule after converting the equivalents of acid and base to volume as follows:

$$V_{a/b} = \frac{Eq_{a/b}}{N_{a/b}}$$

Where: $V_a/_b$ = volume of acid or base to be entered in the schedule table (mL)
$Eq_{a/b}$ = equivalents of acid or base selected for the target pH as determined from the pre-test titration curve (meq/g)
$N_{a/b}$ = normality of the acid or base solution (meq/mL)

11.4.6 In Column F of the schedule table, calculate the volume of moisture contained in the “as tested” sample as follows:

$$V_{W,sample} = \frac{M_{test} \times (1 - SC)}{\rho_w}$$

Where: $V_{W,sample}$ = volume of water in the “as tested” sample (mL)
M_{test} = mass of the “as tested” sample (g)
SC = solids content of the “as tested” sample (g-dry/g)
ρ_w = density of water (1.0 g/mL at room temperature)

11.4.7 In Column G of the schedule table, calculate the volume of reagent water required to bring each extraction to a LS ratio of 10 mL/g-dry solid as follows:

$$V_{RW} = M_{dry} \times LS - V_{W,sample} - V_{a/b}$$

Where: V_{RW} = volume of reagent water required to complete LS ratio (mL)
M_{dry} = dry mass equivalent of solid sample (g)
LS = liquid-to-dry-solid ratio (10 mL/g)
$V_{W,sample}$ = volume of water in “as used” sample (mL)
$V_{a/b}$ = volume of acid or base for the extraction recipe (mL)

11.4.8 Method Blanks

In the schedule table, include three additional extractions for processing method blanks. Method blanks extractions are performed using the same equipment, reagents, and extraction process as the test positions, but without solid sample. The three method blanks should include:

a) reagent water (B01 in Table 4);
b) reagent water + maximum volume of acid in the schedule (B02 in Table 4); and
c) reagent water + maximum volume of base in the schedule (B03 in Table 4).

NOTE: If multiple materials or replicate tests are carried out in parallel, only one set of method blanks is necessary.

11.4.9 Schedule formulation using Excel template

The "Test Data" worksheet in the provided Excel template may be used to automatically calculate a schedule of acid and base additions, as well as to plot the response eluate pH and conductivity as a function of acid addition. Mandatory input data for the template includes:

a) particle size of the "as tested" material (see Sec. 11.1);
b) solid content of the "as tested" material (see Sec. 11.2); and
c) nine acid/base additions determined from the pre-test titration curve with respect to target pH values designated in Table 5.

Subsequent to the extraction procedure, eluate pH, conductivity, and oxidation/reduction potential (optional) for up to three replicates may be entered and plotted as a function of acid added.

12.0 EXTRACTION PROCEDURE

Use the schedule of acid and base additions (Sec. 11.4) as a guide to set up nine test extractions and three method blanks as follows:

12.1 Label nine bottles with test position numbers and three bottles with method blank labels according to the schedule of acid and base additions (see Column A in Table 4).

12.2 Use the extraction parameters in Table 1 to identify the recommended dry-mass equivalent associated with the particle size of the "as tested" sample. Calculate and record the amount of "as tested" material equivalent to the identified dry mass from Table 1 as follows:

$$M_{test} = \frac{M_{dry}}{SC}$$

Where: M_{test} = mass of "as tested" solid equivalent to g of dry material (g)
M_{dry} = mass of dry material specified in method (g)
SC = solids content of "as tested" material (g/g)

12.3 Place the dry equivalent mass (± 0.1 g) of the "as tested" sample, calculated above, into each of the nine test position extraction vessels.

NOTE: Do NOT put solid material in the method blank extraction vessels.

12.4 Add the appropriate volume of reagent water (± 5% of target value) to both the test position and method blank extraction vessels, as specified in the schedule for the LS ratio makeup (see Column G in Table 4).

12.5 Add the appropriate volume of acid or base (± 1% of target value) to each vessel, using a continuously adjustable pipettor, as designated in the schedule for acid/base addition (see Column D and Column E in Table 4).

12.6 Tighten the leak-proof lid on each bottle and tumble all extractions (i.e., test positions and method blanks) in an end-over-end fashion at a speed of 28 ± 2 rpm at room temperature (20 ± 2 °C). The contact time for this method will vary depending on the sample particle size as shown in Table 1.

NOTE: The length of the contact time is designed to enhance the approach toward liquid-solid equilibrium. Longer contact times are required for larger particles to compensate for the effects of intra-particle diffusion. See Table 1 for recommended contact times based on particle size.

12.7 Remove the extraction vessels from the rotary tumbler and clarify the extractants by allowing the bottles to stand for 15 ± 5 min. Alternately, centrifuge the extraction vessels at 4000 ± 100 rpm for 10 ± 2 min.

12.8 For each extract vessel, decant a minimum volume (~ 5 mL) of clear, unpreserved supernatant into a clean container.

12.9 Measure and record the pH, specific conductivity, and oxidation-reduction potential (ORP) (optional, but strongly recommended) of the extracts (see Methods 9040, 9045, and 9050).

12.10 Separate the solid from the remaining liquid in each extraction vessel by pressure or vacuum filtration through a clean 0.45-µm pore size membrane (Sec. 6.5). The filtration apparatus may be exchanged for a clean apparatus as often as necessary until all liquid has been filtered.

NOTE: If COPCs which might be lost under vacuum (e.g., mercury) are suspected, the samples should be pressure-filtered using an inert gas (e.g., nitrogen or argon).

12.11 Immediately, preserve and store the volume(s) of eluate required for chemical analysis. Preserve all analytical samples in a manner that is consistent with the determinative chemical analyses to be performed.

13.0 DATA ANALYSIS AND CALCULATIONS (EXCEL TEMPLATE PROVIDED)

13.1 Data reporting

13.1.1 Figure 5 shows an example of a data sheet that may be used to report the concentration results of this method. This example is included in the Excel template. At a minimum, the basic test report should include:

a) Name of the laboratory
b) Laboratory technical contact information
c) Date at the start of the test
d) Name or code of the solid material
e) Particle size (85 wt% less than)
f) Type of acid and/or base used in test
g) Extraction contact time (h)
h) Ambient temperature during extraction (°C)
i) Eluate specific information (see Sec. 13.1.2 below)

13.1.2 The minimum set of data that should be reported for each eluate includes:

a) Eluate sample ID
b) Mass of “as tested” solid material used (g)
c) Moisture content of material used (g_{H_2O}/g)
d) Volume (mL) and normality (N) of acid and/or base used
e) Volume of water added (mL)
f) Target pH
g) Measured final eluate pH
h) Measured eluate conductivity (mS/cm)
I) Measured ORP (mV) (optional)
j) Concentrations of all COPCs
k) Analytical QC qualifiers as appropriate

13.2 Data interpretation (optional)

13.2.1 Acid/base neutralization curve

Plot the pH of each extract as a function of the equivalents of acid or base added per dry gram of material to generate an acid/base neutralization curve.

<u>NOTE</u>: For materials in which both acid and base were used, equivalents of base can be presented as the opposite sign of acid equivalents (i.e., 5 meq/g-dry of base would correspond to -5 meq/g-dry of acid).

The titration curve can be interpreted as showing the amount of acid or base that is needed to shift the pH of the subject material. This is helpful when evaluating field scenarios where the pH of leachates is not buffered by the acidity or alkalinity of the solid material.

13.2.2 LSP curve

An LSP curve can be generated for each COPC following chemical analyses of all extracts by plotting the target analyte concentration in the liquid phase as a function of the measured extract pH for each extract. As an example, Figure 6 illustrates the LSP curves for arsenic and selenium from a coal combustion fly ash and indicates the limits of quantitation (shown as ML and MDL) and the natural concentration response.

13.2.2.1 The lower limit of quantitation (LLOQ) of the determinative method for each COPC may be shown as a horizontal line. COPC concentrations below this line indicate negligible or non-quantitative concentrations.

NOTE: The lower limit of quantitation is highly matrix dependent and should be determined as part of a QA/QC plan.

13.2.2.2 Natural response is defined as the eluate pH and COPC concentration measured when the solid material is extracted with reagent water at an LS ratio of 10 mL/g-dry. The natural response values can be shown on the LSP curve as a vertical line from the *x*-axis (at the replicate average natural pH) intersected with a horizontal line (at the replicate average COPC concentration). Alternatively, the natural response can be indicated in results using a different symbol from other results.

13.2.2.3 The values on the curve indicate the eluate concentration of the constituent of interest at an LS of 10 mL/g-dry over a pH range. The shape of the LSP curve is indicative of the speciation of the COPC in the solid phase with four characteristic LSP curve shapes (i.e., relative locations of maxima and minima) presented schematically in Figure 7.

Cationic Species (e.g., Cd) — The LSP curve of cationic species typically has a maximum concentration in the acidic pH range that decreases to lower values at alkaline pH.

Amphoteric Species (e.g., Pb, Cr(III), Cu.) — The LSP curves tend to be similar in shape to cationic LSP curves with greater concentrations in the acidic pH range. However, the concentrations pass through a minimum in the near neutral to slightly acid pH range only to increase again for alkaline pH values. Typically, the increase at high pH is due to the solubility of hydroxide complexes (e.g., $[Pb(OH_3)]^-$).

Oxyanionic Species (e.g. $[AsO_4]^-$, $[SeO_4]^-$, $[MnO_4]^-$) — The LSP curves often show maxima in the neutral to slightly alkaline range.
Highly Soluble Species (e.g., Na^+, K^+, Cl^-) — The LSP curve is only a weak function of pH.

The idealized LSP curves in Figure 7 can be compared with the general shape of the test data to infer the speciation of the COPC in the solid matrix. Concentration results from this method may be simulated with geochemical speciation models to infer the mineral phases, adsorption reactions, and soluble complexes that control the release of the COPC (see Ref. 1).

14.0 METHOD PERFORMANCE

14.1 Performance data and related information are provided in SW-846 methods only as examples and guidance. The data do not represent required performance criteria for users of the methods. Instead, performance criteria should be developed on a project-specific basis, and the laboratory should establish in-house QC performance criteria for the application of this method. These performance data are not intended to be and must not be used as absolute QC acceptance criteria for purposes of laboratory accreditation.

14.2 Refs. 2 and 3 may provide additional guidance and insight on the use, performance and application of this method.

15.0 POLLUTION PREVENTION

15.1 Pollution prevention encompasses any technique that reduces or eliminates the quantity and/or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operations. The EPA has established a preferred hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the Agency recommends recycling as the next best option.

15.2 For information about pollution prevention that may be applicable to laboratories and research institutions consult Less is Better: Laboratory Chemical Management for Waste Reduction available from the American Chemical Society's Department of Government Relations and Science Policy, 1155 16th St., N.W. Washington, D.C. 20036, http://www.acs.org.

16.0 WASTE MANAGEMENT

The Environmental Protection Agency requires that laboratory waste management practices be conducted consistent with all applicable rules and regulations. The Agency urges laboratories to protect the air, water, and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any sewer discharge permits and regulations, and by complying with all solid and hazardous waste regulations, particularly the hazardous waste identification rules and land disposal restrictions. For further information on waste management, consult The Waste Management Manual for Laboratory Personnel available from the American Chemical Society at the address listed in Sec. 14.2.

17.0 REFERENCES

1. H. A. van der Sloot, P.F.A.B. Seignette, J.C.L. Meeussen, O. Hjelmar and D.S. Kosson, (2008), "A Database, Speciation Modeling and Decision Support Tool for Soil, Sludge, Sediments, Wastes and Construction Products: LeachXS™-ORCHESTRA," in Venice 2008: Second International Symposium on Energy from Biomass and Waste, Venice, Italy, 17-20 November 2008 (also see www.leaching.com).

2. D.S. Kosson, H.A. van der Sloot, F. Sanchez and A.C. Garrabrants, (2002), “An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials,” Environmental Engineering Science, 19(3) 159-204.

3. D.S. Kosson, A.C. Garrabrants, H.A. van der Sloot (2009) “Background Information for the Development of Leaching Test Draft Methods 1313 through Method 1316”, (in preparation).

4. F. Sanchez, R. Keeney, D. Kosson, and R. DeLapp, (2006), “Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control,” EPA-600/R-06/008, U.S. Environmental Protection Agency, Washington, DC.

5. USEPA (2006) Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control, EPA-600/R-06/008, February 2006.

6. USEPA (2008) Characterization of Coal Combustion Residues from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control, EPA-600/R-08/077, July 2008.

7. USEPA (2009) Characterization of Coal Combustion Residues from Electric Utilities – Leaching and Characterization Data, EPA-600/R-09/151, December 2009.

18.0 TABLES, DIAGRAMS, FLOW CHARTS, AND VALIDATION DATA

The following pages contain the tables and figures referenced by this method.

TABLE 1

EXTRACTION PARAMETERS AS FUNCTION OF MAXIMUM PARTICLE SIZE

Particle Size (85 wt% less than) (mm)	US Sieve Size	Minimum Dry Mass (g-dry)	Contact Time (h)	Suggested Vessel Size (mL)
0.3	50	20 ± 0.02	24 ± 2	250
2.0	10	40 ± 0.02	48 ± 2	500
5.0	4	80 ± 0.02	72 ± 2	1000

TABLE 2

MATERIAL NEUTRALIZATION CLASSIFICATIONS

Neutralization Classification	Material Types
Low Alkalinity	soils; sediments; CCR fly ash; CCR bottom ash; coal milling rejects; MSWI fly ash, MSWI bottom ash; sewage sludge amended soil
Moderate Alkalinity	soils; wood preserving waste; MSWI bottom ash; steel slag; electric arc furnace dust; MSW compost; nickel sludge; Portland cement mortar
High Alkalinity	Portland cement clinker; steel blast furnace slag, solidified waste (fly ash, blast furnace slag, Portland cement)

NOTE: CCR = Coal combustion residue
MSWI = Municipal solid waste incinerator

TABLE 3

PRE-TEST TITRATION: ACID EQUIVALENT SCHEDULE

Neutralization Classification	Equivalents of Acid (meq/g-dry)				
	Bottle 1	Bottle 2	Bottle 3	Bottle 4	Bottle 5
Low Alkalinity	-2.0	-1.0	0	1.0	2.0
Moderate Alkalinity	-2.0	0	2.0	5.0	10.0
High Alkalinity	0	5.0	10.0	15.0	25.0

NOTE: 1) Base additions shown as opposite sign of acid equivalents.
2) Additional pre-test point(s) interpolating or extrapolating from the pre-test schedule may be necessary to provide adequate resolution in the titration curve.

TABLE 4

EXAMPLE SCHEDULE OF ACID AND BASE ADDITIONS

A	B	C	D	E	F	G
Test position	Target extract pH	Equivalents of Acid (meq/g-dry)	Volume of 2N HNO_3 (mL)	Volume of 1N KOH (mL)	Volume of moisture in sample (mL)	Volume of reagent water (mL)
T01	13.0	-1.10	-	22.0	2.22	176
T02	12.0	-0.75	-	15.0	2.22	183
T03	10.5	-0.38	-	7.60	2.22	190
T04	9.0	-0.15	-	3.0	2.22	195
T05	8.0	-0.05	-	1.0	2.22	197
T06	Natural	0	-	-	2.22	198
T07	5.5	0.12	1.20	-	2.22	197
T08	4.0	0.90	9.00	-	2.22	189
T09	2.0	3.10	31.0	-	2.22	167
B01	QA/QC	0	-	-	-	200
B02	QA/QC	3.10	31.0	-	-	169
B03	QA/QC	-1.10	-	22.0	-	178

NOTE: 1) This schedule is based on “as tested” sample mass of 22.2±0.1 g (i.e., equivalent “as tested” mass for a 20.0 g-dry sample at a solids content of 0.90 g-dry/g).
2) In this example, the natural pH is assumed to be 7.0±0.5.
3) Test positions marked B01, B02, and B03 are method blanks of reagent water, reagent water + maximum acid addition, and reagent water + maximum base addition, respectively.

Data modified from Ref. 2.

TABLE 5

FINAL EXTRACT PH TARGETS

pH Target	Rationale
variable	Natural pH at LS 10 mL/g-dry (no acid/base addition)
2.0±0.5	Provides estimates of total or available COPC content
4.0±0.5	Lower pH limit of typical management scenario
5.5±0.5	Typical lower range of industrial waste landfills
7.0±0.5	Neutral pH region; high release of oxyanions
8.0±0.5	Endpoint pH of carbonated alkaline materials
9.0±0.5	Minimum of LSP curve for many cationic and amphoteric COPCs
12.0±0.5	Maximum in alkaline range for LSP curves of amphoteric COPCs
13.0±0.5	Upper bound (field conditions) for amphoteric COPCs
10.5±0.5	Substitution if natural pH falls within range of a mandatory target

FIGURE 1

METHOD FLOWCHART

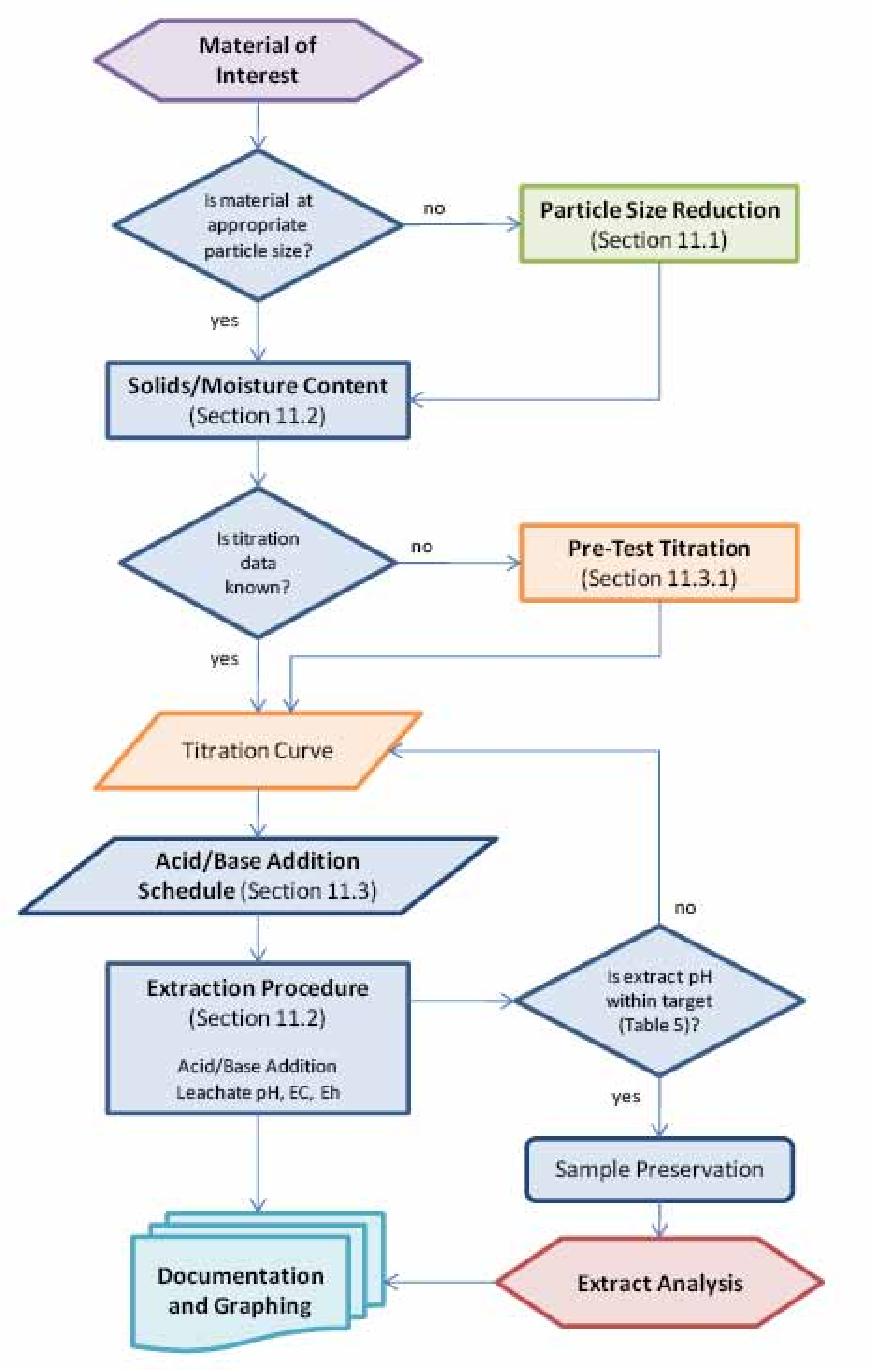
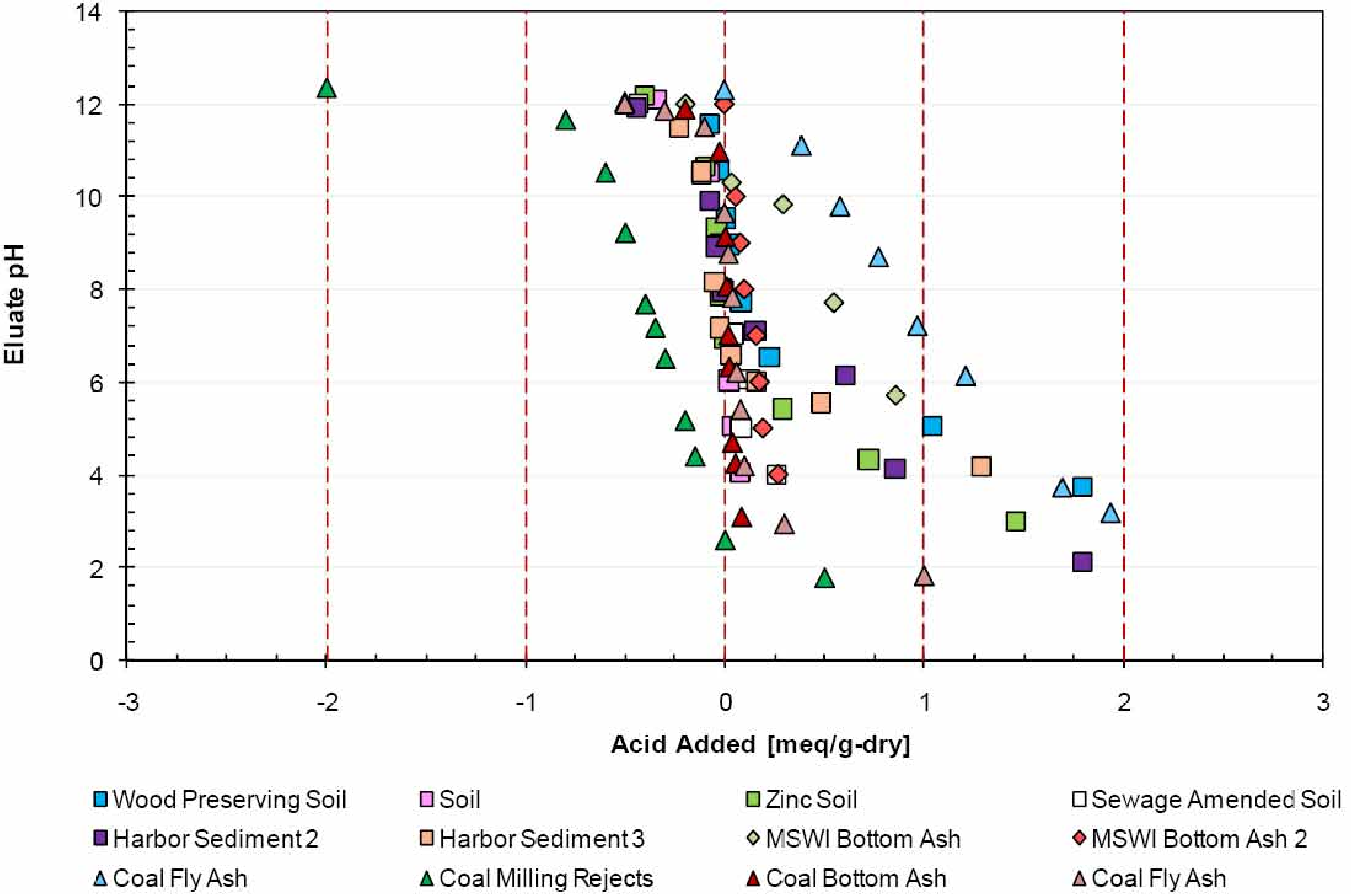


FIGURE 2

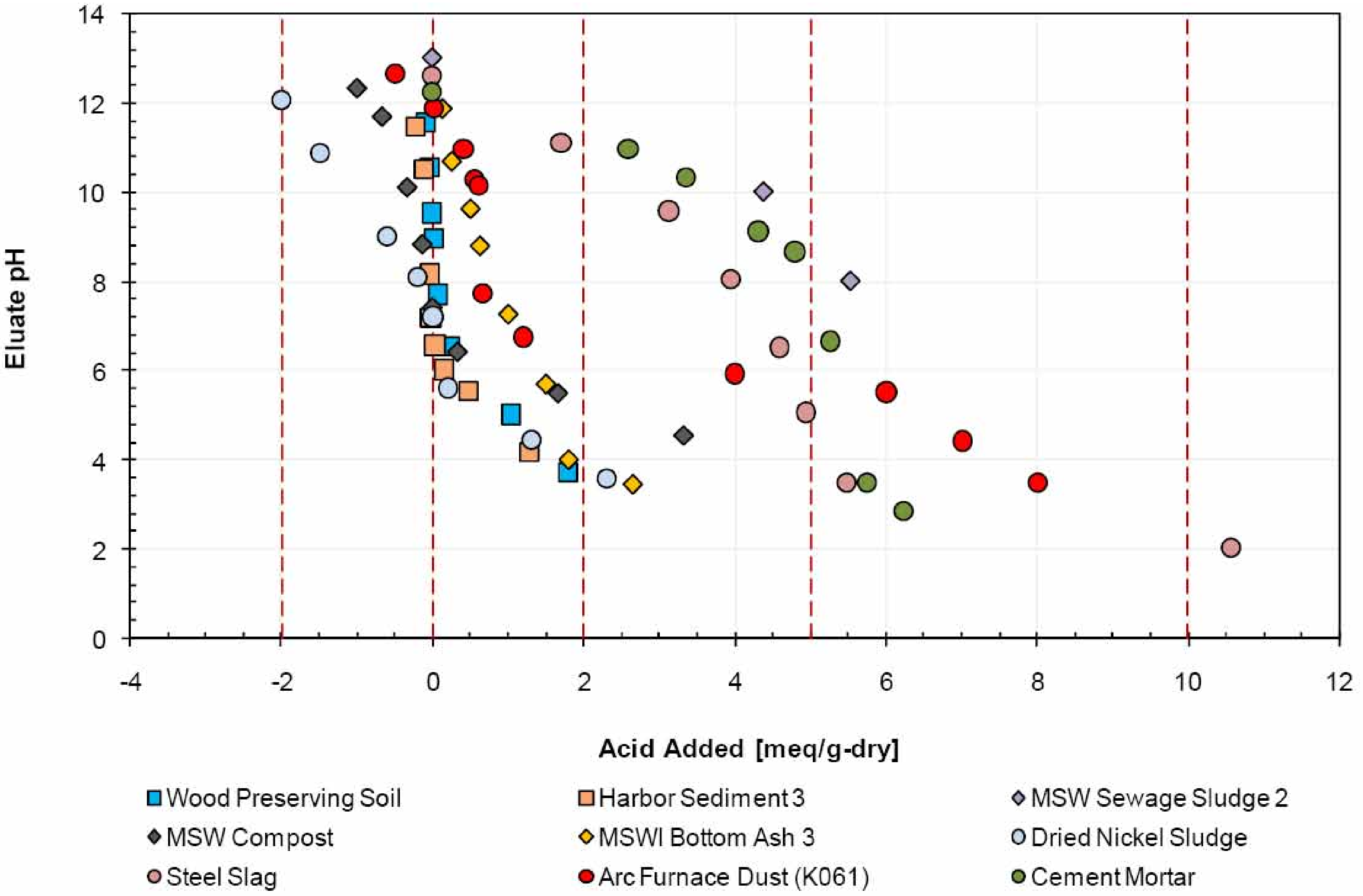
EXAMPLE TITRATION CURVES FOR SELECTED “LOW ALKALINITY” WASTES



Some data taken LeachXS database (Ref. 1).

FIGURE 3

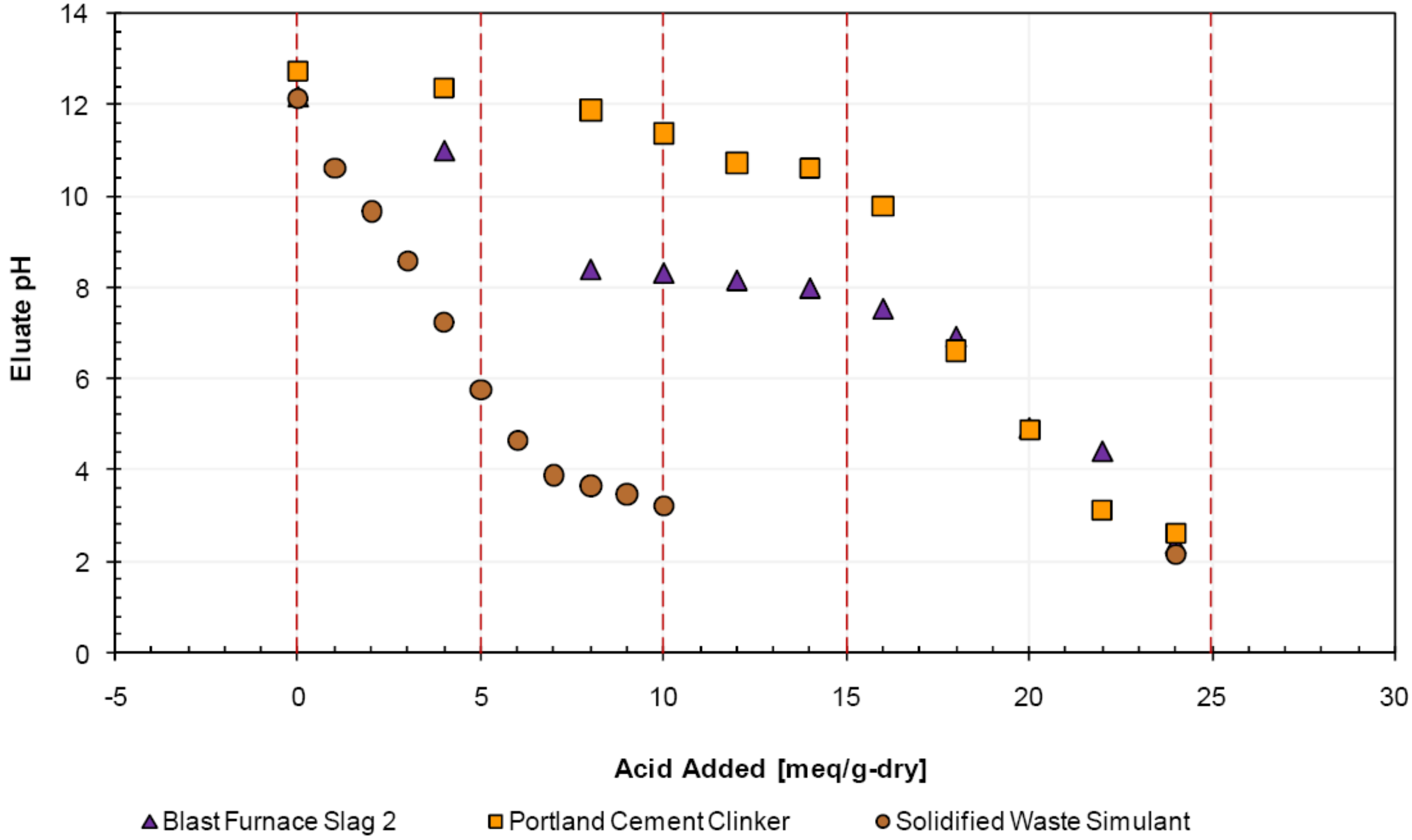
EXAMPLE TITRATION CURVES FOR SELECTED "MODERATE ALKALINITY" WASTES



Some data taken from LeachXS database (Ref. 1).

FIGURE 4

EXAMPLE TITRATION CURVES FOR SELECTED “HIGH ALKALINITY” WASTES



Some data taken from LeachXS database (Ref. 1).

FIGURE 5

EXAMPLE DATA REPORT FORMAT

EPA METHOD 1313
Report of Analysis

ABC Laboratories
123 Main Street
Anytown, USA
Contact: John Smith
(555) 111-1111

Client Contact: Susan Jones
(555) 222-2222

Material Code: **XYZ**
Material Type: Coal Combustion Fly Ash
Date Received: 10/1/20xx
Test Date: 11/1/20xx
Report Date: 12/1/20xx

Particle Size: 88% passing 2-mm sieve
Contact Time: 48 hours
Lab Temperature: 21 ± 2 °C
Acid Used: Nitric acid
Base Used: Sodium hydroxide

Test Position	Replicate	Value	Units	Method	Note
T01	**A**				
	Eluate Sample ID	**XYZ-1313-T01-A**			
	Solid Material	40.0	g		
	Moisture Content	0.01	g		
	Water Added	386.0	g_{H_2O}/g		
	Acid Added	14.0	mL		
	Acid Strength	2.0	mL		
	Base Added	-	N		
	Base Strength	1.0	mL		
	Target pH	2.0 ± 0.5	-		
	Eluate pH	1.89	-	EPA 9040	
	Eluate Conductivity	12.6	mS/c	EPA 9050	
	Eluate ORP	203	mv		

Chemical Analysis	Value	Units	QC Flag	Method	Date	Dilution Factor
Al	216.0	mg/L		EPA 6020	11/7/20xx	1000
As	0.64	mg/L		EPA 6020	11/7/20xx	10
Cl	< 4.13	mg/L	U	EPA 9056	11/9/20xx	1

Test Position	Replicate	Value	Units	Method	Note
T02	**A**				
	Eluate Sample ID	**XYZ-1313-T02-A**			
	Solid Material	40.0	g		
	Moisture Content	0.01	g		
	Water Added	400.0	g_{H_2O}/g		
	Acid Added	14.0	mL		
	Acid Strength	2.0	mL		
	Base Added	-	N		
	Base Strength	1.0	mL		
	Target pH	4.0 ± 0.5	-		
	Eluate pH	3.86	-	EPA 9040	Natural pH
	Eluate Conductivity	0.99	mS/c	EPA 9050	
	Eluate ORP	180	mv		

Chemical Analysis	Value	Units	QC Flag	Method	Date	Dilution Factor
Al	449.0	mg/L		EPA 6020	11/7/20xx	1000
As	0.979	mg/L		EPA 6020	11/7/20xx	10
Cl	< 4.13	mg/L	U	EPA 9056	11/7/20xx	1

QC Flag Key: U Value below lower limit of quantitation as reported (< "LLOQ")

Appendix C
Solid Characterization
(Organic Carbon Content, Elemental Carbon Content, Total Carbon Content, Loss on Ignition, Moisture Content, and Pore Size Distribution)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO$_3$ Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition	Moisture	Surface Area
						(%)	(%)	(%)	(%)	(%)	m2/g
Fly Ash without Hg Sorbent Injection											
Bituminous, Low S											
Brayton Point	BPB	CS ESP	None	None	None	BML	2.22	2.25	5.5	0.2	6.5
Facility F	FFA	CS ESP	None	None	None	1.63	2.52	4.15	7.7	0.2	6.4
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	BML	1.38	1.41	6.2	4.7	2.4
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	0.10	3.55	3.65	5.3	1.6	2.6
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	0.43	1.51	1.93	5.3	3.4	5.7
Facility U	UFA	CS ESP	SCR	None	None	0.04	0.07	0.11	0.4	0.3	1.0
Salem Harbor	SHB	CS ESP	SNCR	None	None	BML	7.82	7.84	21.0	0.2	28.0
Facility G	GFA	CS ESP	SNCR	None	None	0.27	2.47	2.74	1.6	0.4	4.4
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	0.11	9.03	9.15	17.6	8.5	13.9
Facility L	LAB	HS ESP	SOFA	None	None	0.05	5.51	5.56	12.3	0.9	8.2
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.10	7.66	7.75	18.0	BML	15.3
Bituminous, Med S											
Facility T	TFA	CS ESP	None	None	None	0.59	7.74	8.33	16.0	2.0	6.1
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	0.21	2.32	2.53	5.3	0.5	2.2
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	0.66	6.09	6.74	5.3	0.2	1.0
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	0.31	7.40	7.72	19.5	0.3	4.5
Facility K	KFA	CS ESP	None	None	None	0.13	0.08	0.21	1.6	0.3	1.3
Facility Aa	AaFA	CS ESP	SCR	None	None	0.40	8.02	8.42	7.9	BML	1.6
Facility Aa	AaFB	CS ESP	SCR	None	None	0.83	12.6	13.4	11.0	BML	4.9
Facility Da	DaFA	CS ESP	SCR	None	None	1.33	4.23	5.56	2.3	BML	0.5
Facility Aa	AaFC	HS ESP	SCR	None	None	1.18	3.03	4.22	6.5	BML	1.7

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition	Moisture	Surface Area
						(%)	(%)	(%)	(%)	(%)	m2/g
Fly Ash without Hg Sorbent Injection											
Bituminous, High S											
Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	0.05	2.14	2.20	4.3	0.3	5.2
Facility H	HFA	CS ESP	SCR	None	None	0.25	0.69	0.94	6.7	0.3	1.0
Sub-Bituminous & Sub-bit/bituminous mix											
Pleasant Prairie	PPB	CS ESP	None	None	None	BML	0.25	0.25	0.6	0.2	1.8
St. Clair	JAB	CS ESP	None	None	None	BML	0.13	0.16	0.4	0.1	2.5
Facility Z	ZFA	CS ESP	None	None	None	1.00	BML	1.00	0.6	0.1	0.5
Facility Z	ZFB	CS ESP	None	None	None	0.92	0.14	1.06	6.1	0.1	0.8
Facility X	XFA	CS ESP	SCR	None	None	0.11	0.05	0.16	0.4	0.1	2.2
Lignite											
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	0.27	0.31	0.59	2.4	BML	0.5

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition	Moisture	Surface Area
						(%)	(%)	(%)	(%)	(%)	m2/g

Fly Ash without and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)	Moisture (%)	Surface Area m2/g
Brayton Point	BPB	CS ESP	None	None	None	BML	2.22	2.25	5.5	0.2	6.5
Brayton Point	BPT	CS ESP	None	PAC	None	0.12	12.89	13.01	12.0	0.5	92.0
Salem Harbor	SHB	CS ESP	SNCR	None	None	BML	7.82	7.84	21.0	0.2	28.0
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	BML	11.2	11.2	25.0	0.2	36.0
Facility L	LAB	HS ESP	SOFA	None	None	0.05	5.51	5.56	12.3	0.9	8.2
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	0.09	5.83	5.92	12.4	BML	27.0
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.10	7.66	7.75	18.0	BML	15.3
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	0.25	24.2	24.4	36.3	0.5	36.6

Sub-bituminous (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)	Moisture (%)	Surface Area m2/g
Pleasant Prairie	PPB	CS ESP	None	None	None	BML	0.25	0.25	0.6	0.2	1.8
Pleasant Prairie	PPT	CS ESP	None	PAC	None	BML	3.57	3.58	3.5	0.3	23.0
St. Clair	JAB	CS ESP	None	None	None	BML	0.13	0.16	0.4	0.1	2.5
St. Clair	JAT	CS ESP	None	Br-PAC	None	BML	2.61	2.65	3.2	BML	24.9

Lignite (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)	Moisture (%)	Surface Area m2/g
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	0.31	0.27	0.57	1.3	BML	0.6

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition	Moisture	Surface Area
						(%)	(%)	(%)	(%)	(%)	m2/g
Spray dryer with Fabric Filter (fly ash and FGD collected together)											
Sub-bituminous											
Facility V	VSD	Fabric F.	SCR	None	None	0.44	0.01	0.45	2.6	0.9	6.3
Facility Y	YSD	Fabric F.	SCR	None	None	2.13	2.12	4.25	4.0	0.8	14.7

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)

Gypsum, unwashed and washed

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	2.27	0.42	2.69	3.7

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	1.53	0.11	1.64	5.2
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	4.14	0.16	4.30	7.7
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	2.26	0.08	2.34	15.4
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	3.08	0.08	3.16	5.3
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	4.85	0.08	4.95	1.9
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	2.68	0.06	2.74	2.7
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.73	0.56	1.28	7.7
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	0.12	BML	0.12	2.8

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture	Surface Area
								(%)	m2/g

Gypsum, unwashed and washed

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	25.8	4.4

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	38.2	9.8
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	25.6	11.0
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	38.3	4.3
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	25.9	7.5
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	26.0	9.1
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	26.0	8.4
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	24.4	3.3
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	7.5	11.3

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition
								(%)	(%)	(%)	(%)

Gypsum, unwashed and washed

Bituminous, High S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.55	BML	0.55	9.2
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.51	BML	0.51	2.1
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1.77	0.21	1.99	5.0
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1.10	0.11	1.21	4.7
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	2.50	0.43	2.93	20.4
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	2.31	BML	2.35	3.9

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	2.93	0.04	2.98	4.8
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	0.87	BML	0.91	6.1
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	3.65	BML	3.65	2.2
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1.04	1.30	2.34	4.6

Lignite

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1.64	BML	1.64	4.8

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture	Surface Area
								(%)	m2/g

Gypsum, unwashed and washed

Bituminous, High S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	27.8	9.9
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	28.0	3.9
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	27.9	19.7
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	23.4	20.5
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	21.3	7.6
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	21.3	3.4

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	26.5	15.1
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	12.8	22.0
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	34.6	2.2
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	22.9	2.7

Lignite

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	38.2	5.3

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition
								(%)	(%)	(%)	(%)
Scrubber Sludge											
Bituminous, Low S											
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.14	0.30	0.44	9.3
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.12	0.27	0.39	22.1
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	0.22	0.93	1.15	9.6
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.35	0.10	0.45	15.5
Bituminous, Med S											
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	0.49	0.22	0.71	8.6

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture	Surface Area
								(%)	m2/g
Scrubber Sludge									
Bituminous, Low S									
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	8.9	17.5
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	21.7	16.6
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	8.5	22.7
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	15.1	14.5
Bituminous, Med S									
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	45.3	47.3

BML - below method limit (not detected)

Mixed Fly Ash and Scrubber Sludge (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.17	0.91	1.08	7.6
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	BML	3.93	3.98	8.9
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	0.17	0.49	0.66	14.6
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.57	8.73	9.30	14.0

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon (%)	Elemental Carbon (%)	Total Carbon (%)	Loss on Ignition (%)
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	0.58	0.26	0.85	5.6
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	0.98	0.35	1.33	7.1
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	0.60	BML	0.61	7.7

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture	Surface Area
								(%)	m2/g

Mixed Fly Ash and Scrubber Sludge (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	6.5	3.5
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	4.9	4.9
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	13.9	14.5
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	4.7	10.2

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	51.4	13.3
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	32.1	20.7
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	27.2	7.4

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Organic Carbon	Elemental Carbon	Total Carbon	Loss on Ignition
								(%)	(%)	(%)	(%)
Mixed Fly Ash and Gypsum (as managed)											
Bituminous, Low S											
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	4.13	0.18	4.32	3.6
Filter Cake											
Bituminous, Med S											
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	2.43	1.03	3.46	12.6
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	9.05	1.01	10.1	17.7
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	2.01	0.39	2.41	6.1
Sub-bituminous											
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	6.13	1.00	7.13	18.7

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture	Surface Area
								(%)	m2/g

Mixed Fly Ash and Gypsum (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	11.8	7.0

Filter Cake

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	66.3	25.0
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	33.4	9.9
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	40.2	22.0

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Moisture (%)	Surface Area m2/g
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	55.2	35.7

BML - below method limit (not detected)

Appendix D

Total Content by Digestion

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection															
Bituminous, Low S															
Brayton Point	BPB	CS ESP	None	None	None	NA	81	NA	BML	NA	NA	NA	117	NA	51
Facility F	FFA	CS ESP	None	None	None	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	105900	90	1360	0.70	21	169	11	36	2.8	2.9
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	138200	88	1361	1.0	49	151	15	69	8.2	22
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	109400	82	1461	0 90	24	192	11	47	3.6	2.5
Facility U	UFA	CS ESP	SCR	None	None	92200	42	2143	14	22	214	77	55	6.3	3.8
Salem Harbor	SHB	CS ESP	SNCR	None	None	NA	26	NA	NA	NA	NA	NA	25	NA	42
Facility G	GFA	CS ESP	SNCR	None	None	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	127100	71	1016	1.3	55	152	17	81	14	26
Facility L	LAB	HS ESP	SOFA	None	None	NA	20	NA	0.4	NA	NA	NA	45	NA	4
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	NA	94	NA	NA	NA	NA	NA	56	NA	BML
Bituminous, Med S															
Facility T	TFA	CS ESP	None	None	None	93100	155	839	0.92	27	142	19	55	5.5	9.0
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	130600	32	1229	0.78	38	122	11	46	4.2	13
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Facility K	KFA	CS ESP	None	None	None	123200	85	585	1.0	38	124	23	93	6.0	4.8
Facility Aa	AaFA	CS ESP	SCR	None	None	85200	31	935	0 52	53	141	13	55	4.1	17
Facility Aa	AaFB	CS ESP	SCR	None	None	82000	36	900	0.68	55	134	15	60	5.2	30
Facility Da	DaFA	CS ESP	SCR	None	None	103600	58	1297	0.77	66	170	17	72	7.0	13
Facility Aa	AaFC	HS ESP	SCR	None	None	83200	73	1113	0.76	50	136	22	74	11	1.1

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Tl	Hg (7470)	Hg (7473)
						mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection								
Bituminous, Low S								
Brayton Point	BPB	CS ESP	None	None	None	NA	0.65	0.58
Facility F	FFA	CS ESP	None	None	None	NA	NA	NA
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	4.5	0.11	NA
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	3.2	0.38	NA
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	4.7	0.09	NA
Facility U	UFA	CS ESP	SCR	None	None	13	0.01	0.02
Salem Harbor	SHB	CS ESP	SNCR	None	None	NA	0.53	0.57
Facility G	GFA	CS ESP	SNCR	None	None	NA	NA	NA
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	3.8	0.60	NA
Facility L	LAB	HS ESP	SOFA	None	None	NA	0.01	NA
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	NA	0.02	0.01
Bituminous, Med S								
Facility T	TFA	CS ESP	None	None	None	6.0	0.59	0.70
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	NA	NA	NA
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Trona	2.3	0.16	NA
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	NA	NA	NA
Facility K	KFA	CS ESP	None	None	None	13	0.04	NA
Facility Aa	AaFA	CS ESP	SCR	None	None	2.0	0.15	0.23
Facility Aa	AaFB	CS ESP	SCR	None	None	2.2	0.22	0.34
Facility Da	DaFA	CS ESP	SCR	None	None	2.3	0.19	0.18
Facility Aa	AaFC	HS ESP	SCR	None	None	4.4	0.01	0.01

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection															
Bituminous, High S															
Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Facility H	HFA	CS ESP	SCR	None	None	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sub-Bituminous & Sub-bit/bituminous mix															
Pleasant Prairie	PPB	CS ESP	None	None	None	NA	21	NA	BML	NA	NA	NA	42	NA	BML
St. Clair	JAB	CS ESP	None	None	None	NA	43	NA	1.4	NA	NA	NA	46	NA	11
Facility Z	ZFA	CS ESP	None	None	None	68600	17	6907	1.5	34	70	8.4	41	2.5	11
Facility Z	ZFB	CS ESP	None	None	None	73800	22	7034	1.6	31	74	9.4	55	3.0	14
Facility X	XFA	CS ESP	SCR	None	None	98900	36	6306	1.8	29	129	22	51	4.2	15
Lignite															
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	77200	22	955	1.7	21	88	19	56	6.2	8.6

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Tl	Hg (7470)	Hg (7473)
						mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection								
Bituminous, High S								
Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	NA	NA	NA
Facility H	HFA	CS ESP	SCR	None	None	NA	NA	NA
Sub-Bituminous & Sub-bit/bituminous mix								
Pleasant Prairie	PPB	CS ESP	None	None	None	NA	0.16	0.15
St. Clair	JAB	CS ESP	None	None	None	NA	0.11	NA
Facility Z	ZFA	CS ESP	None	None	None	0.81	0.33	0.35
Facility Z	ZFB	CS ESP	None	None	None	0.72	0.63	0.61
Facility X	XFA	CS ESP	SCR	None	None	0.99	0.24	0.46
Lignite								
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	1.5	0.08	0.10

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Fly Ash without and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

Brayton Point	BPB	CS ESP	None	None	None	NA	81	NA	BML	NA	NA	NA	117	NA	51
Brayton Point	BPT	CS ESP	None	PAC	None	NA	28	NA	BML	NA	NA	NA	83	NA	152
Salem Harbor	SHB	CS ESP	SNCR	None	None	NA	26	NA	NA	NA	NA	NA	25	NA	42
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	NA	26	NA	NA	NA	NA	NA	24	NA	44
Facility L	LAB	HS ESP	SOFA	None	None	NA	20	NA	0.40	NA	NA	NA	45	NA	4.1
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	NA	19	NA	0 30	NA	NA	NA	42	NA	4.3
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	NA	94	NA	NA	NA	NA	NA	56	NA	BML
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	NA	506	NA	NA	NA	NA	NA	114	NA	206

Sub-bituminous (Class C)

Pleasant Prairie	PPB	CS ESP	None	None	None	NA	21	NA	BML	NA	NA	NA	42	NA	BML
Pleasant Prairie	PPT	CS ESP	None	PAC	None	NA	24	NA	BML	NA	NA	NA	47	NA	BML
St. Clair	JAB	CS ESP	None	None	None	NA	43	NA	1.4	NA	NA	NA	46	NA	11
St. Clair	JAT	CS ESP	None	Br-PAC	None	NA	41	NA	1.3	NA	NA	NA	35	NA	13

Lignite (Class C)

Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	63800	19	2381	0 99	16	66	6.9	30	2.7	10

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Spray dryer with Fabric Filter (fly ash and FGD collected together)

Sub-bituminous

Facility V	VSD	Fabric F.	SCR	None	None	58900	22	272	1.0	16	51	7.1	25	2.2	16
Facility Y	YSD	Fabric F.	SCR	None	None	51100	11	511	0.98	18	48	9.6	23	0.10	6.3

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Tl	Hg (7470)	Hg (7473)
						mg/kg	mg/kg	mg/kg
Fly Ash without and with Hg Sorbent Injection Pairs								
Bituminous, Low S (Class F)								
Brayton Point	BPB	CS ESP	None	None	None	NA	0.65	0.58
Brayton Point	BPT	CS ESP	None	PAC	None	NA	1.5	1.4
Salem Harbor	SHB	CS ESP	SNCR	None	None	NA	0.53	0.57
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	NA	0.41	0.45
Facility L	LAB	HS ESP	SOFA	None	None	NA	0.01	NA
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	NA	0.04	NA
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	NA	0.02	0.01
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	NA	1.2	1.1
Sub-bituminous (Class C)								
Pleasant Prairie	PPB	CS ESP	None	None	None	NA	0.16	0.15
Pleasant Prairie	PPT	CS ESP	None	PAC	None	NA	1.2	1.2
St. Clair	JAB	CS ESP	None	None	None	NA	0.11	NA
St. Clair	JAT	CS ESP	None	Br-PAC	None	NA	1.2	NA
Lignite (Class C)								
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	1.2	0.48	0.69

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Tl	Hg (7470)	Hg (7473)
						mg/kg	mg/kg	mg/kg
Spray dryer with Fabric Filter (fly ash and FGD collected toge								
Sub-bituminous								
Facility V	VSD	Fabric F.	SCR	None	None	0.60	0.18	0.35
Facility Y	YSD	Fabric F.	SCR	None	None	0.45	0.32	0.47

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed																		
Bituminous, Low S																		
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	4103	2.9	48	0.58	2.1	11	2.0	2.1	0.66	2.4	0.55
Bituminous, Med S																		
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	2108	3.8	47	0.61	2.0	13	5.6	1.4	3.1	4.9	1.1
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	1836	3.5	53	0.40	4.2	7.8	5.4	1.6	1.9	4.5	1.1
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	335	0.95	2.4	0.11	4.4	1.5	1.5	0.63	0.57	11	0.29
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	411	0.97	2.4	0.13	4.2	1.2	1.2	0.73	0.58	12	0.50
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	959	5.8	8.7	0.13	1.7	2.3	1.1	0.89	0.21	33	0.26
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	951	6.1	8.8	0.13	1.9	2.2	1.3	0.72	0.64	31	0.26
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	950	10	9.3	0.12	1.5	2.2	1.2	0.75	0.32	35	0.24
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	12700	2.6	53	0.30	3.5	5.7	2.4	3.3	2.6	19	0.60

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed																		
Bituminous, High S																		
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	8030	2.5	57	0.50	2.7	9.1	4.0	2.4	2.4	2.8	0.70
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	9836	3.5	53	0.40	2.6	18	3.7	5.5	2.1	2.6	0.70
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1691	3.0	19	0.56	2.3	9.8	4.8	3.0	5.1	3.7	1.2
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	2176	3.4	14	0.43	2.6	20	8.1	3.4	3.0	2.9	1.0
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	456	1.6	3.2	0.30	2.9	17	3.1	0.90	1.6	2.3	0.60
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	11600	3.8	52	0.40	3.3	8.3	4.6	12	1.9	2.3	0.60
Sub-bituminous																		
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	1270	2.1	67	0.50	2.1	5.8	5.0	2.6	8.2	3.2	1.0
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	3187	1.8	56	0.30	1.1	8.7	12	2.4	5.8	28.2	2.3
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	472	1.1	10	0.12	1.4	3.4	1.2	0.87	0.14	16	0.28
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	398	1.0	14	0.31	0.77	2.5	3.1	0.51	0.50	9.8	0.60
Lignite																		
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	4595	3.1	19	0.12	2.5	7.7	3.7	3.3	0.46	46	0.28

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
								mg/kg	mg/kg

Gypsum, unwashed and washed

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.25	0.09

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.80	0.51
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.89	0.66
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.77	0.62
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.79	NA
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.53	0.63
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.37	0.49
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.45	0.43
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	0.01	NA

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
								mg/kg	mg/kg

Gypsum, unwashed and washed

Bituminous, High S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.54	NA
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.05	NA
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.31	0.26
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.30	0.26
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.39	NA
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.04	NA

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.26	0.23
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	0.51	NA
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1.2	2.0
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.82	0.94

Lignite

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1.8	3.1

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Scrubber Sludge																		
Bituminous, Low S																		
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	12700	10	76	0.60	1.5	21	14	11	8.8	1.8	3.5
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	7969	3.6	82	0.30	1.0	9.2	8.9	2.5	3.9	2.1	2.4
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	198100	23	2426	1.5	42	343	27	13	7.8	2.9	12
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	12700	7.3	147	0.40	3.4	12	19	4.8	9.4	3.0	3.7
Bituminous, Med S																		
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	40300	41	243	0.8	13	49	26	26	13	4.2	4.6

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mixed Fly Ash and Scrubber Sludge (as managed)																		
Bituminous, Low S																		
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	35100	16	370	0.8	6.4	53	8.6	9.7	4.7	2.0	0.8
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	106500	72	1065	0.7	40	119	11	55	5.7	23	2.5
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	29400	4.3	100	0.9	2.4	35	26	5.7	14	2.4	6.4
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	114000	56	713	1.2	45	130	14	64	9.7	20	3.4
Bituminous, Med S																		
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	30600	3.3	77	1.0	1.7	39	31	3.7	17	3.9	7.9
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	46500	44	232	1.6	20	54	22	68	6.0	2.0	4.2
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	44900	42	262	1.4	22	53	18	95	9.6	3.9	3.3

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
								mg/kg	mg/kg
Scrubber Sludge									
Bituminous, Low S									
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.30	NA
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.43	NA
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	0.61	NA
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.05	NA
Bituminous, Med S									
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	0.57	NA

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
								mg/kg	mg/kg
Mixed Fly Ash and Scrubber Sludge (as managed)									
Bituminous, Low S									
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.20	NA
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.39	NA
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	0.41	NA
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.51	NA
Bituminous, Med S									
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	1.0	NA
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	0.23	NA
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	0.36	NA

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mixed Fly Ash and Gypsum (as managed)																		
Bituminous, Low S																		
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	13800	5.9	525	1.1	11	46	9.9	6.4	1.5	2.6	0.98
Filter Cake																		
Bituminous, Med S																		
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	41700	89	867	3.4	29	118	22	24	8.2	168	2.5
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent in	4530	8.1	40	0.92	10	15	7.5	13	2.0	215	0.62
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	36100	230	406	1.1	31	105	15	52	5.2	1800	0.47
Sub-bituminous																		
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	22800	19	455	2.8	22	138	33	39	0.21	1127	1.6

BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg (7470)	Hg (7473)
								mg/kg	mg/kg
Mixed Fly Ash and Gypsum (as managed)									
Bituminous, Low S									
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	0.03	0.05
Filter Cake									
Bituminous, Med S									
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	27	8.6
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent in	9.2	10
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	37	34
Sub-bituminous									
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	54	65

BML - below method limit (not detected); NA - not analyzed.

Appendix E

Total Content by XRF

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	Ba	C	Ca	Cl
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

Brayton Point	BPB	CS ESP	None	None	None	150450	755	22500	46870	184
Facility F	FFA	CS ESP	None	None	None	150450	1145	41500	6004	191
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	109975	1223	14600	31075	295
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	128125	1240	36900	36050	6103
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	108433	1280	19300	34050	440
Facility U	UFA	CS ESP	SCR	None	None	114850	2130	1100	33450	295
Salem Harbor	SHB	CS ESP	SNCR	None	None	120250	812	78000	12265	660
Facility G	GFA	CS ESP	SNCR	None	None	152717	1031	27400	5848	262
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	114425	956	91500	35275	5418
Facility L	LAB	HS ESP	SOFA	None	None	131900	652	122800	3283	389
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	122475	2058	180000	20700	373

Bituminous, Med S

Facility T	TFA	CS ESP	None	None	None	134025	1010	83300	14293	344
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	150775	1630	25200	6523	132
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	140950	741	67400	9692	2120
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	136300	1285	76900	6948	758
Facility K	KFA	CS ESP	None	None	None	124250	582	2100	14150	BML
Facility Aa	AaFA	CS ESP	SCR	None	None	138800	1111	84200	5682	1538
Facility Aa	AaFB	CS ESP	SCR	None	None	133600	1061	134300	6032	391
Facility Da	DaFA	CS ESP	SCR	None	None	148400	1366	55600	6835	163
Facility Aa	AaFC	HS ESP	SCR	None	None	156300	1281	42200	14265	611

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	F	Fe	K	Mg	Na	P
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection											
Bituminous, Low S											
Brayton Point	BPB	CS ESP	None	None	None	BML	32185	12930	7339	9736	1513
Facility F	FFA	CS ESP	None	None	None	BML	32653	21750	5061	1898	517
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	BML	111000	18700	7735	6625	1703
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	BML	52025	20950	9313	3617	1373
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	BML	107817	19600	8688	7242	2353
Facility U	UFA	CS ESP	SCR	None	None	BML	98965	26605	6392	7592	2725
Salem Harbor	SHB	CS ESP	SNCR	None	None	BML	42935	10415	7330	5299	940
Facility G	GFA	CS ESP	SNCR	None	None	BML	29617	21213	4919	1849	451
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	BML	46750	16700	8345	3753	1223
Facility L	LAB	HS ESP	SOFA	None	None	BML	23850	22650	5838	1335	262
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	BML	74325	18400	6790	3743	3028
Bituminous, Med S											
Facility T	TFA	CS ESP	None	None	None	BML	98210	16053	4085	4030	1416
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	BML	41425	24700	6248	2418	731
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	BML	47520	17138	3545	18945	880
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	BML	56200	21500	4948	2348	768
Facility K	KFA	CS ESP	None	None	None	BML	161175	15800	5898	2588	1083
Facility Aa	AaFA	CS ESP	SCR	None	None	BML	29870	17020	3655	2193	532
Facility Aa	AaFB	CS ESP	SCR	None	None	BML	29840	15425	3579	1802	613
Facility Da	DaFA	CS ESP	SCR	None	None	BML	31995	21625	4657	2379	1074
Facility Aa	AaFC	HS ESP	SCR	None	None	BML	62910	19570	4733	4811	723

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S	Si	Sr	Ti
						mg/kg	mg/kg	mg/kg	mg/kg

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S	Si	Sr	Ti
Brayton Point	BPB	CS ESP	None	None	None	3985	239350	850	6683
Facility F	FFA	CS ESP	None	None	None	2938	259550	594	8454
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	5115	211650	991	5700
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	3935	230825	1158	9308
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	7110	212333	1112	BML
Facility U	UFA	CS ESP	SCR	None	None	9071	231650	344	6306
Salem Harbor	SHB	CS ESP	SNCR	None	None	4345	262500	384	3673
Facility G	GFA	CS ESP	SNCR	None	None	2093	267717	563	8571
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	3638	195000	922	7665
Facility L	LAB	HS ESP	SOFA	None	None	2275	247525	322	8820
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	5435	174825	1433	7093

Bituminous, Med S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S	Si	Sr	Ti
Facility T	TFA	CS ESP	None	None	None	7512	202850	824	6814
Facility E	*EFB*	*CS ESP*	*SCR-BP*	*None*	*None*	2265	254625	672	9060
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	9403	228450	582	7788
Facility E	*EFA*	*CS ESP*	*SCR*	*None*	*None*	7743	236375	695	8550
Facility K	KFA	CS ESP	None	None	None	2980	213325	512	6208
Facility Aa	AaFA	CS ESP	SCR	None	None	2720	255450	661	8008
Facility Aa	AaFB	CS ESP	SCR	None	None	4602	235900	691	7782
Facility Da	DaFA	CS ESP	SCR	None	None	2134	254850	639	8470
Facility Aa	AaFC	HS ESP	SCR	None	None	3654	226900	1063	7587

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	Ba	C	Ca	Cl
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection										
Bituminous, High S										
Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	151650	826	22000	7298	361
Facility H	HFA	CS ESP	SCR	None	None	111250	570	9400	44645	159
Sub-Bituminous & Sub-bit/bituminous mix										
Pleasant Prairie	PPB	CS ESP	None	None	None	119450	4579	2500	138400	57
St. Clair	JAB	CS ESP	None	None	None	106475	12000	1600	120875	156
Facility Z	ZFA	CS ESP	None	None	None	100750	7342	10000	184900	160
Facility Z	ZFB	CS ESP	None	None	None	104800	7219	10600	174450	194
Facility X	XFA	CS ESP	SCR	None	None	107800	5864	1600	163025	173
Lignite										
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	132500	1151	5900	62875	236

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	F	Fe	K	Mg	Na	P
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Fly Ash without Hg Sorbent Injection

Bituminous, High S

Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	BML	49800	19675	4970	1945	777
Facility H	HFA	CS ESP	SCR	None	None	BML	132750	19810	4816	2378	1574

Sub-Bituminous & Sub-bit/bituminous mix

Pleasant Prairie	PPB	CS ESP	None	None	None	BML	29530	2626	37265	30965	5301
St. Clair	JAB	CS ESP	None	None	None	BML	53625	7968	30725	46675	2195
Facility Z	ZFA	CS ESP	None	None	None	1195	39180	4084	32375	20595	6548
Facility Z	ZFB	CS ESP	None	None	None	1322	40395	4394	31125	21240	7656
Facility X	XFA	CS ESP	SCR	None	None	BML	38250	4837	23903	16330	5092

Lignite

Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	BML	31290	7698	8318	1800	533

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S	Si	Sr	Ti
						mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without Hg Sorbent Injection									
Bituminous, High S									
Facility E	*EFC*	*CS ESP*	*SCR*	*None*	*None*	2555	254200	554	9328
Facility H	HFA	CS ESP	SCR	None	None	6259	200950	365	22879
Sub-Bituminous & Sub-bit/bituminous mix									
Pleasant Prairie	PPB	CS ESP	None	None	None	7528	177100	2570	6197
St. Clair	JAB	CS ESP	None	None	None	12275	166875	5665	7610
Facility Z	ZFA	CS ESP	None	None	None	8838	155650	2949	8655
Facility Z	ZFB	CS ESP	None	None	None	8522	157850	3050	8239
Facility X	XFA	CS ESP	SCR	None	None	13660	174075	3209	8389
Lignite									
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	2050	262600	733	8167

BML - below method limit (not detected)

Fly Ash without and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
Brayton Point	BPB	CS ESP	None	None	None	150450	755	22500	46870	184
Brayton Point	BPT	CS ESP	None	PAC	None	133250	736	130000	13390	2387
Salem Harbor	SHB	CS ESP	SNCR	None	None	120250	812	78000	12265	660
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	97595	827	112000	7480	1007
Facility L	LAB	HS ESP	SOFA	None	None	131900	652	122800	3283	389
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	131450	632	123800	3185	339
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	122475	2058	180000	20700	373
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	89600	1475	362600	19150	790

Sub-bituminous (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
Pleasant Prairie	PPB	CS ESP	None	None	None	119450	4579	2500	138400	57
Pleasant Prairie	PPT	CS ESP	None	PAC	None	120800	4261	36000	124600	233
St. Clair	JAB	CS ESP	None	None	None	106475	12000	1600	120875	156
St. Clair	JAT	CS ESP	None	Br-PAC	None	102125	10075	26500	114150	414

Lignite (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	105650	2973	5700	105950	310

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	F	Fe	K	Mg	Na	P
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fly Ash without and with Hg Sorbent Injection Pairs											
Bituminous, Low S (Class F)											
Brayton Point	BPB	CS ESP	None	None	None	BML	32185	12930	7339	9736	1513
Brayton Point	BPT	CS ESP	None	PAC	None	39730	15895	9259	5553	4309	337
Salem Harbor	SHB	CS ESP	SNCR	None	None	BML	42935	10415	7330	5299	940
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	BML	32835	8519	4011	6266	668
Facility L	LAB	HS ESP	SOFA	None	None	BML	23850	22650	5838	1335	262
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	BML	23625	22225	5795	1320	240
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	BML	74325	18400	6790	3743	3028
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	BML	59025	13400	5863	2865	1840
Sub-bituminous (Class C)											
Pleasant Prairie	PPB	CS ESP	None	None	None	BML	29530	2626	37265	30965	5301
Pleasant Prairie	PPT	CS ESP	None	PAC	None	BML	29300	3283	31605	24615	4974
St. Clair	JAB	CS ESP	None	None	None	BML	53625	7968	30725	46675	2195
St. Clair	JAT	CS ESP	None	Br-PAC	None	BML	55550	7723	29325	41075	1705
Lignite (Class C)											
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	BML	33890	8963	17175	9310	1450

BML - below method limit (not detected)

Fly Ash without and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg
Brayton Point	BPB	CS ESP	None	None	None	3985	239350	850	6683
Brayton Point	BPT	CS ESP	None	PAC	None	6444	223450	520	6073
Salem Harbor	SHB	CS ESP	SNCR	None	None	4345	262500	384	3673
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	5183	279450	300	3493
Facility L	LAB	HS ESP	SOFA	None	None	2275	247525	322	8820
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	2245	248000	322	8775
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	5435	174825	1433	7093
Facility C	GAT	HS ESP w/ COHPAC	None	PAC	None	11825	129150	1040	5740

Sub-bituminous (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg
Pleasant Prairie	PPB	CS ESP	None	None	None	7528	177100	2570	6197
Pleasant Prairie	PPT	CS ESP	None	PAC	None	12155	172750	2382	6011
St. Clair	JAB	CS ESP	None	None	None	12275	166875	5665	7610
St. Clair	JAT	CS ESP	None	Br-PAC	None	10300	170875	5205	7178

Lignite (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	4717	239050	2533	6651

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Al	Ba	C	Ca	Cl
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Spray dryer with Fabric Filter (fly ash and FGD collected together)										
Sub-bituminous										
Facility V	VSD	Fabric F.	SCR	None	None	57035	5705	4500	255050	836
Facility Y	YSD	Fabric F.	SCR	None	None	57588	4150	42500	252800	16403

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	F	Fe	K	Mg	Na	P
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Spray dryer with Fabric Filter (fly ash and FGD collected together)											
Sub-bituminous											
Facility V	VSD	Fabric F.	SCR	None	None	BML	30975	2531	21885	9440	3545
Facility Y	YSD	Fabric F.	SCR	None	None	BML	27000	4214	16300	31635	3122

BML - below method limit (not detected)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	S	Si	Sr	Ti
						mg/kg	mg/kg	mg/kg	mg/kg
Spray dryer with Fabric Filter (fly ash and FGD collected together)									
Sub-bituminous									
Facility V	VSD	Fabric F.	SCR	None	None	83575	91475	3083	6068
Facility Y	YSD	Fabric F.	SCR	None	None	52880	97668	1949	5571

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed												
Bituminous, Low S												
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	3532	BML	26900	309650	414
Bituminous, Med S												
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	1661	BML	16400	292950	4816
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	2099	BML	43000	288750	415
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	388	BML	23400	303800	2805
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	404	BML	31600	298525	275
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1705	BML	49500	281400	1270
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1140	BML	27400	288700	571
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1281	BML	12800	296900	215
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	1470	BML	1200	306650	368

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed													
Bituminous, Low S													
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	BML	5881	906	4553	204	78
Bituminous, Med S													
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	BML	1610	440	1927	897	88
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	BML	1830	401	399	197	100
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1273	1004	128	1710	167	42
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	956	887	138	989	BML	40
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1124	1252	391	370	593	38
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1386	1160	352	304	775	37
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1040	1287	380	512	241	38
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	925	1783	376	264	BML	199

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
								mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed											
Bituminous, Low S											
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	198200	9024	359	281
Bituminous, Med S											
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	219725	4173	397	BML
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	213675	4882	382	129
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	216000	1138	145	BML
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	217700	1061	133	BML
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	216500	3054	146	BML
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	222400	2427	144	BML
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	223550	3105	148	BML
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	222600	2821	122	BML

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Gypsum, unwashed and washed

Bituminous, High S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	729	BML	5500	309050	1639
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	672	BML	5100	306350	284
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	2976	BML	19900	290200	2506
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	3228	BML	12100	292500	257
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1419	227	29300	299000	869
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	1133	BML	23500	301100	222

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	1862	BML	29800	293200	272
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	4623	BML	9100	305800	1205
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1002	BML	36500	278900	1341
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	449	BML	23400	293800	174

Lignite

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	3933	BML	16400	291550	1255

BML - below method limit (not detected)

Gypsum, unwashed and washed

Bituminous, High S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	BML	1690	BML	201	178	389
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	BML	1583	BML	58	BML	367
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	BML	1916	706	3390	558	88
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	BML	2025	710	1998	220	101
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	BML	2202	380	1601	138	BML
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	BML	2114	320	1219	BML	BML

Sub-bituminous

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	BML	1393	453	1411	174	67
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	3775	1679	468	7054	1093	366
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	1724	1257	326	5861	520	65
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	BML	747	122	1164	BML	40

Lignite

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1365	1667	370	4134	565	50

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
								mg/kg	mg/kg	mg/kg	mg/kg
Gypsum, unwashed and washed											
Bituminous, High S											
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	219100	3641	281	BML
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	222000	3190	289	BML
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	213600	10095	331	184
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	215800	11705	331	232
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	212900	4698	534	BML
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	215200	4415	527	BML
Sub-bituminous											
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	215800	5473	147	BML
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	201800	13035	177	207
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	218800	4146	151	BML
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	223450	1451	160	BML
Lignite											
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	214900	8342	222	158

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Scrubber Sludge												
Bituminous, Low S												
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	2168	BML	4400	309600	4580
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	4392	150	3900	272867	6320
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	19075	382	11500	263450	3665
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	7380	161	4500	278500	7253
Bituminous, Med S												
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	24950	213	7100	249725	1900

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Scrubber Sludge													
Bituminous, Low S													
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	BML	3070	486	14475	522	79
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	2687	2803	1147	2943	711	307
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	BML	32450	4008	10625	1605	355
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	1670	5348	2093	8400	1335	397
Bituminous, Med S													
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	BML	36100	3745	11575	62	238

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
								mg/kg	mg/kg	mg/kg	mg/kg
Scrubber Sludge											
Bituminous, Low S											
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	168475	6533	168	191
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	138650	9775	136	202
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	135375	38350	405	1485
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	144250	20700	215	301
Bituminous, Med S											
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	178225	32100	324	1558

BML - below method limit (not detected)

Mixed Fly Ash and Scrubber Sludge (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	15825	311	10800	286100	5853
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	105550	1088	39800	74300	5138
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	4263	136	6600	281425	3815
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	97525	917	93000	78125	7428

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	1628	BML	8500	291100	812
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	31470	266	13000	206600	2088
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	29445	331	7500	234550	703

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg

Mixed Fly Ash and Scrubber Sludge (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	BML	16100	3655	14500	1400	257
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	BML	44225	17225	8590	3348	1110
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	BML	9193	908	9943	656	96
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	BML	42575	15275	9773	3260	1010

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	BML	938	165	9933	355	BML
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	BML	67660	7495	4829	944	271
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	BML	63570	6954	2953	4344	202

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
								mg/kg	mg/kg	mg/kg	mg/kg

Mixed Fly Ash and Scrubber Sludge (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	148425	30975	378	1255
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	32725	185575	999	7875
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	157725	10053	196	380
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	36975	162950	763	6683

Bituminous, Med S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	220400	5075	231	79
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	149650	66170	314	2303
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	180050	61595	330	2504

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Al	Ba	C	Ca	Cl
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mixed Fly Ash and Gypsum (as managed)												
Bituminous, Low S												
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	12408	738	43200	351700	701
Filter Cake												
Bituminous, Med S												
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	46055	884	34600	157600	16348
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	5870	BML	100500	306367	3877
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	44050	581	24100	198150	8267
Sub-bituminous												
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	28450	649	71300	109400	9140

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	F	Fe	K	Mg	Na	P
								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mixed Fly Ash and Gypsum (as managed)													
Bituminous, Low S													
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	BML	99953	2385	9883	572	545
Filter Cake													
Bituminous, Med S													
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	10157	55558	12138	13168	2355	1769
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	15923	16083	2808	17620	454	629
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	47385	42215	13070	13205	1308	1572
Sub-bituminous													
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	27640	68475	11720	77370	3387	2181

BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
								mg/kg	mg/kg	mg/kg	mg/kg

Mixed Fly Ash and Gypsum (as managed)

Bituminous, Low S

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	85198	27858	540	1328

Filter Cake

Bituminous, Med S

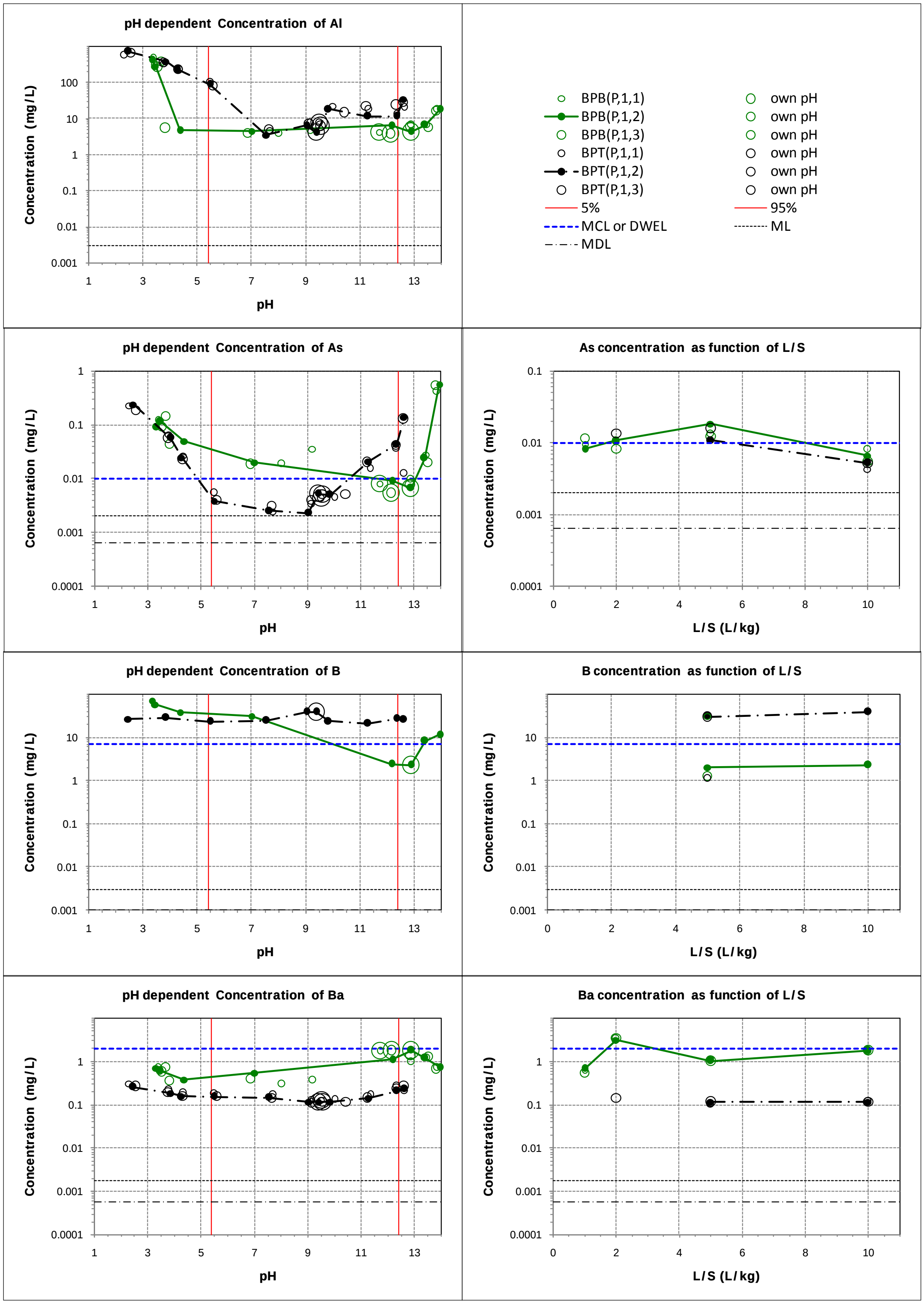
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
Facility T	TFC	Other	CS ESP	None	Forced Ox.	Limestone	None	109750	101175	358	2008
Facility W	WFC	Other	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	135167	18807	164	429
Facility Da	DaFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	93545	98485	202	3051

Sub-bituminous

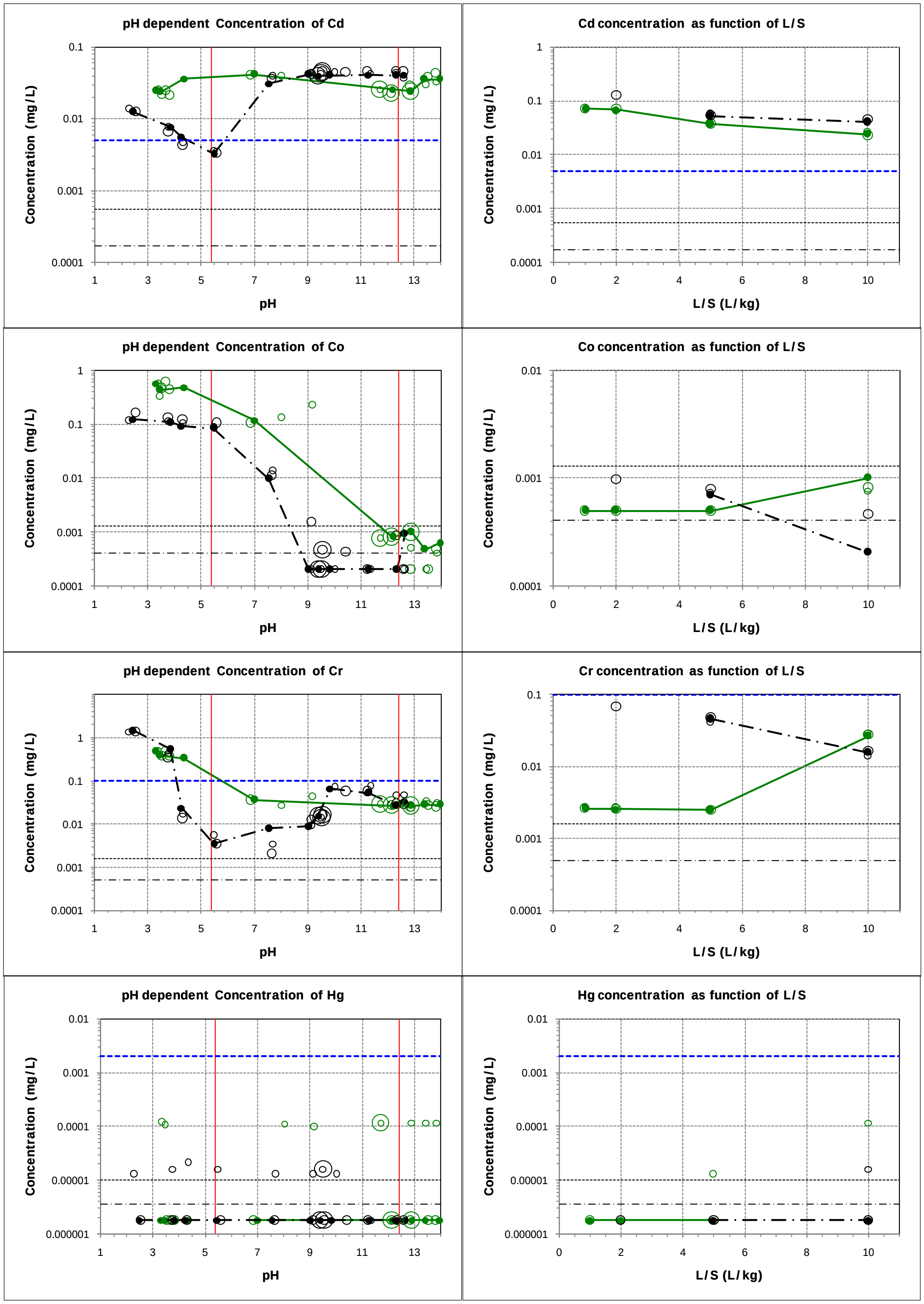
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	S	Si	Sr	Ti
Facility X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	96640	80960	156	2088

BML - below method limit (not detected)

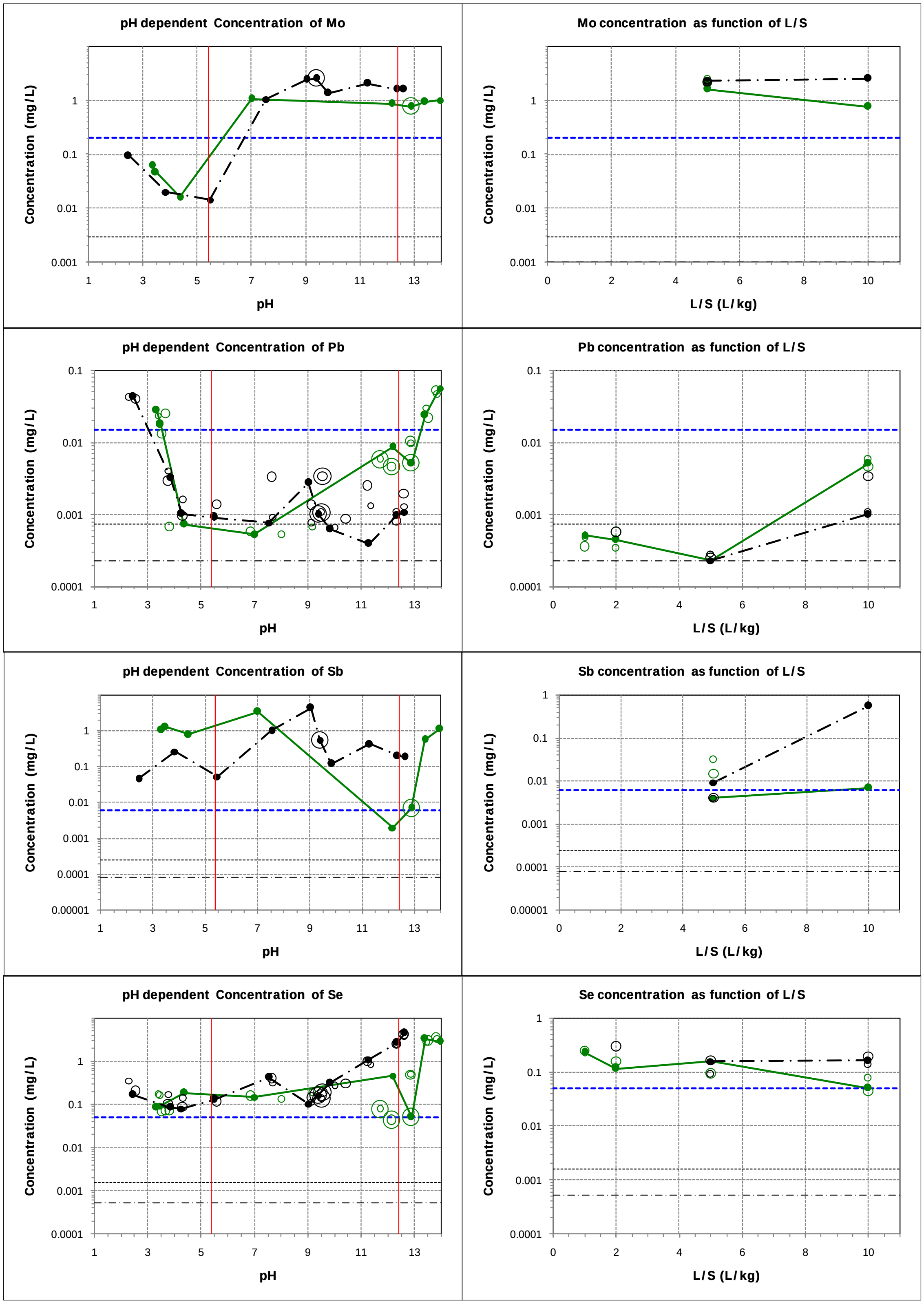
Appendix F
Leaching Test Results
SR002 - Concentration as a Function of pH and
SR003 - Concentration as a Function of LS
Elements Reported: Al, As, B, Ba, Cd, Co, Cr, Hg, Mo, Pb, Sb, Se, and Tl



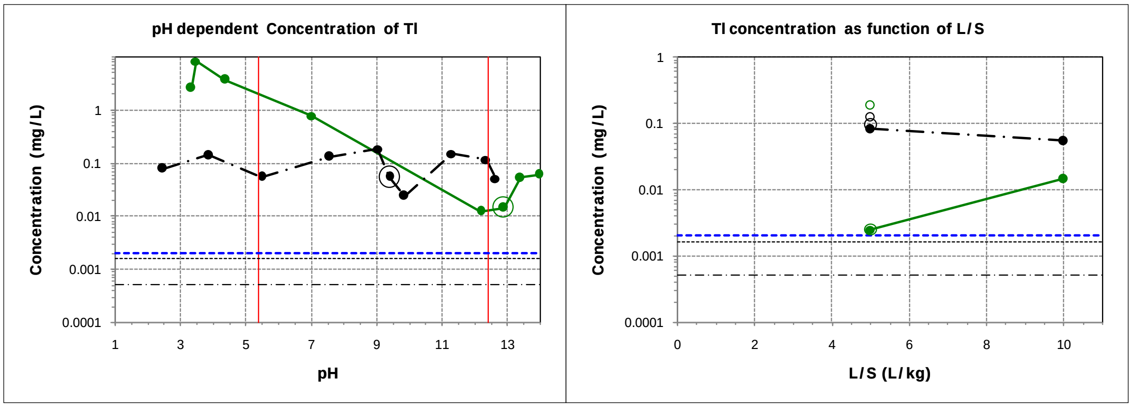
Brayton Point (East-Bit., CS-ESP). **BPB** - fly ash without ACI; **BPT** - fly ash with ACI.



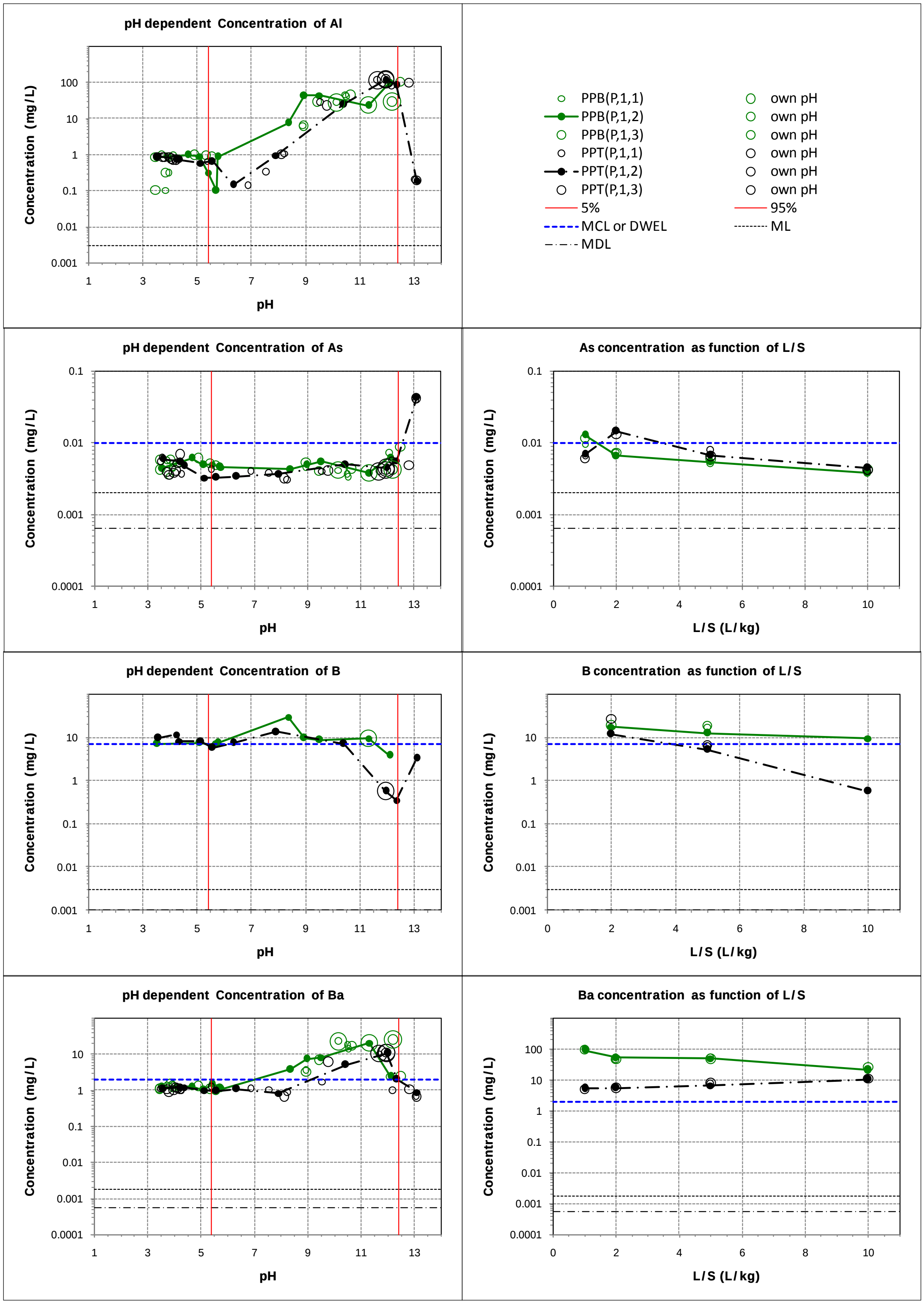
Brayton Point (East-Bit., CS-ESP). **BPB** - fly ash without ACI; **BPT** - fly ash with ACI.



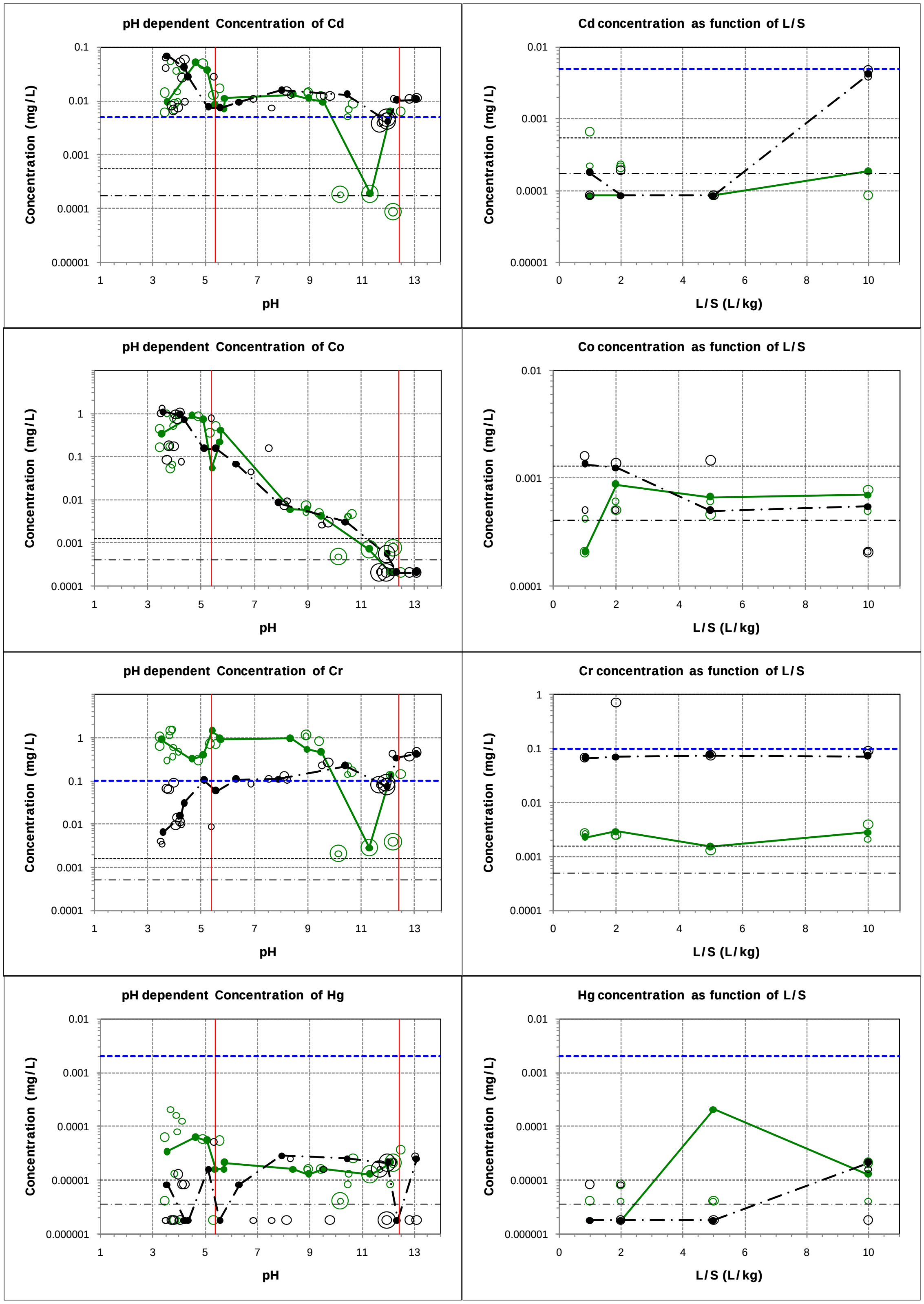
Brayton Point (East-Bit., CS-ESP). **BPB -** fly ash without ACI; **BPT -** fly ash with ACI.



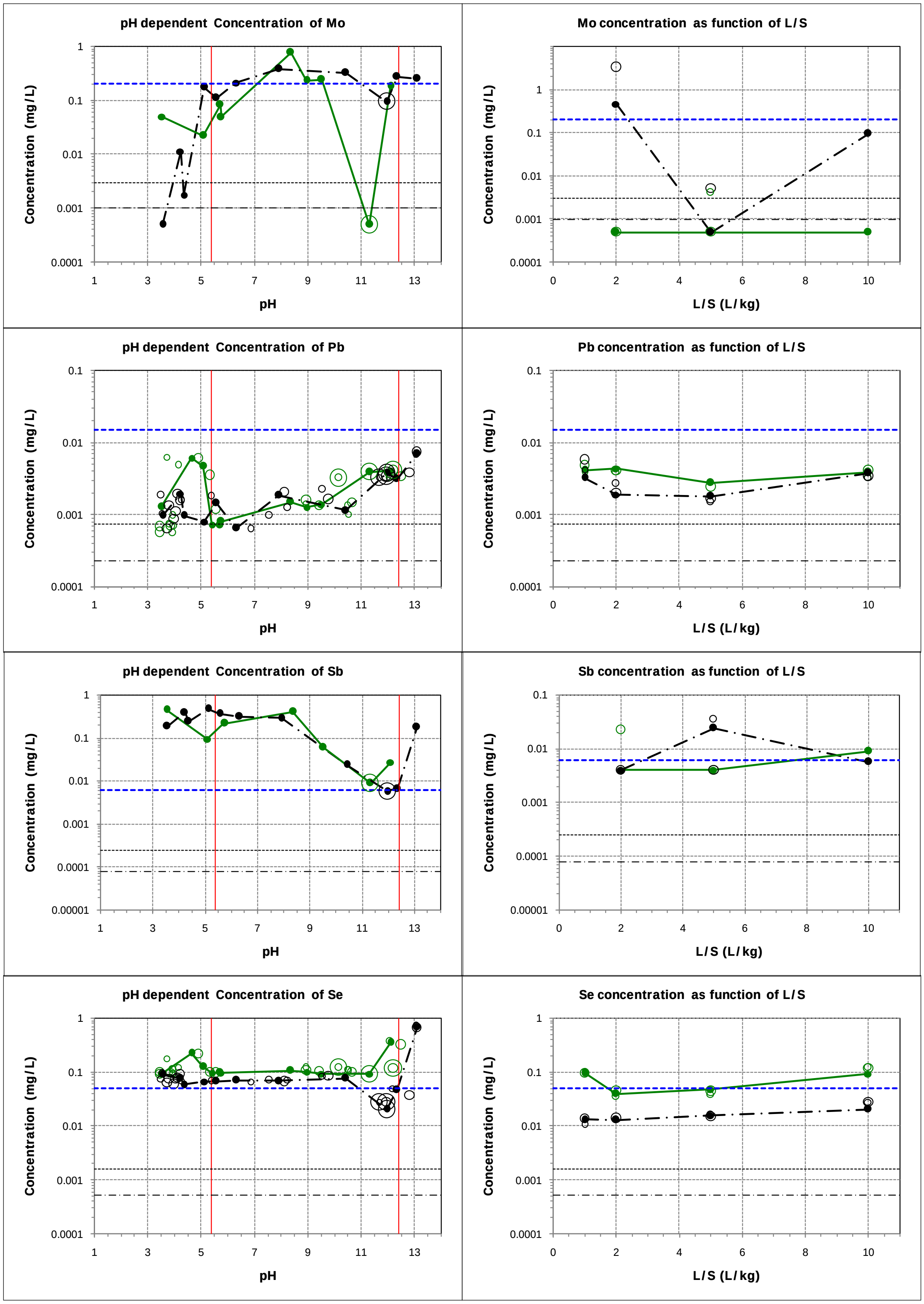
Brayton Point (East-Bit., CS-ESP). **BPB -** fly ash without ACI; **BPT -** fly ash with ACI.



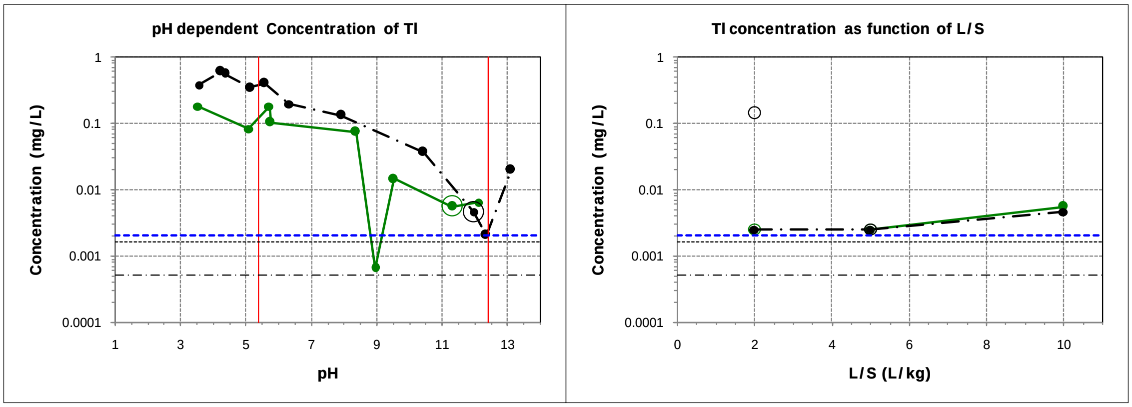
Pleasant Prairie (PRB, CS-ESP). **PPB** - fly ash without ACI; **PPT** - fly ash with ACI.



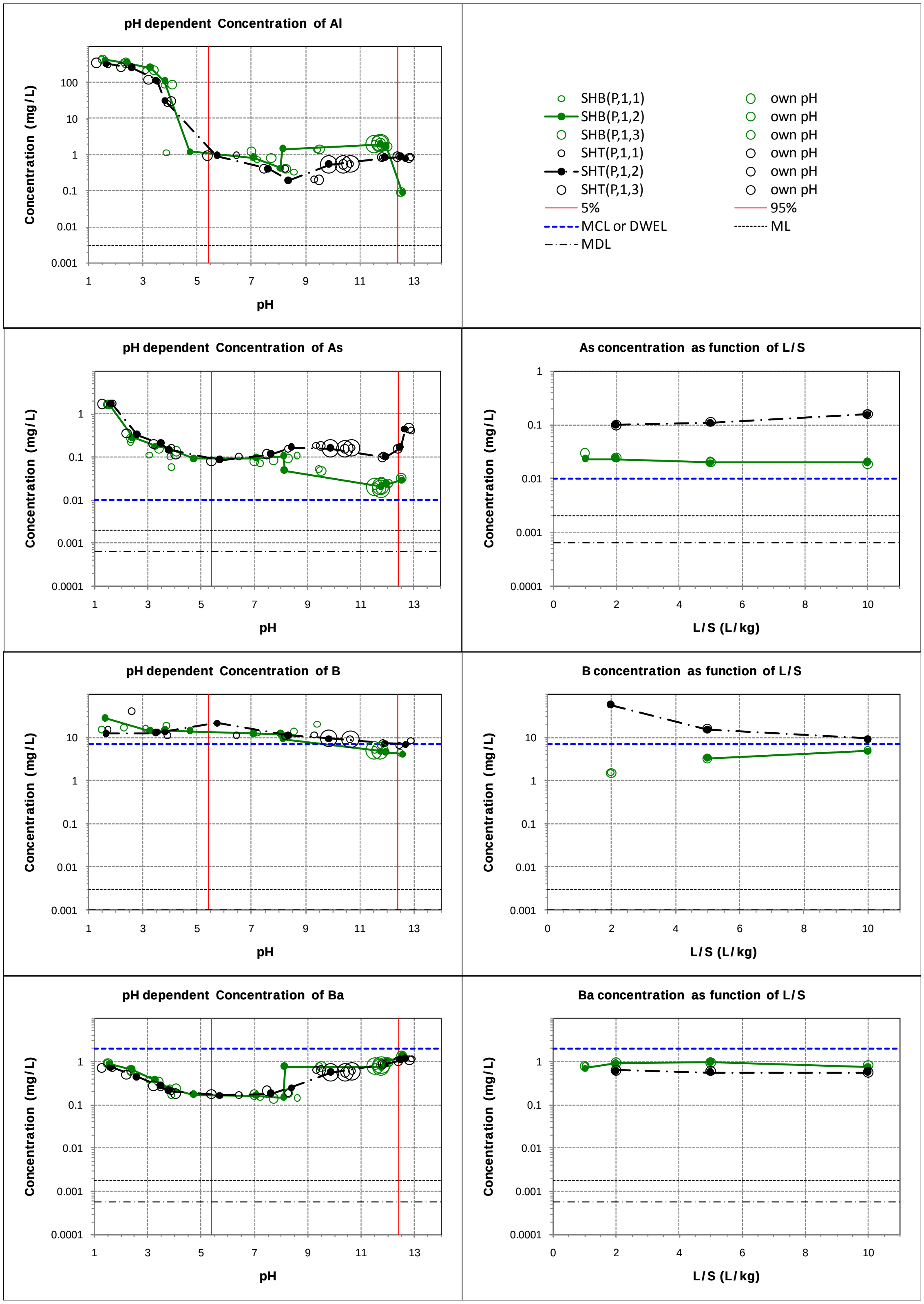
Pleasant Prairie (PRB, CS-ESP). **PPB -** fly ash without ACI; **PPT -** fly ash with ACI.



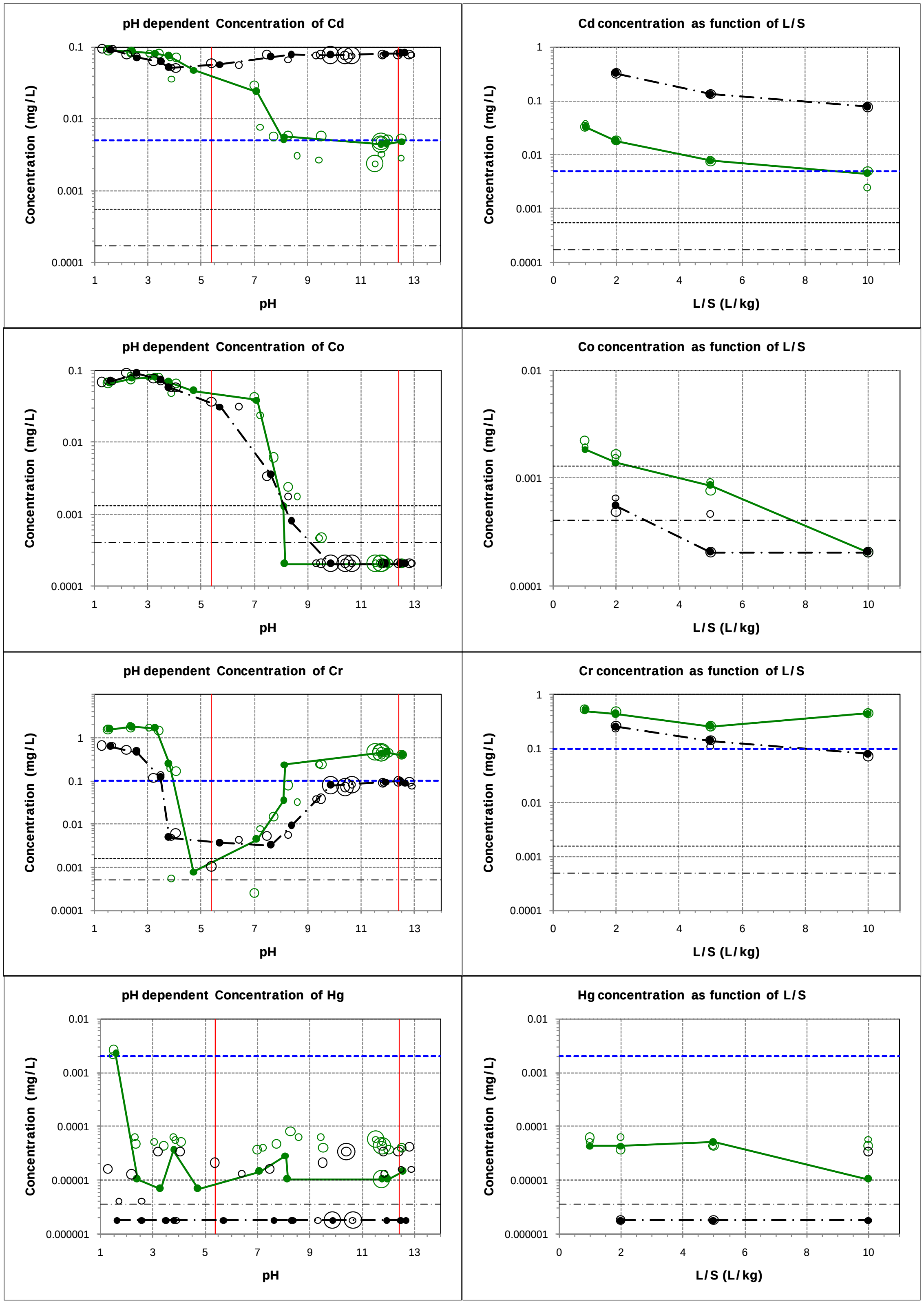
Pleasant Prairie (PRB, CS-ESP). **PPB -** fly ash without ACI; **PPT -** fly ash with ACI.



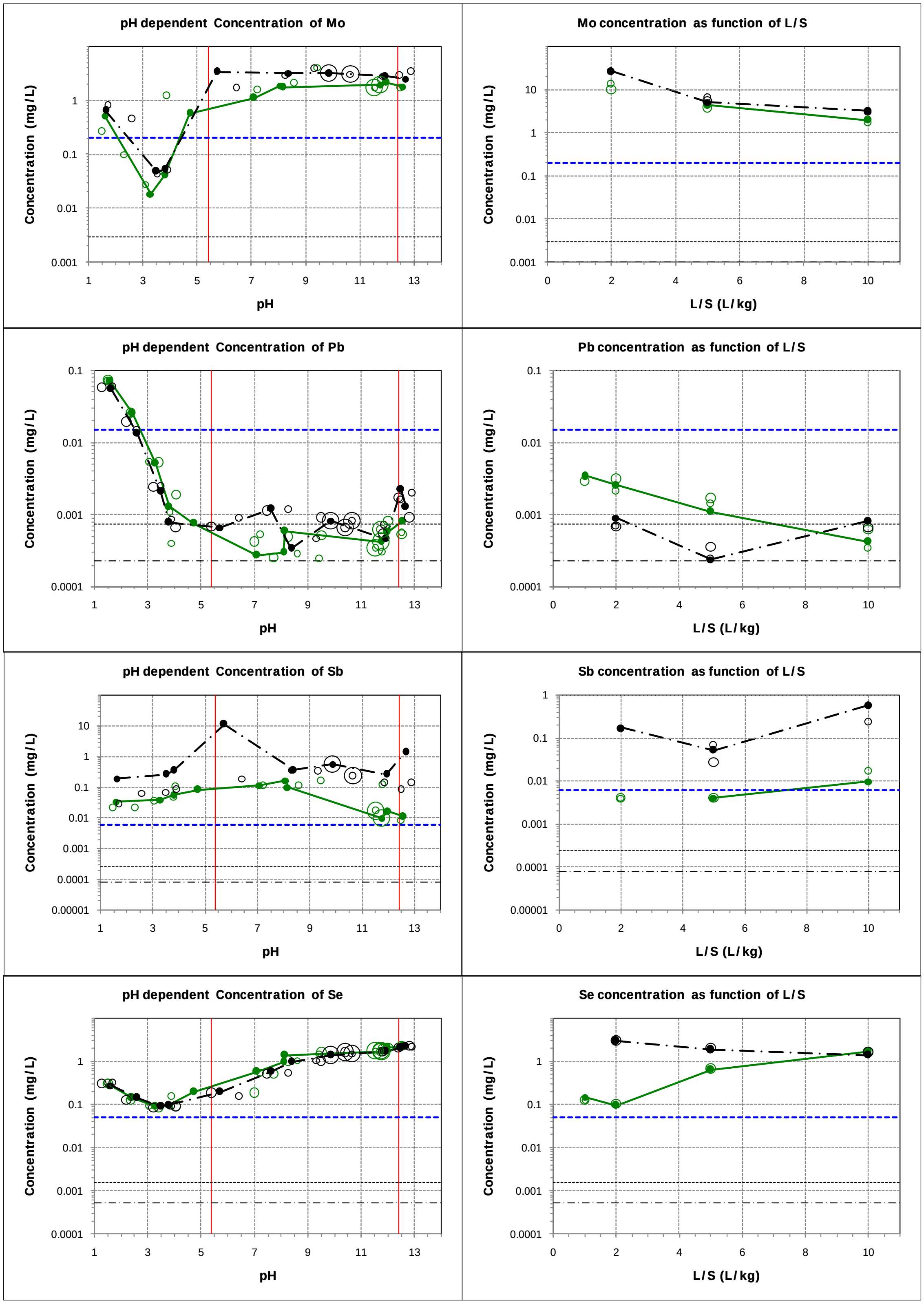
Pleasant Prairie (PRB, CS-ESP). **PPB** - fly ash without ACI; **PPT** - fly ash with ACI.



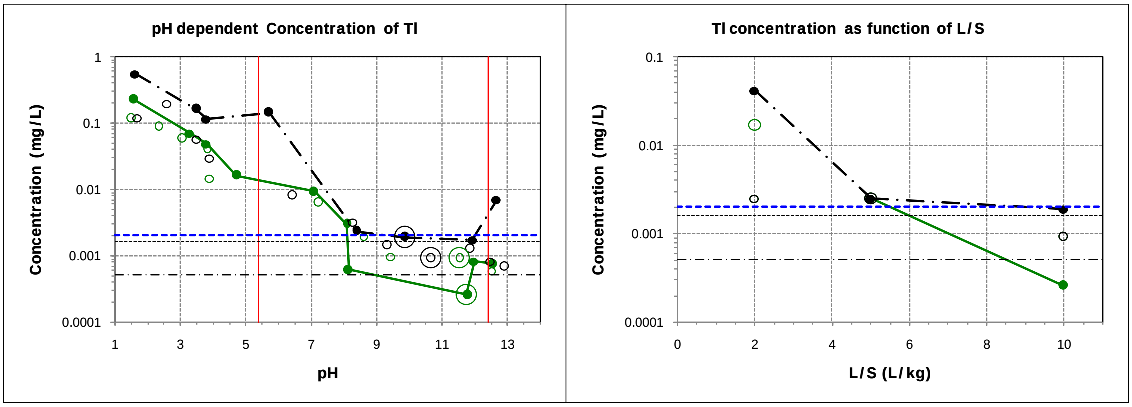
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



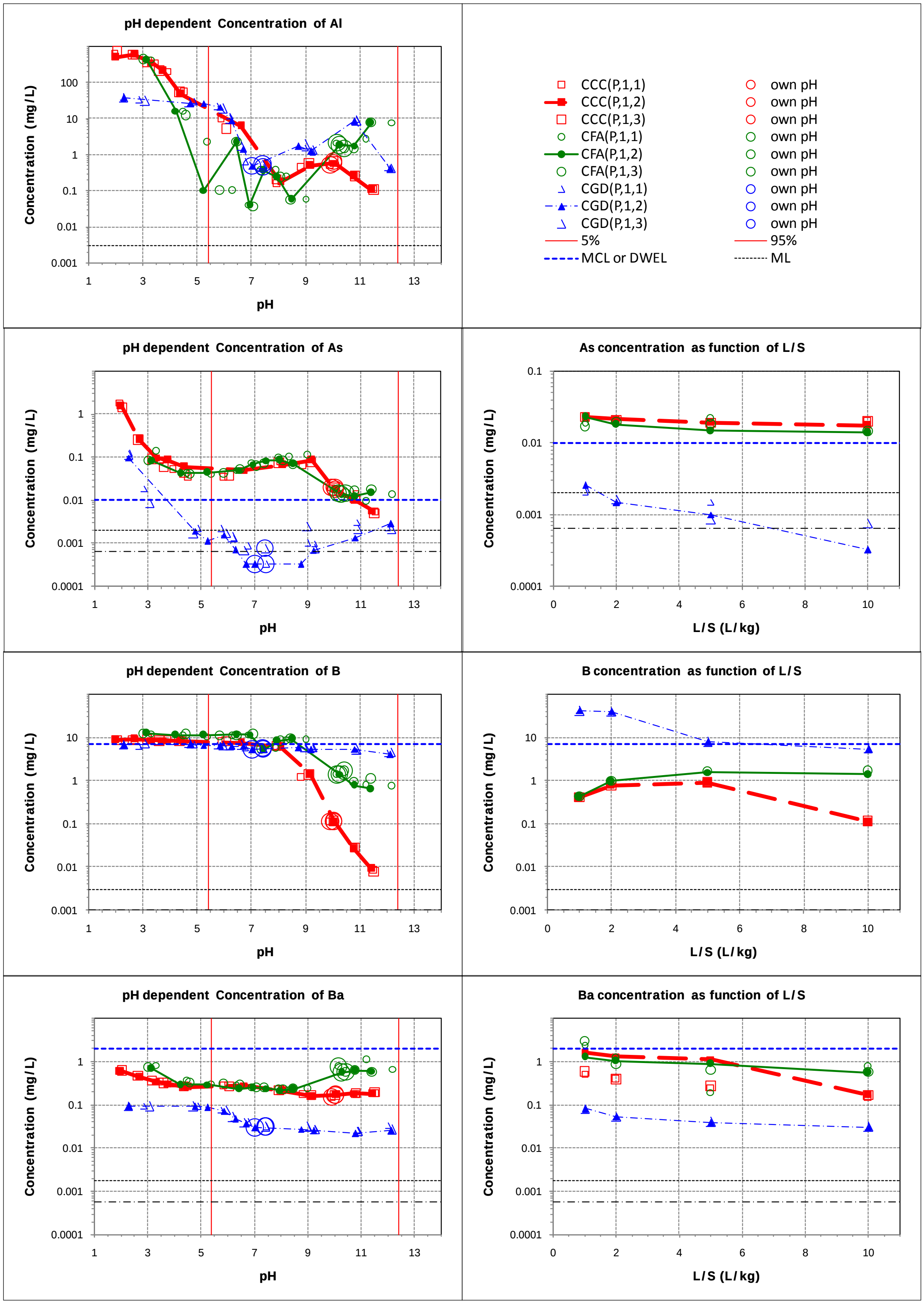
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



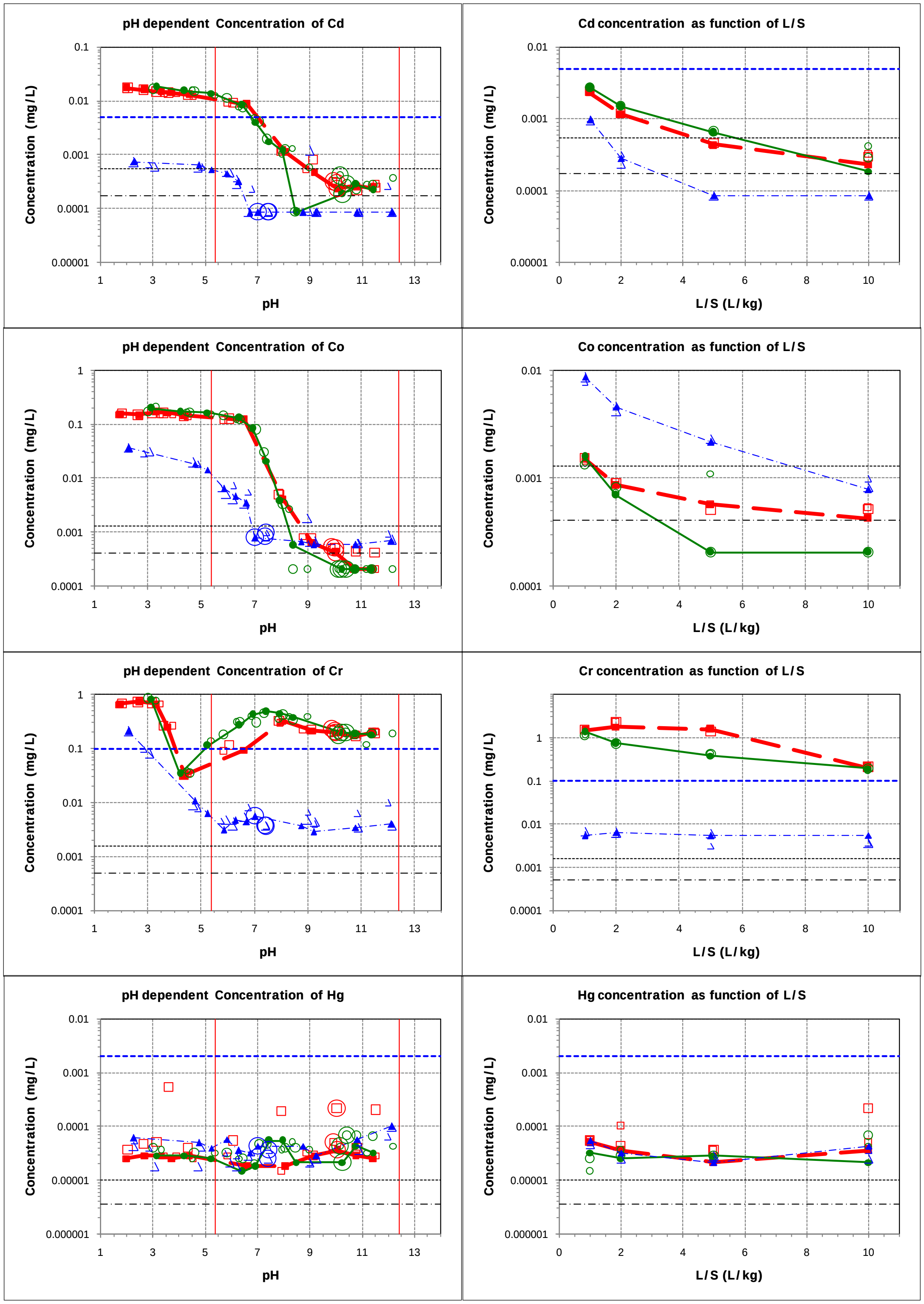
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



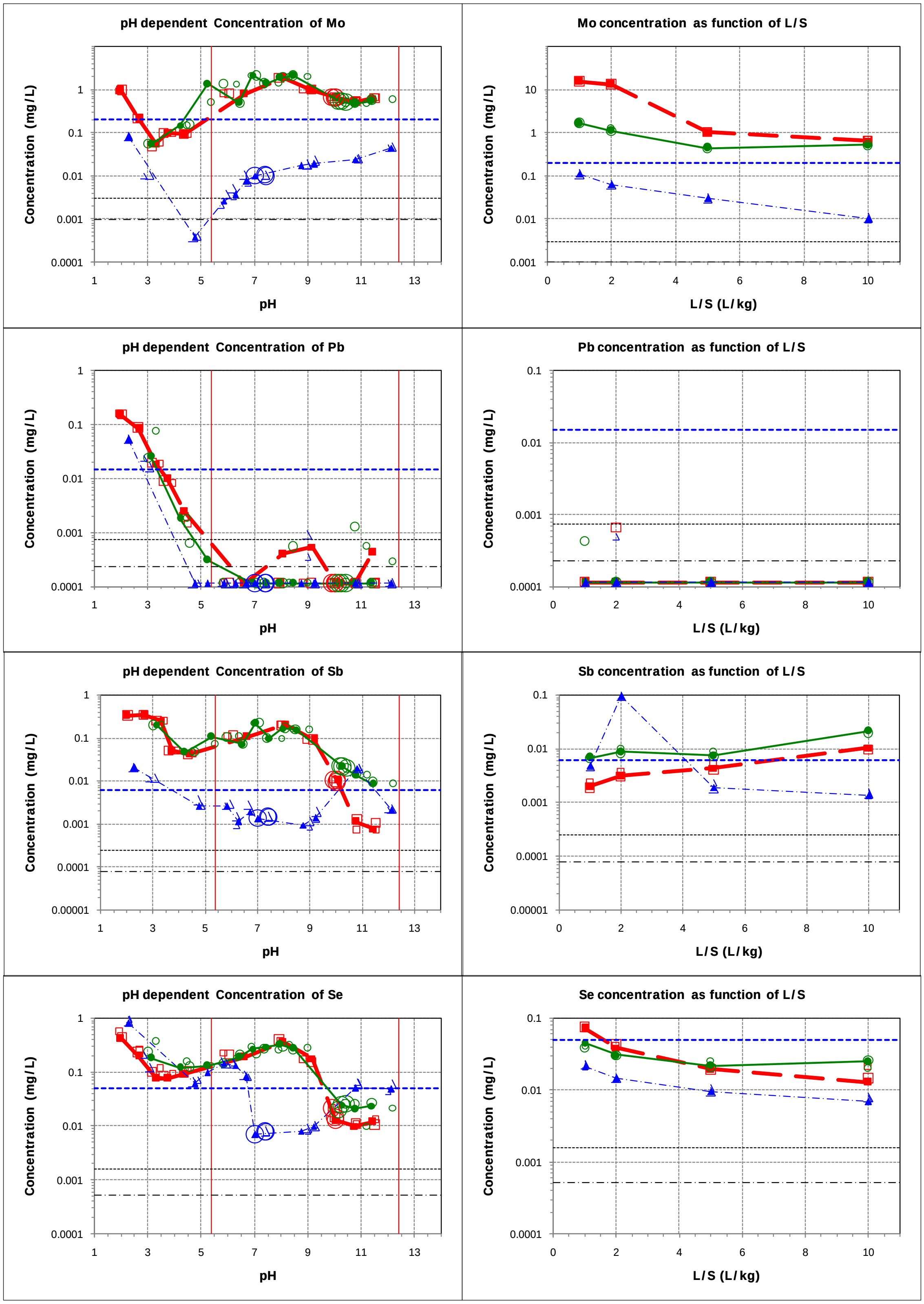
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB -** fly ash without ACI; **SHT -** fly ash with ACI.



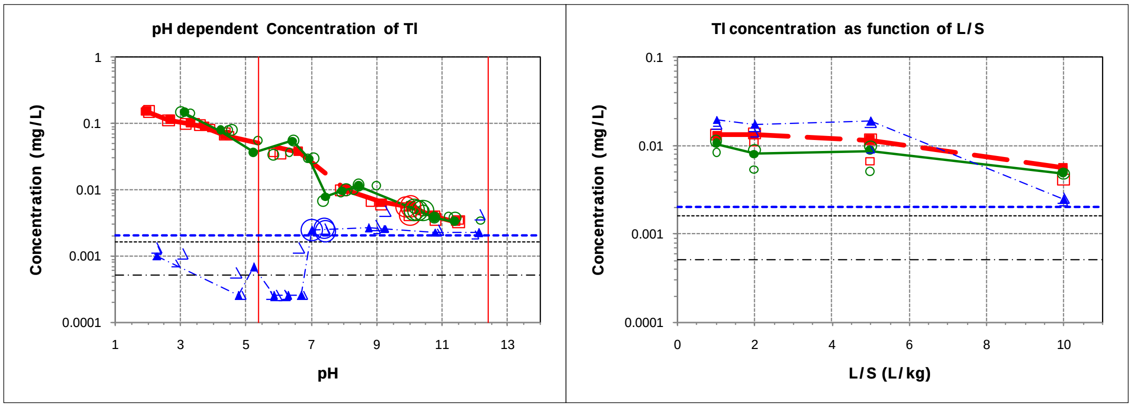
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



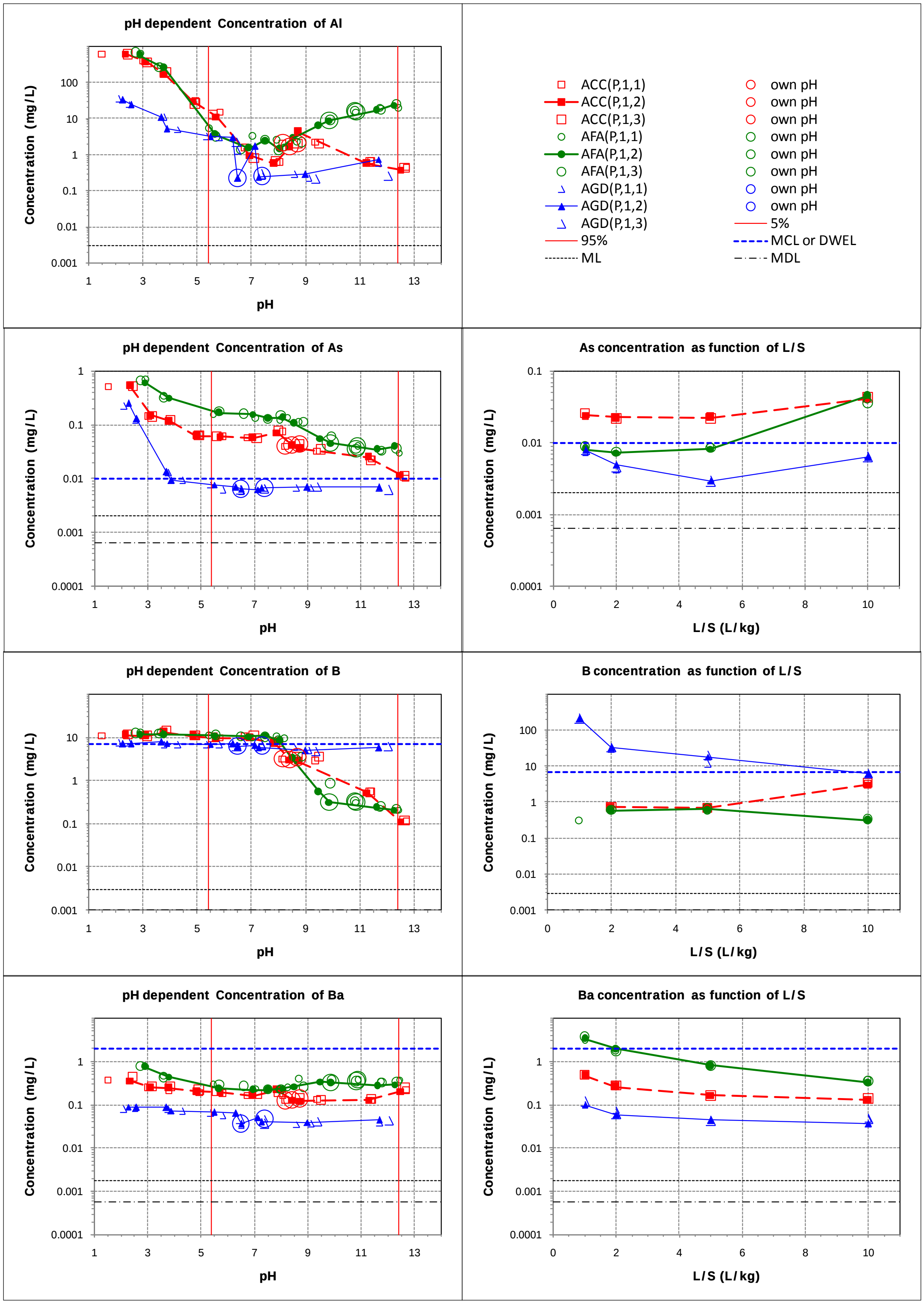
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



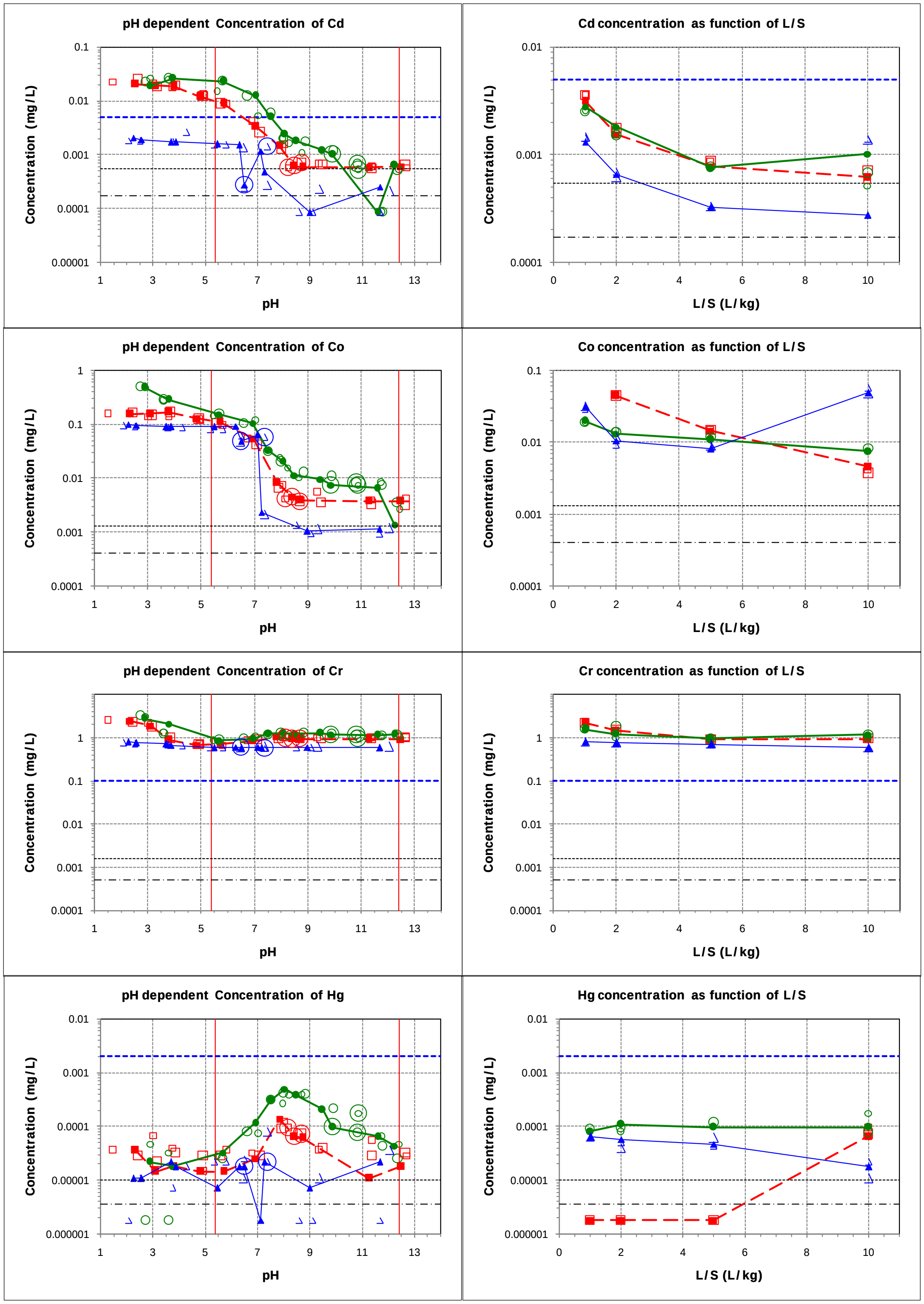
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



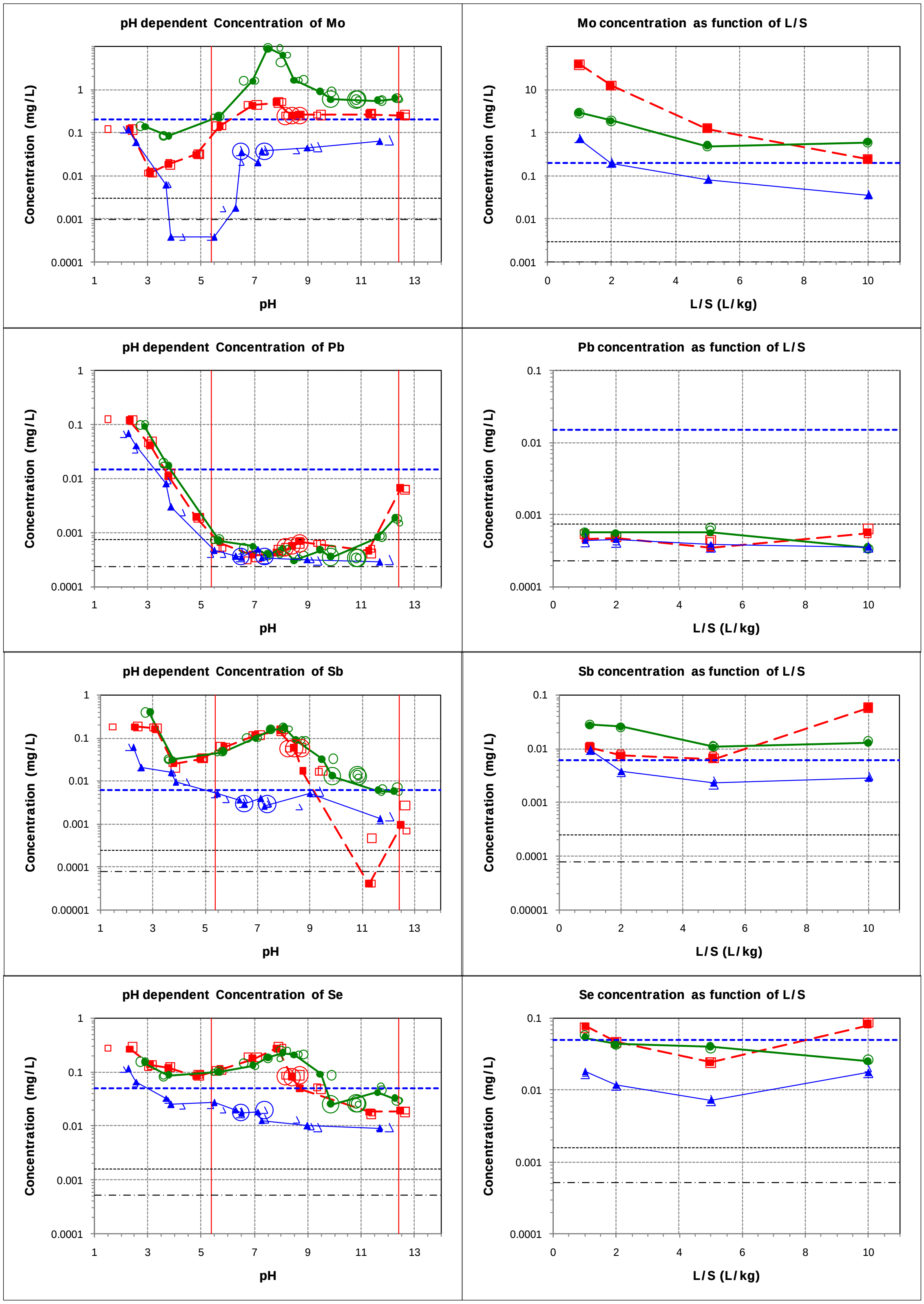
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



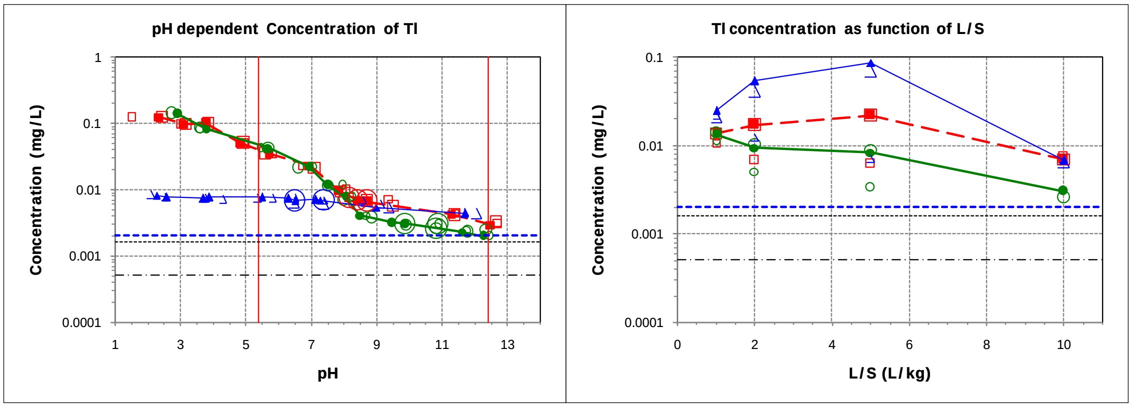
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



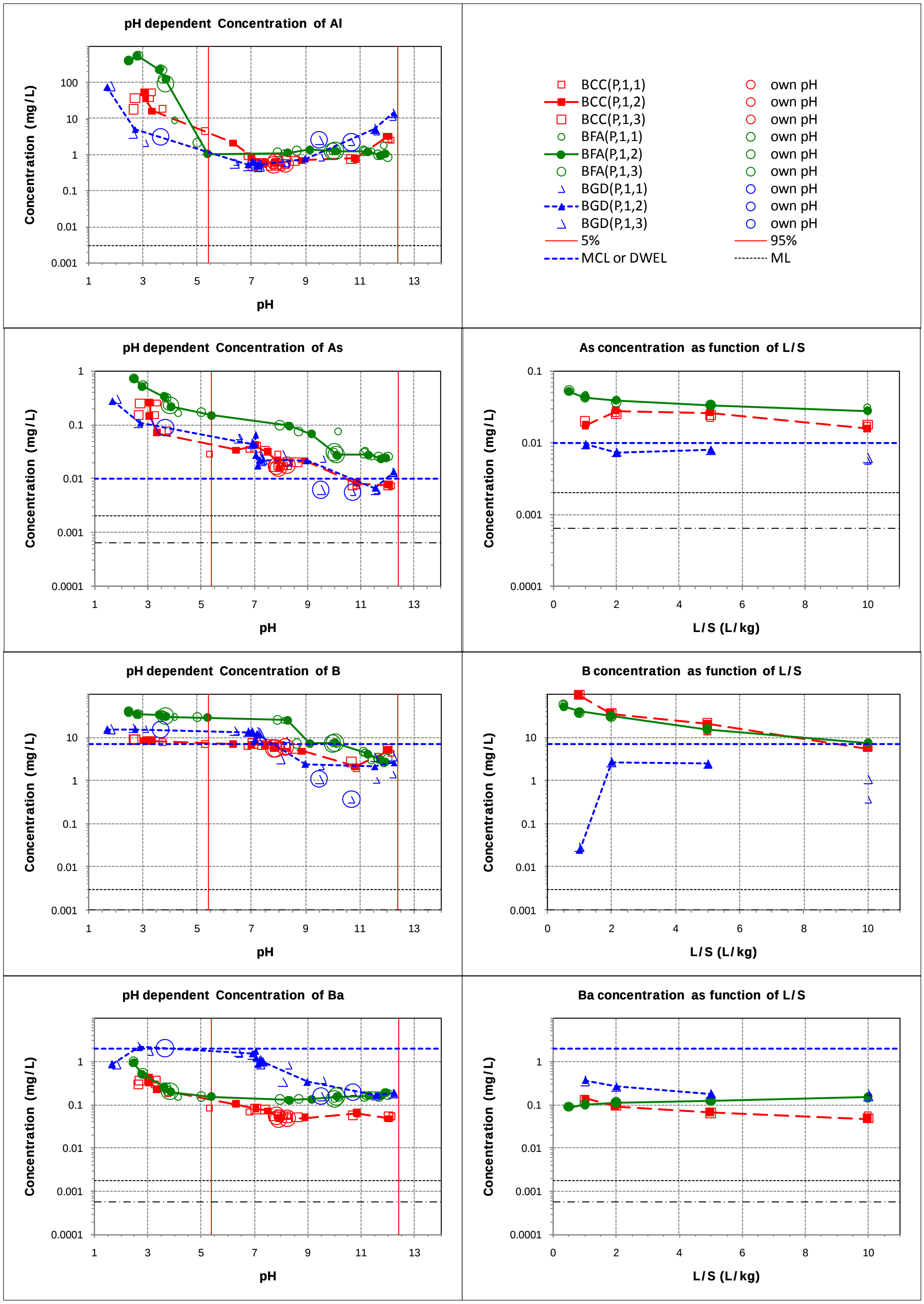
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



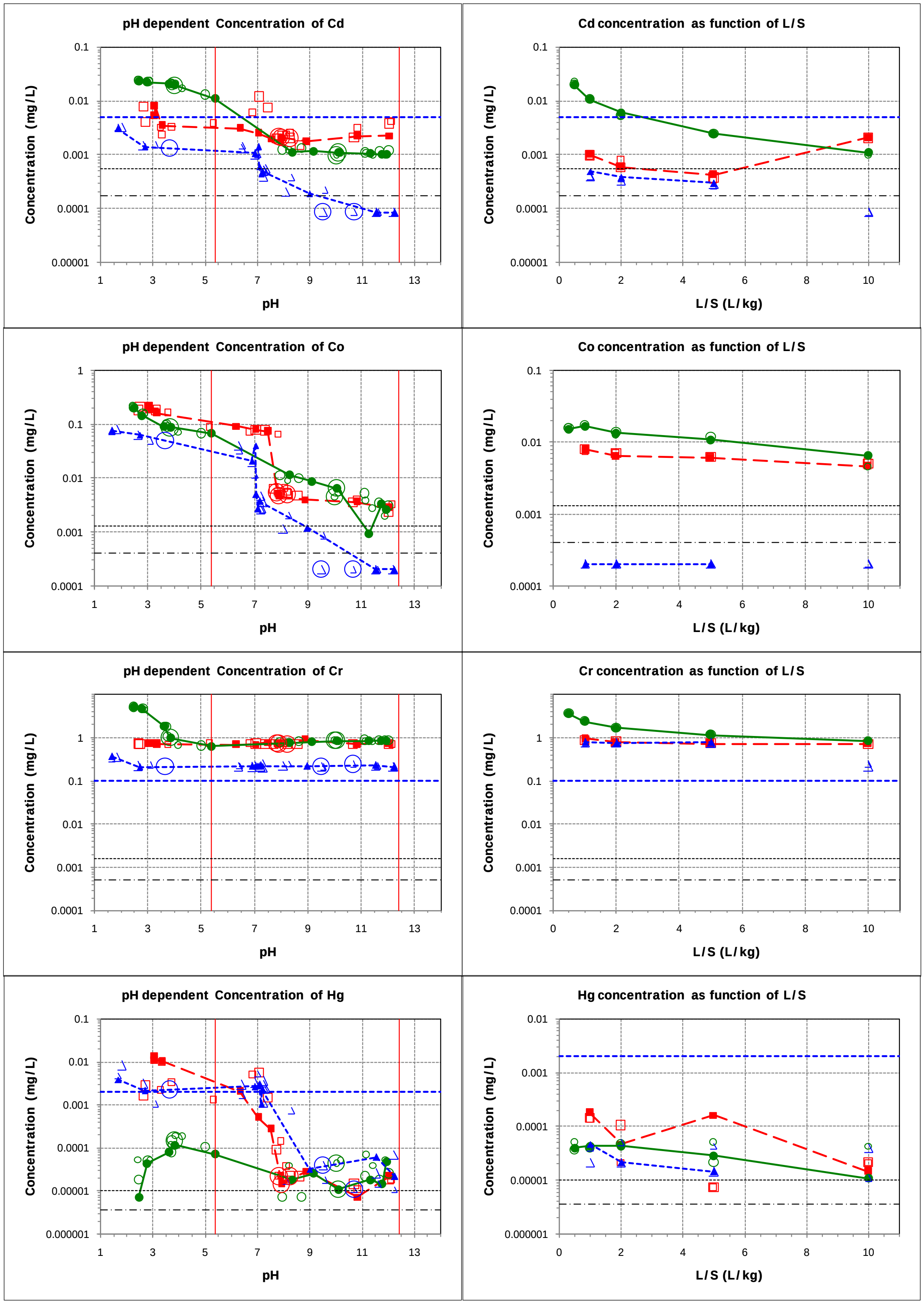
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



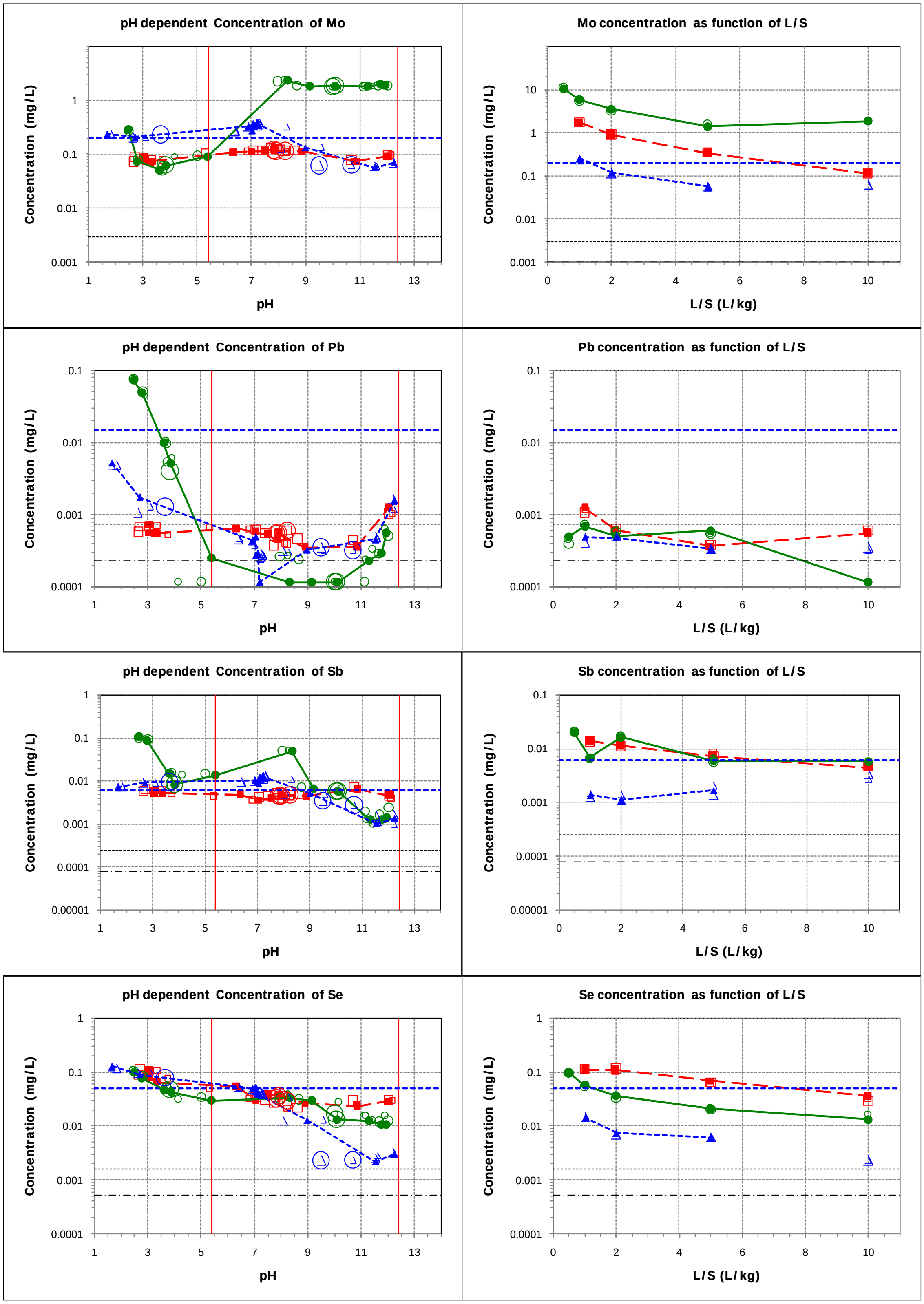
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



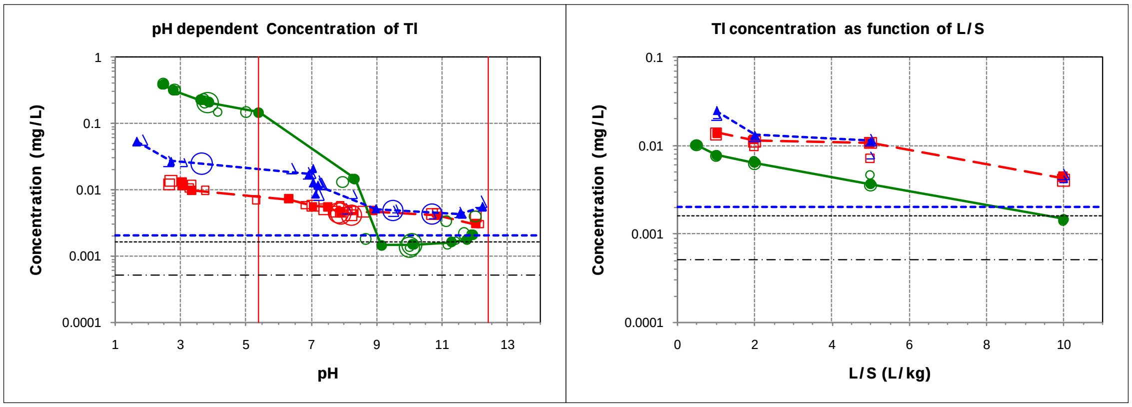
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



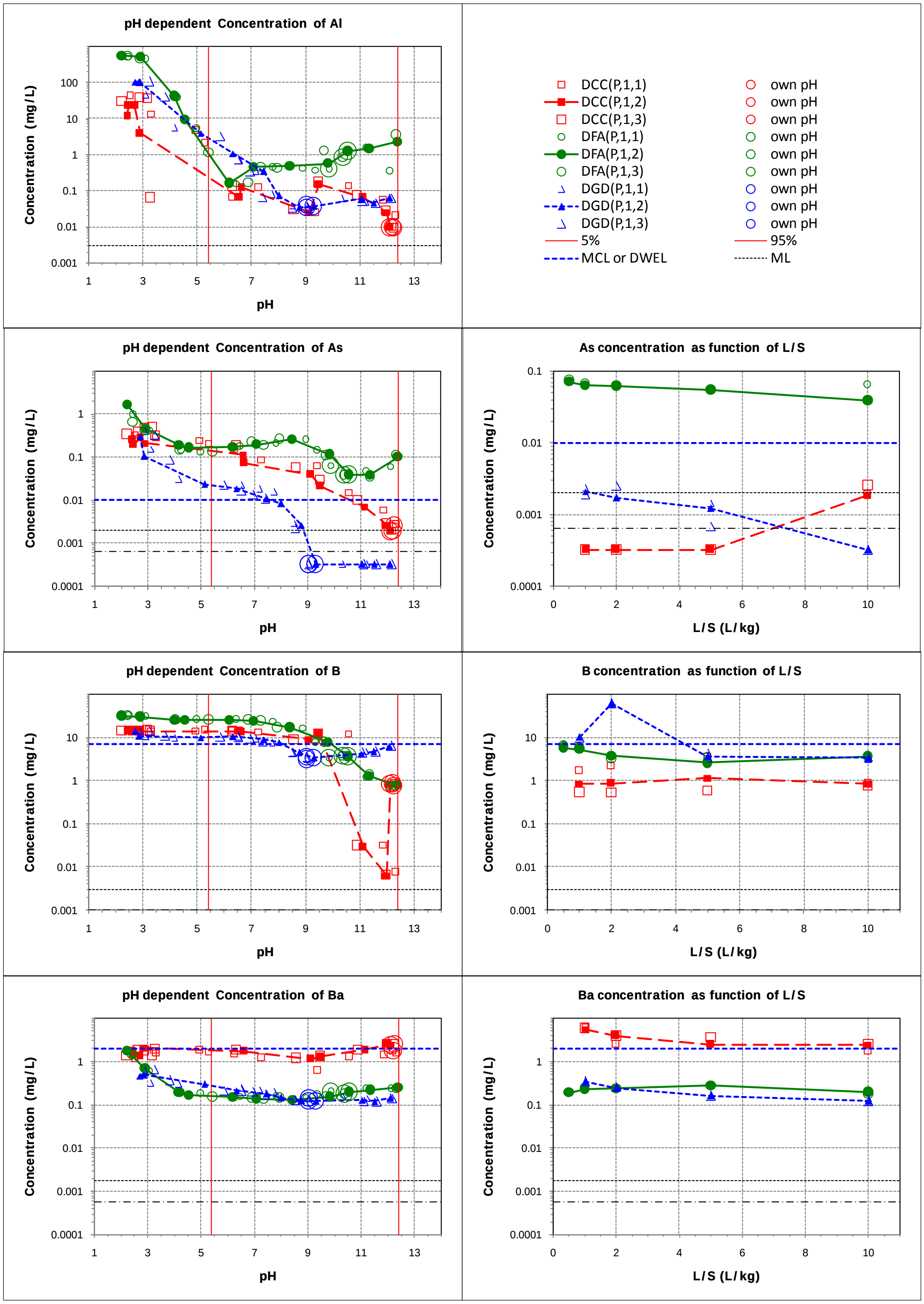
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



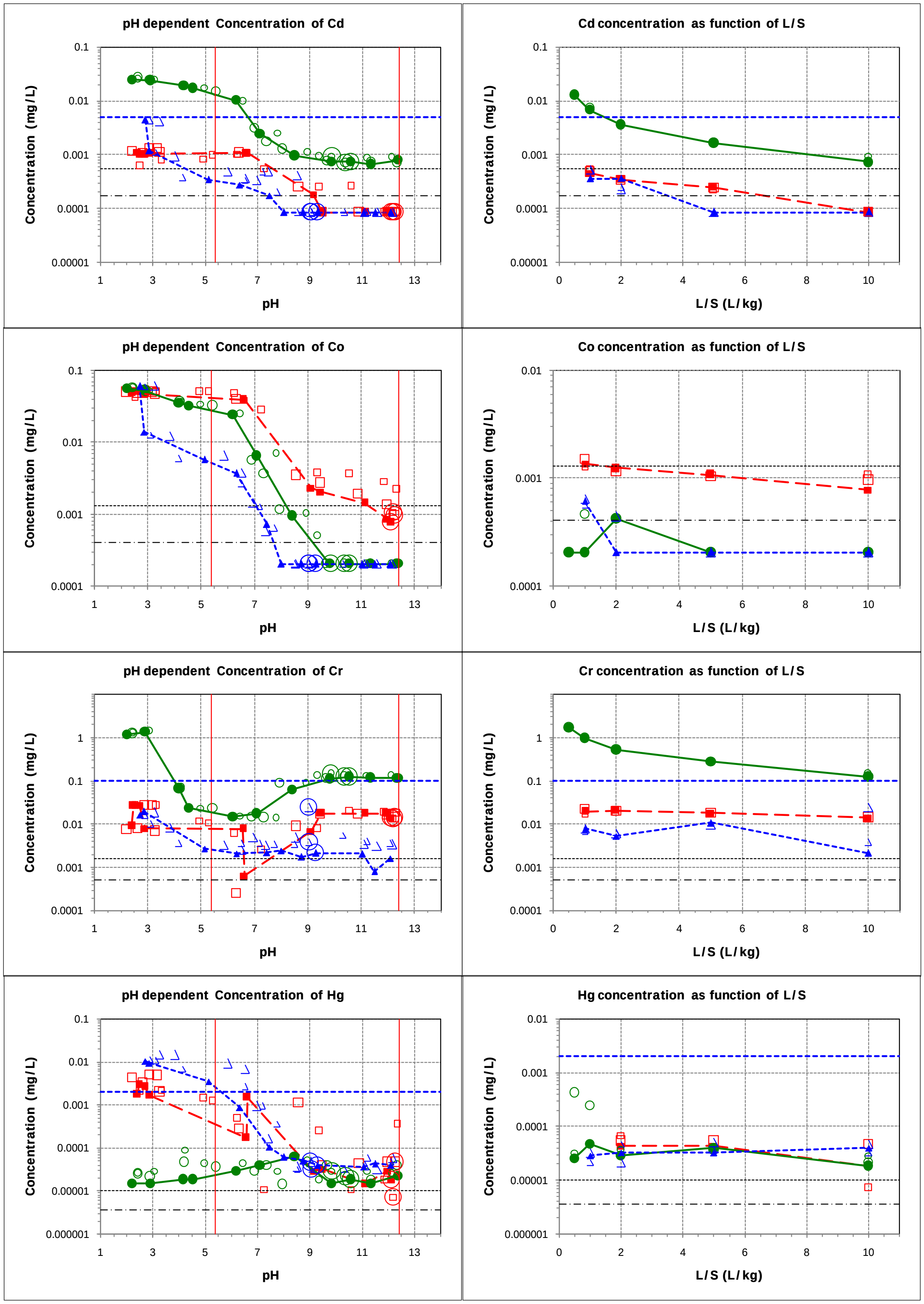
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



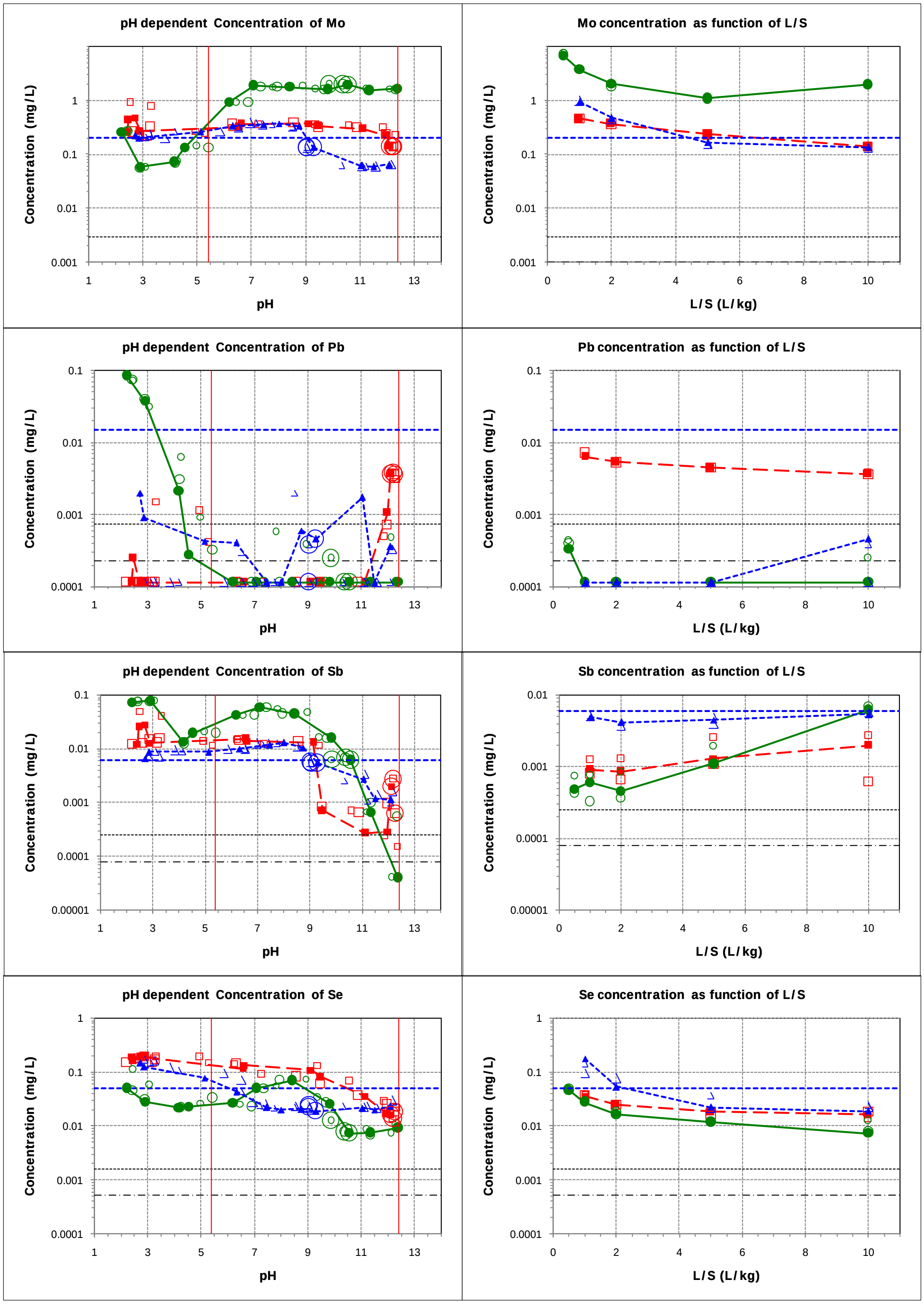
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



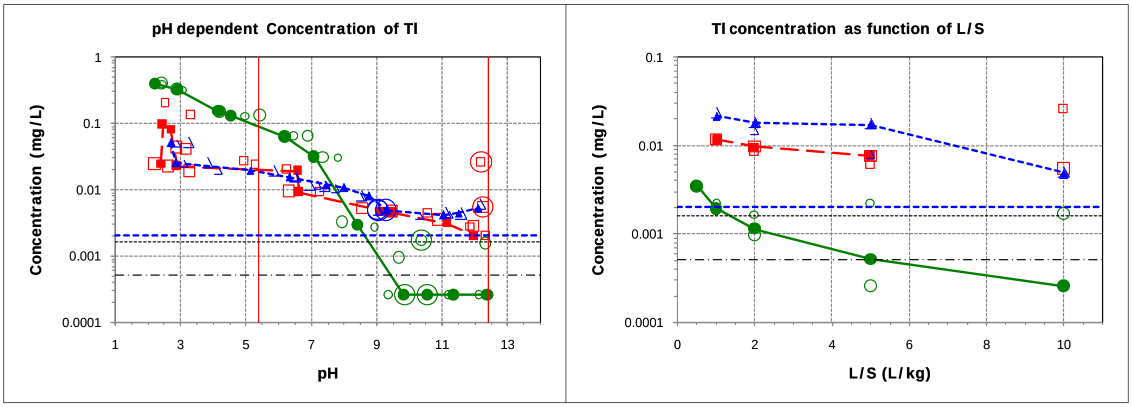
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



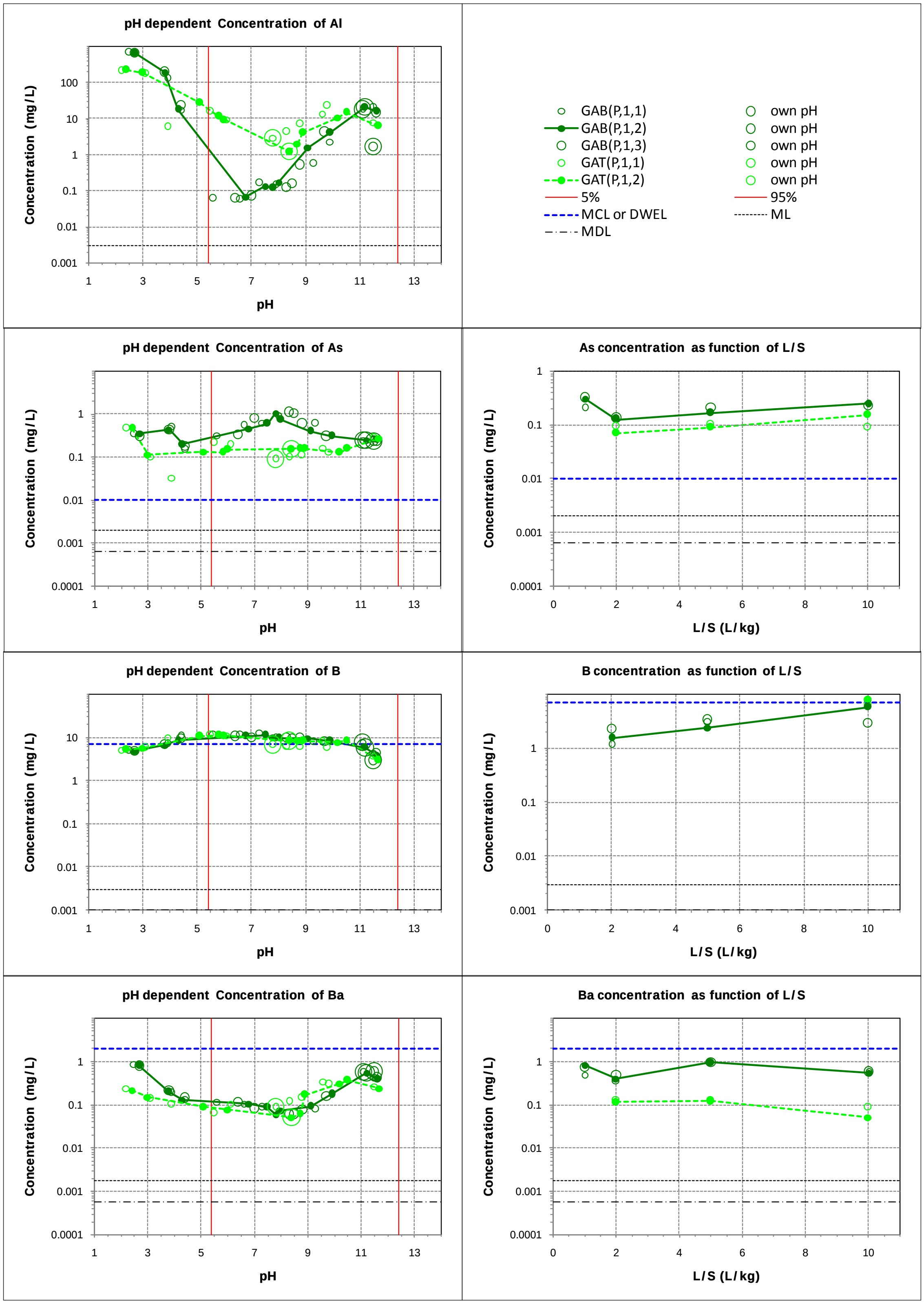
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



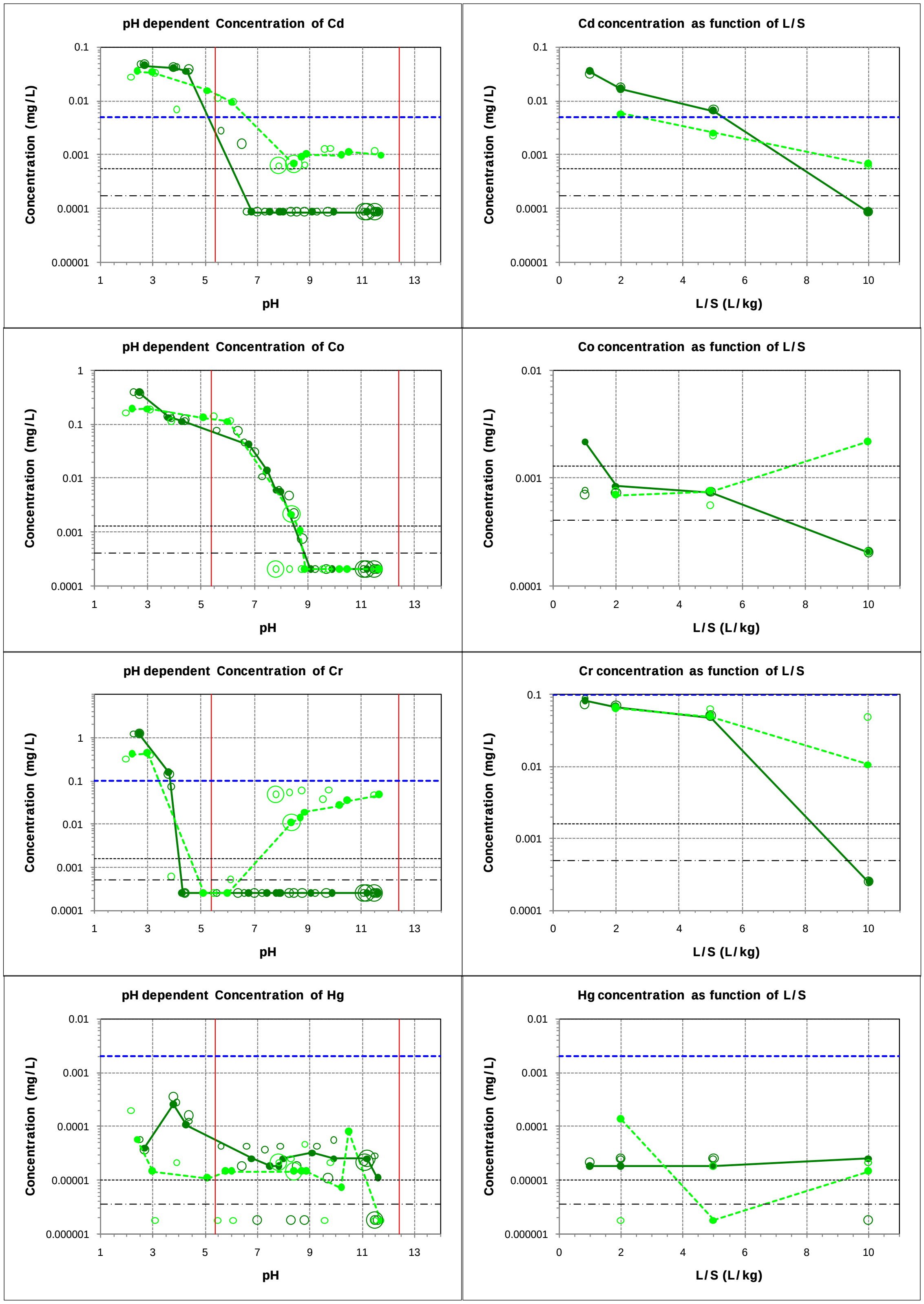
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



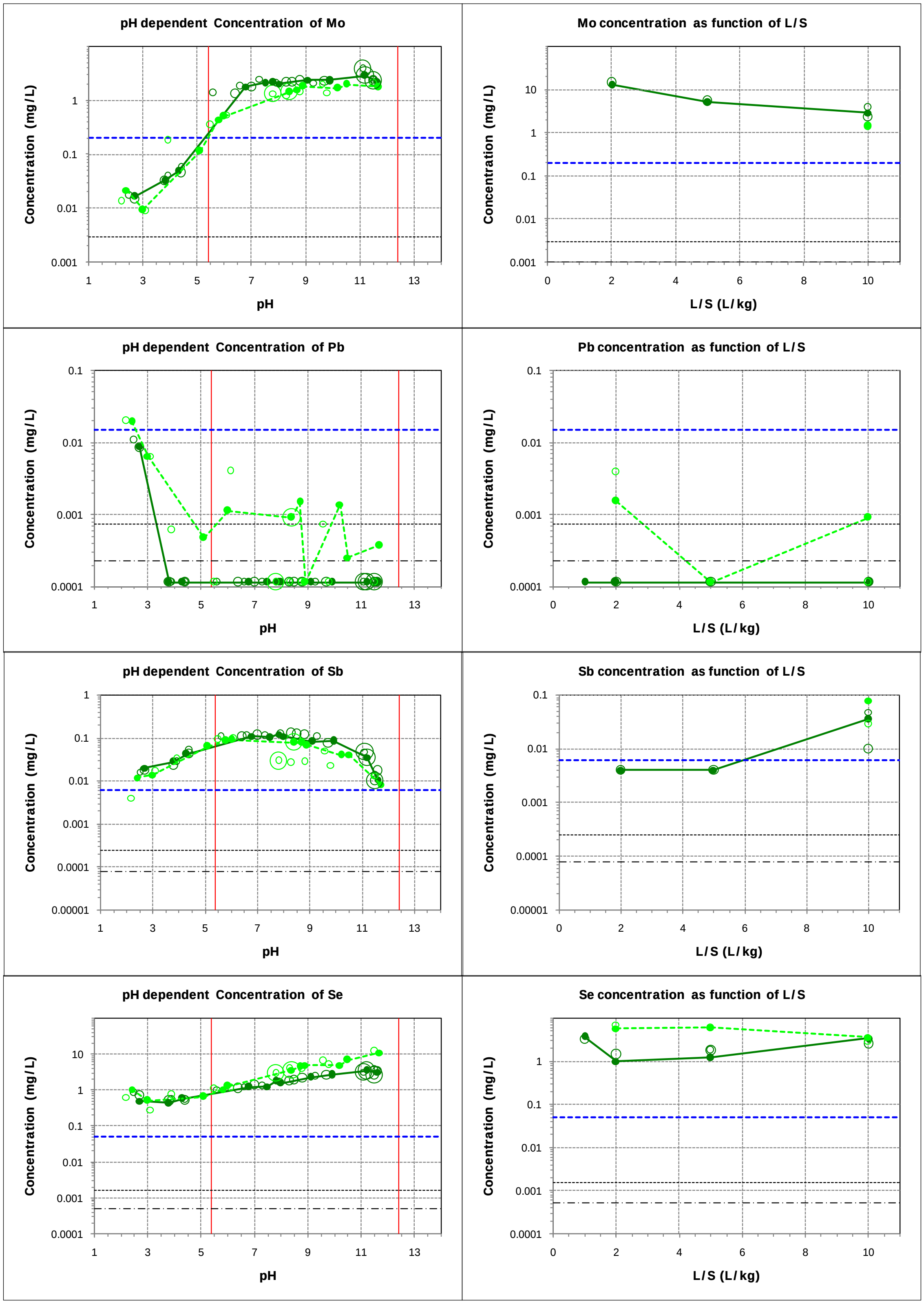
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



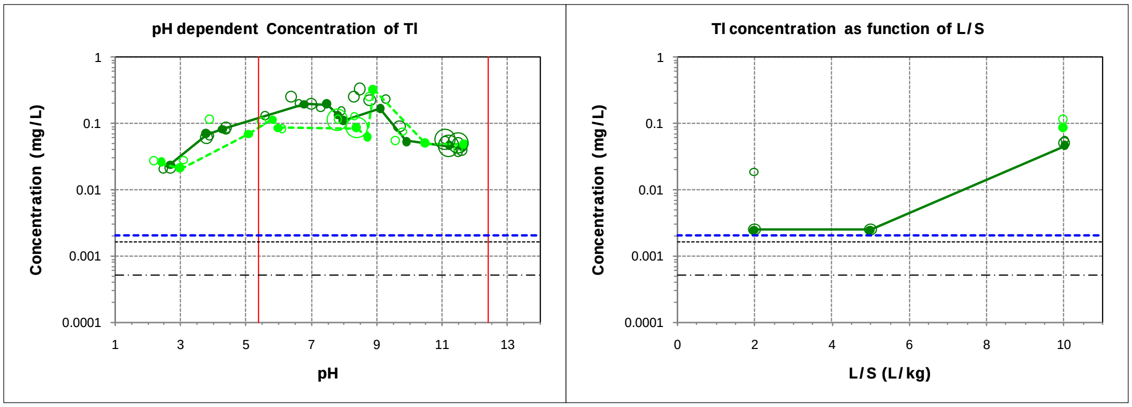
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



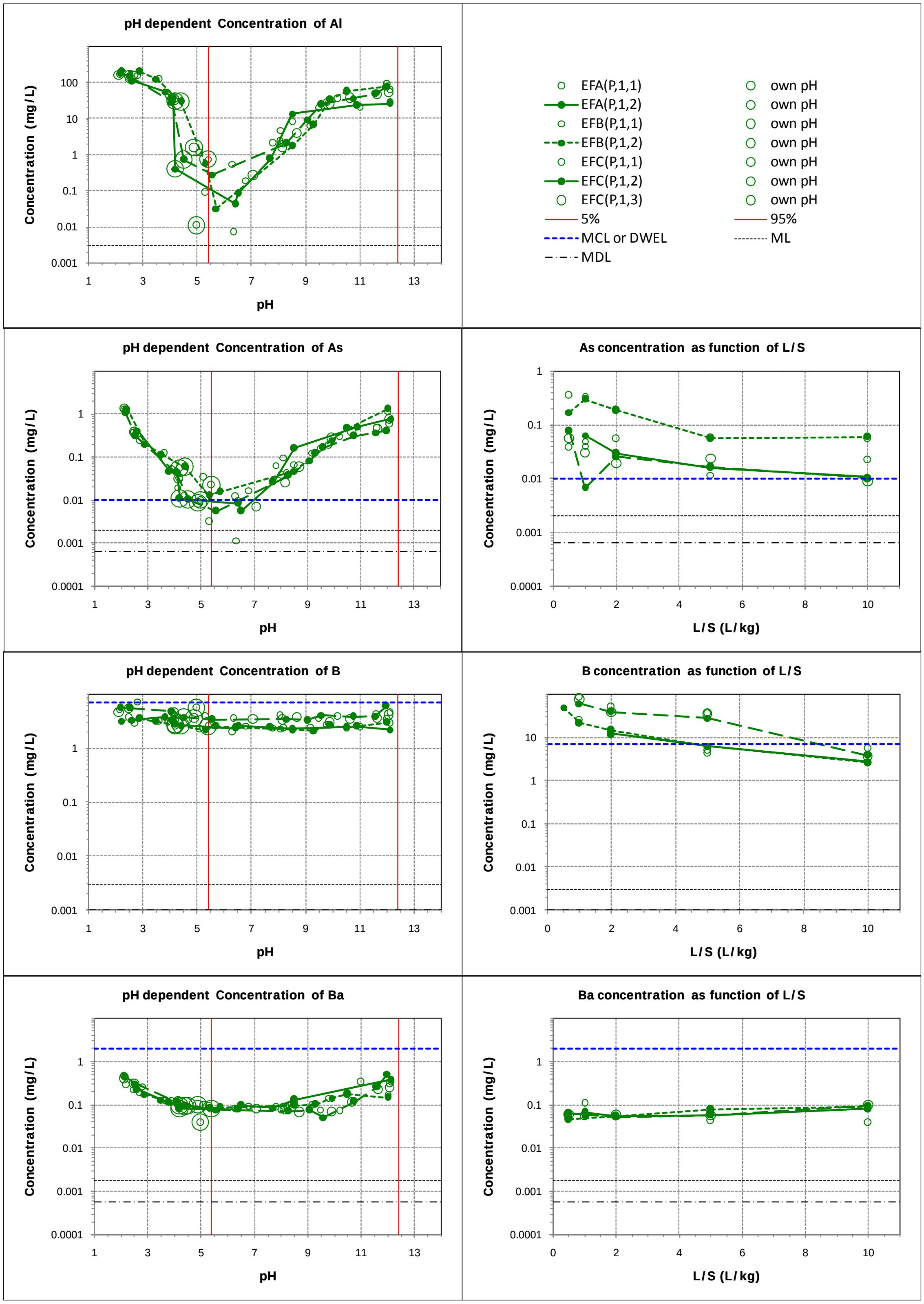
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



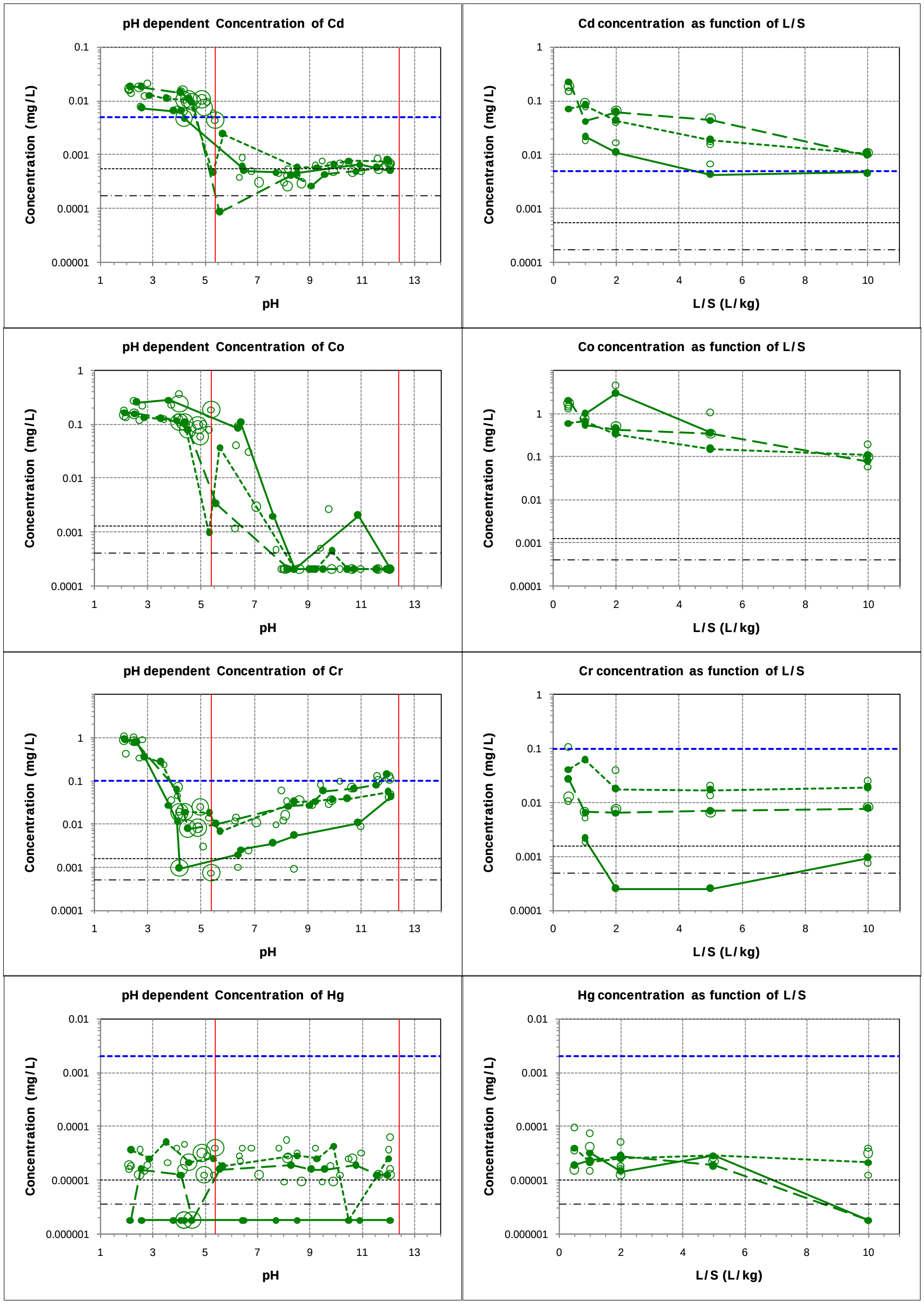
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



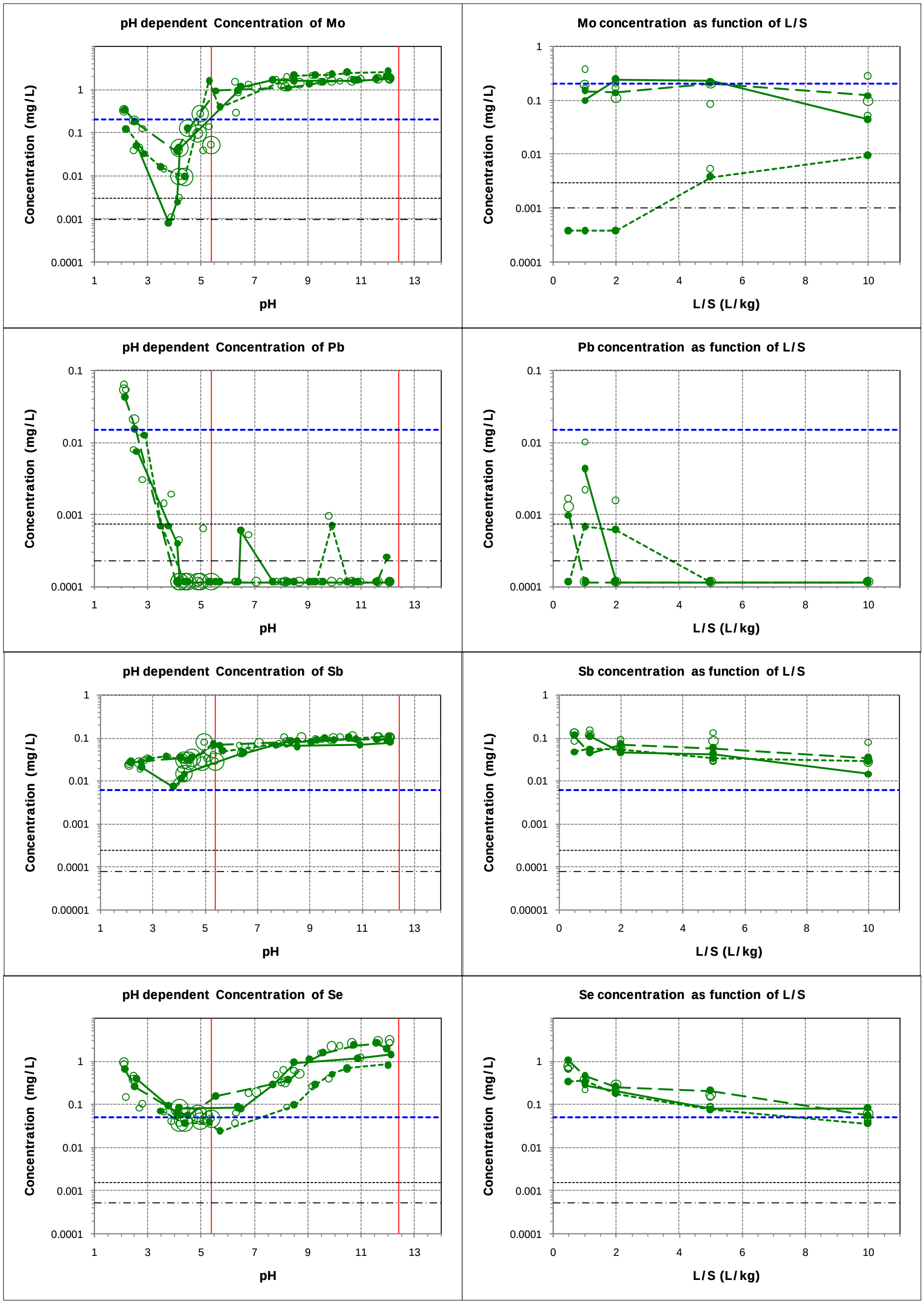
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



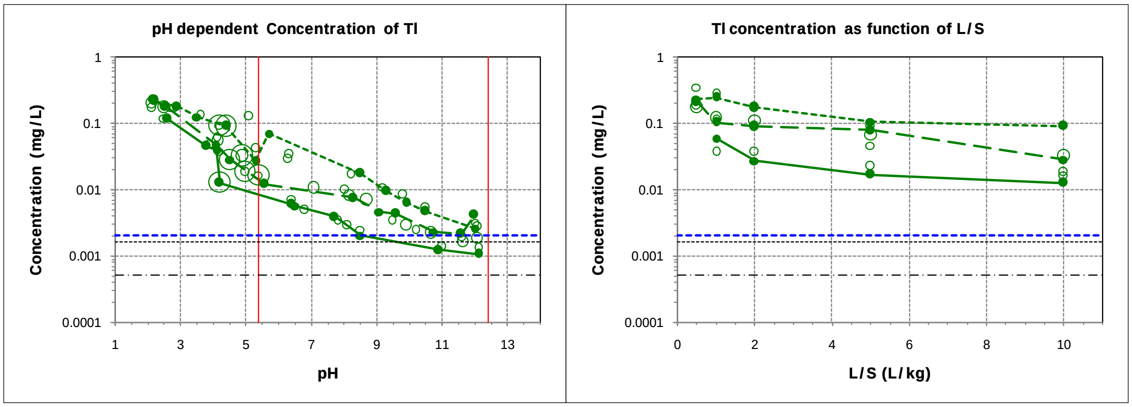
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



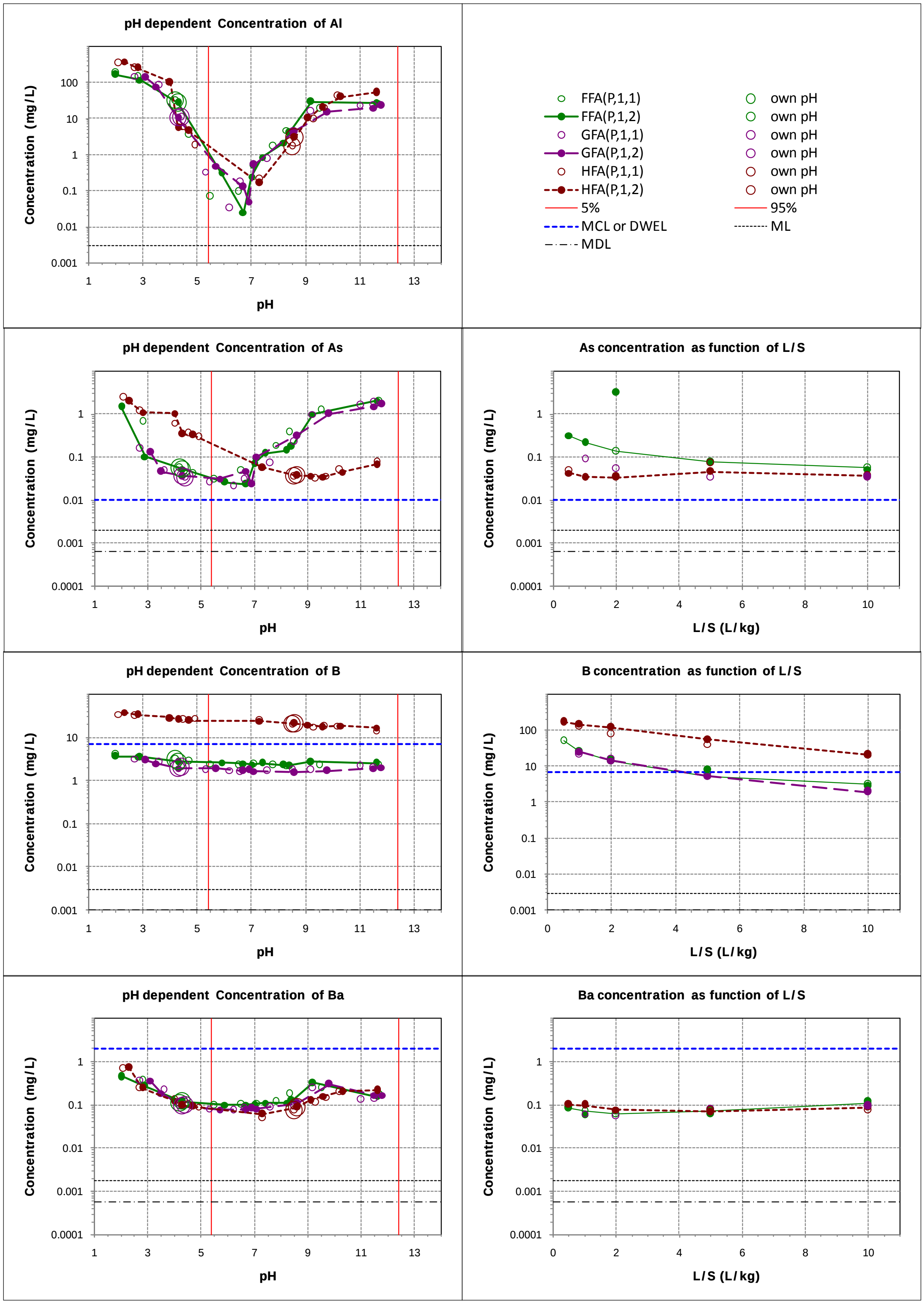
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



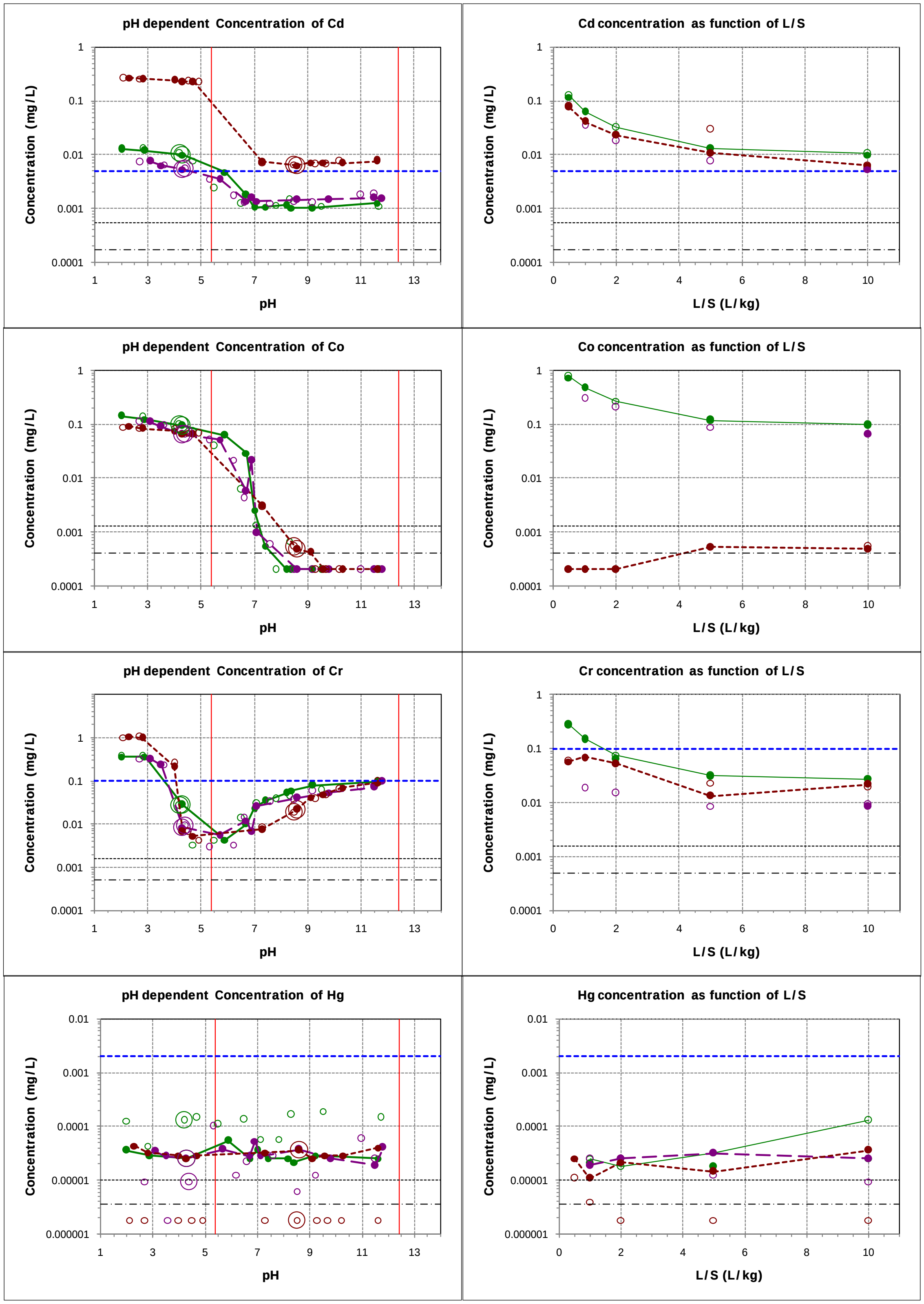
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



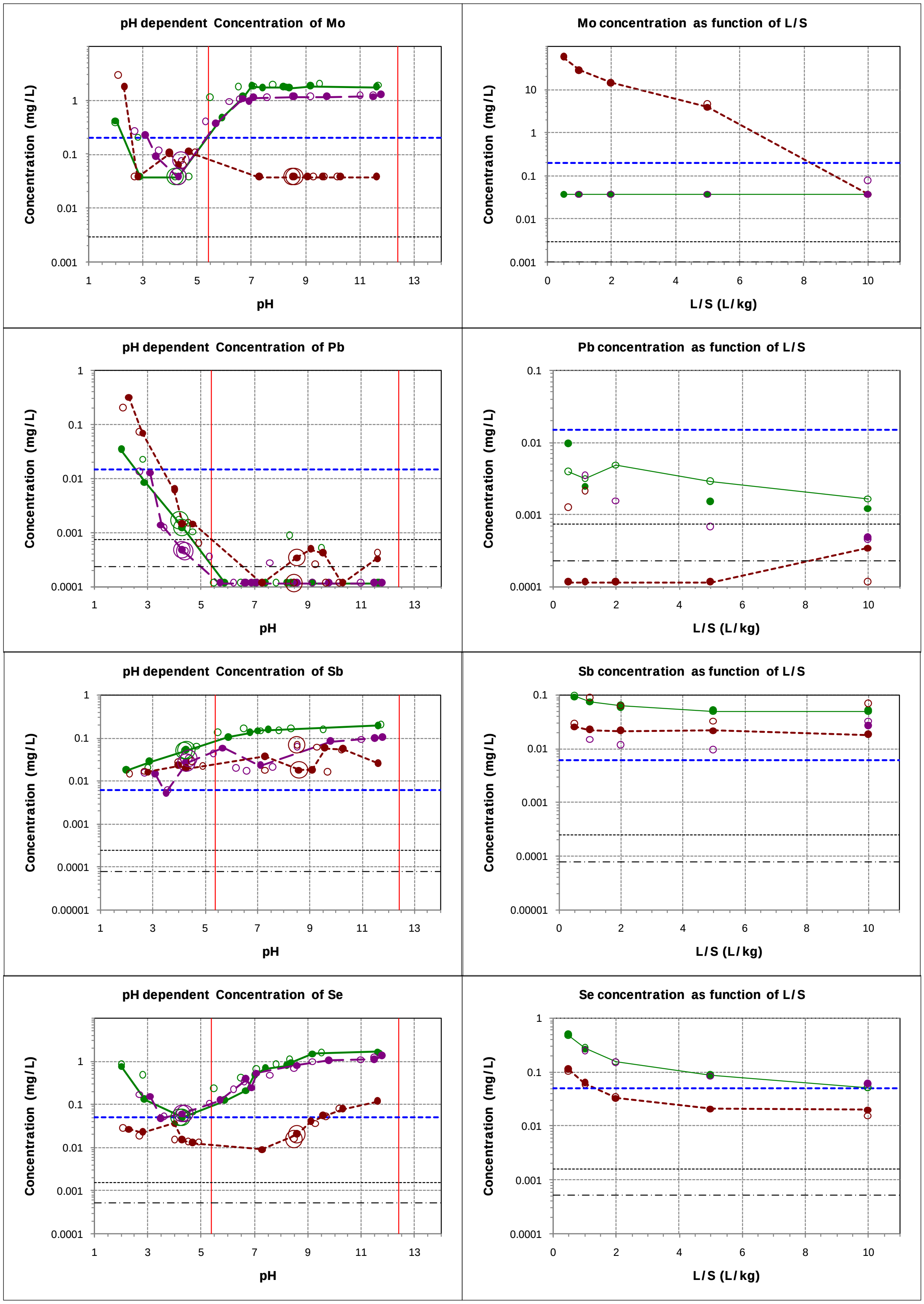
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



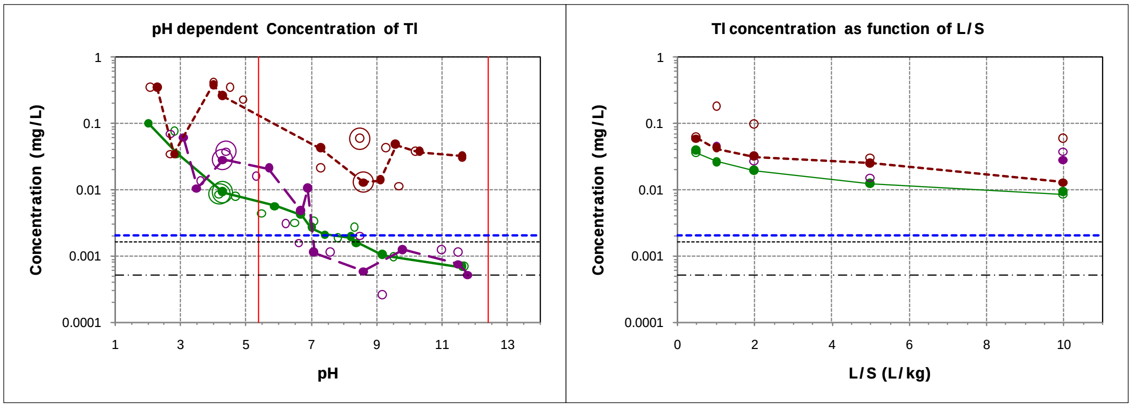
Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.
Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



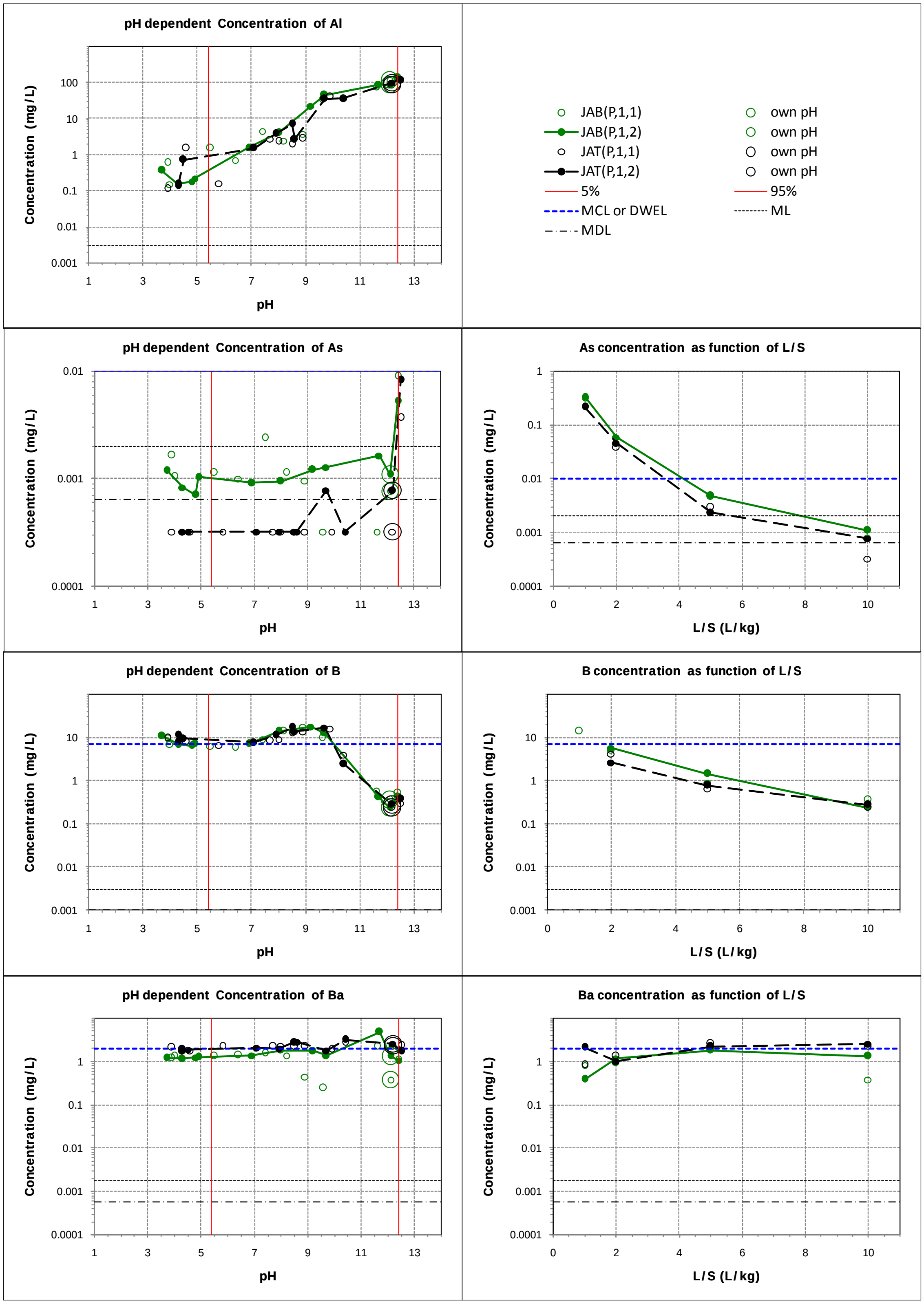
Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.
Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



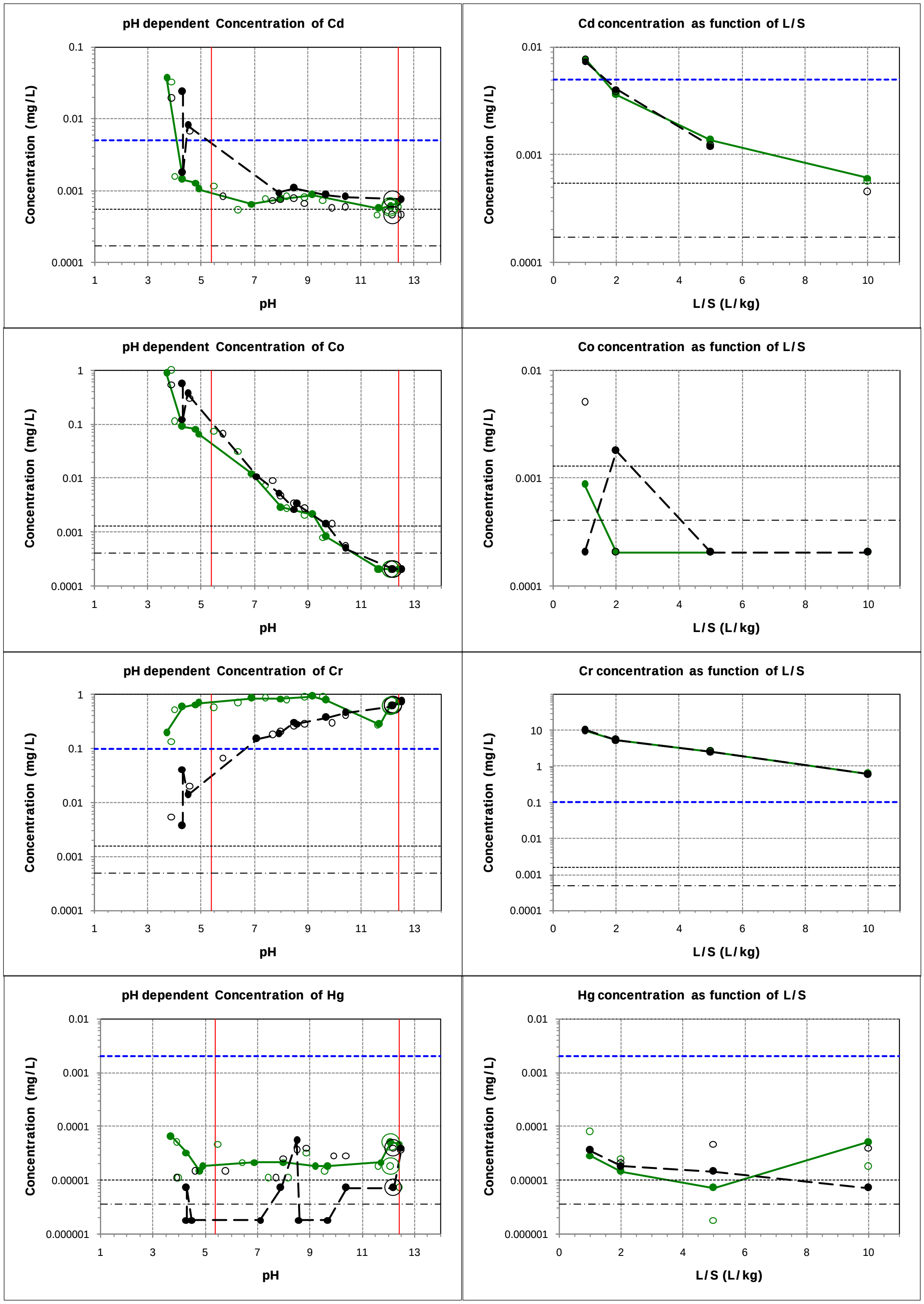
Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.
Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



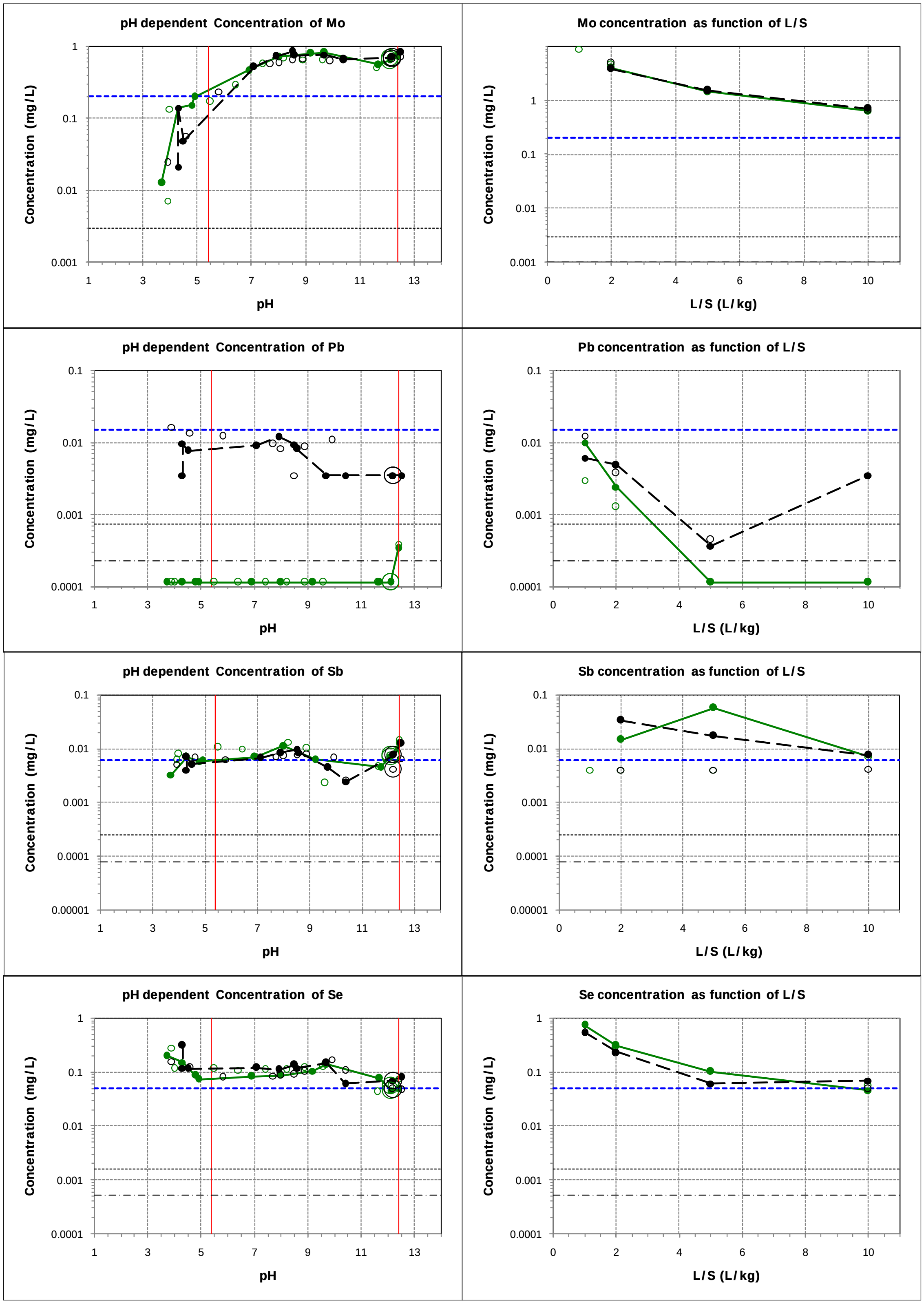
Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.
Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



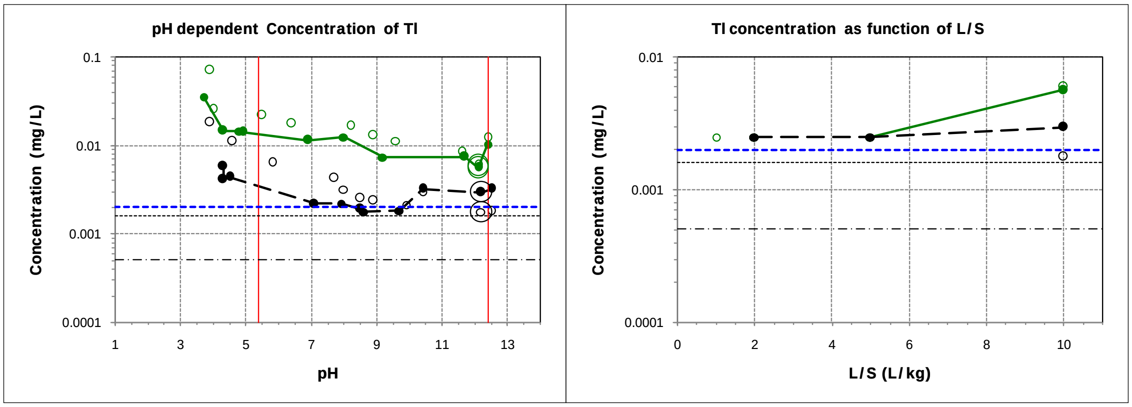
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



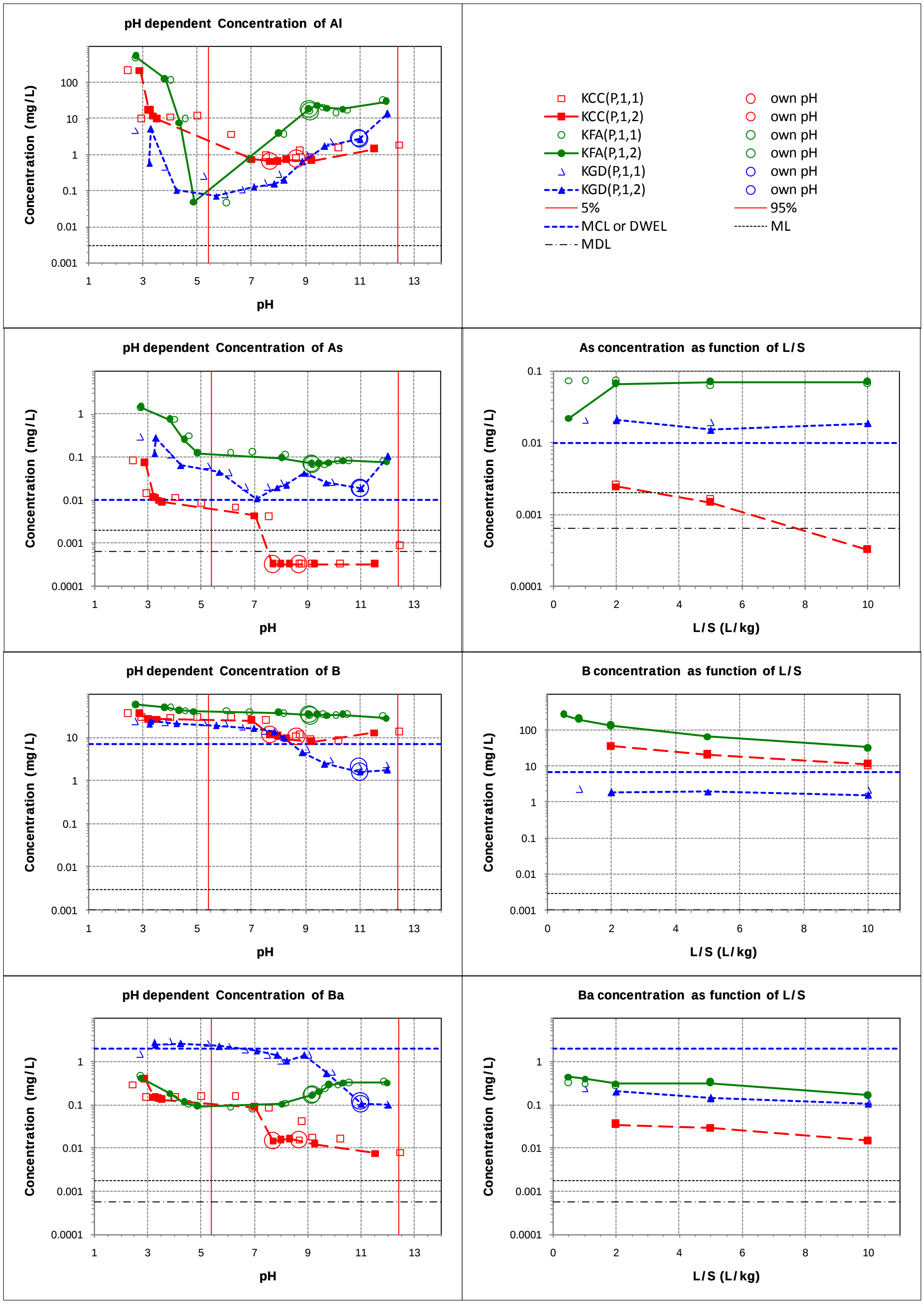
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



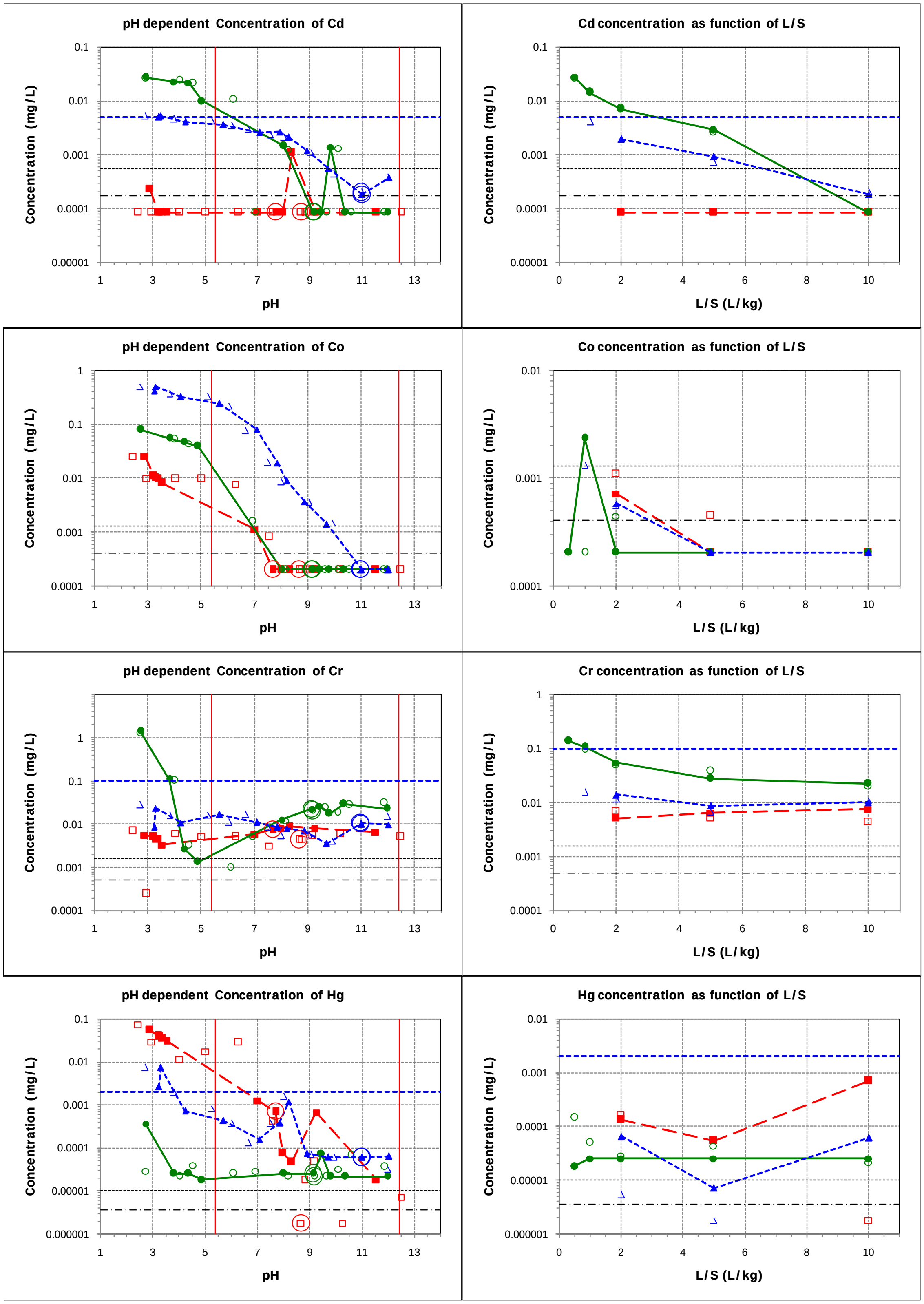
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



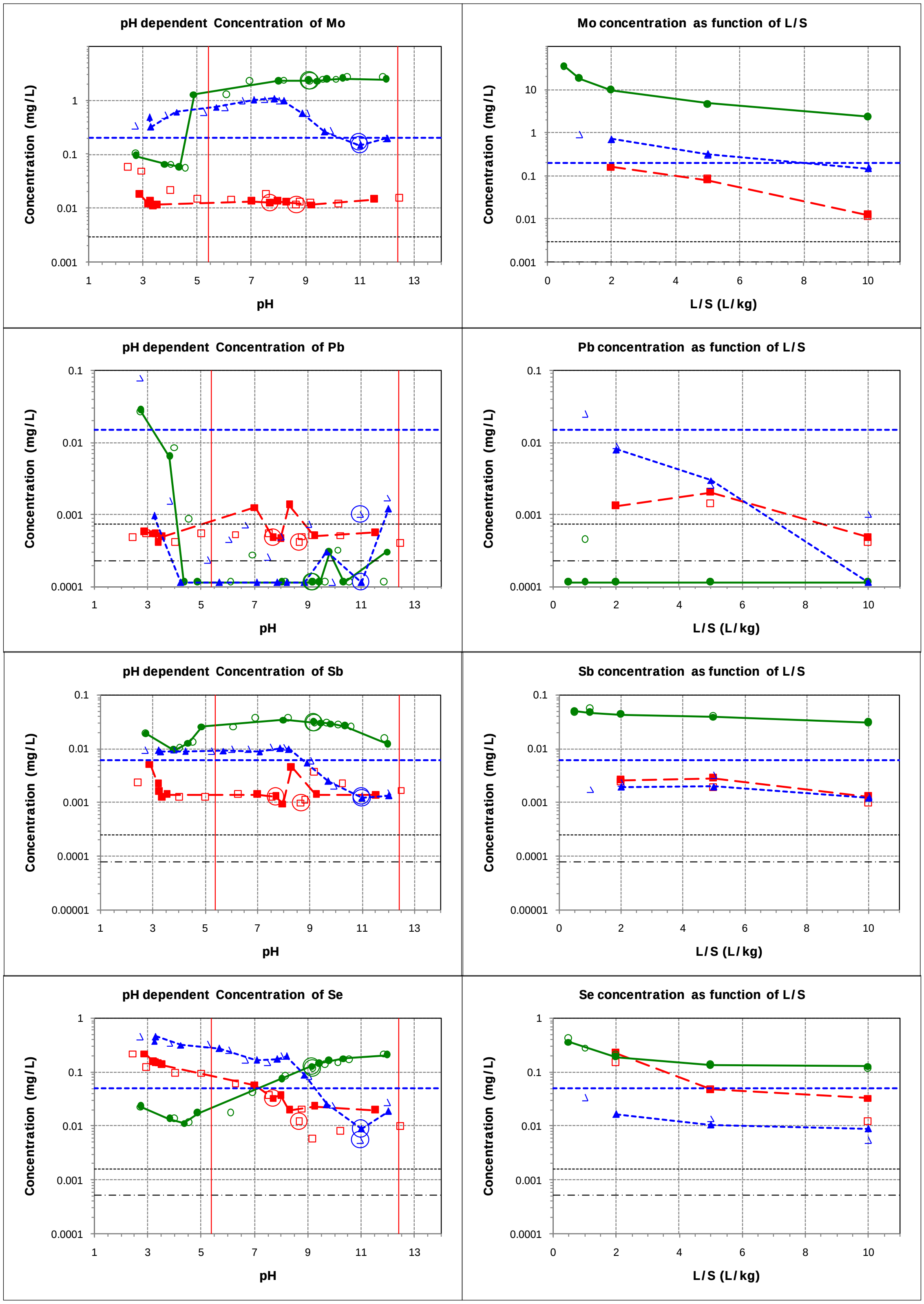
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



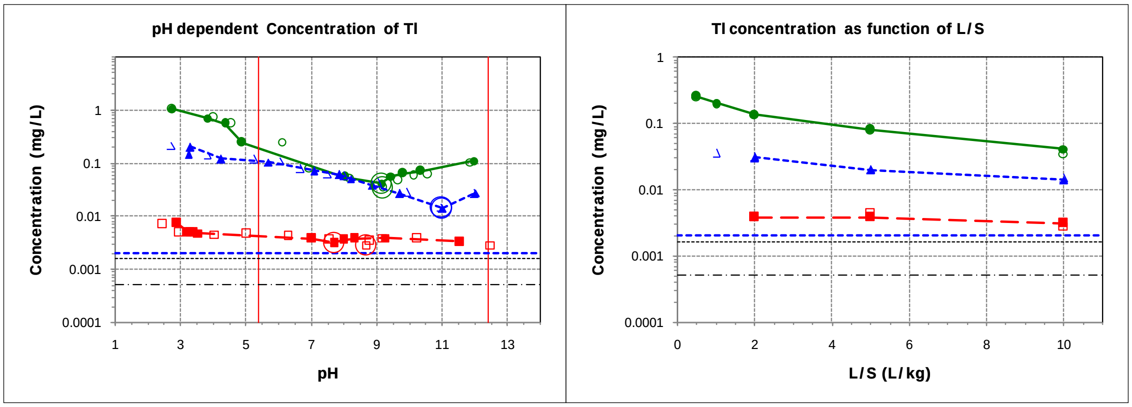
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



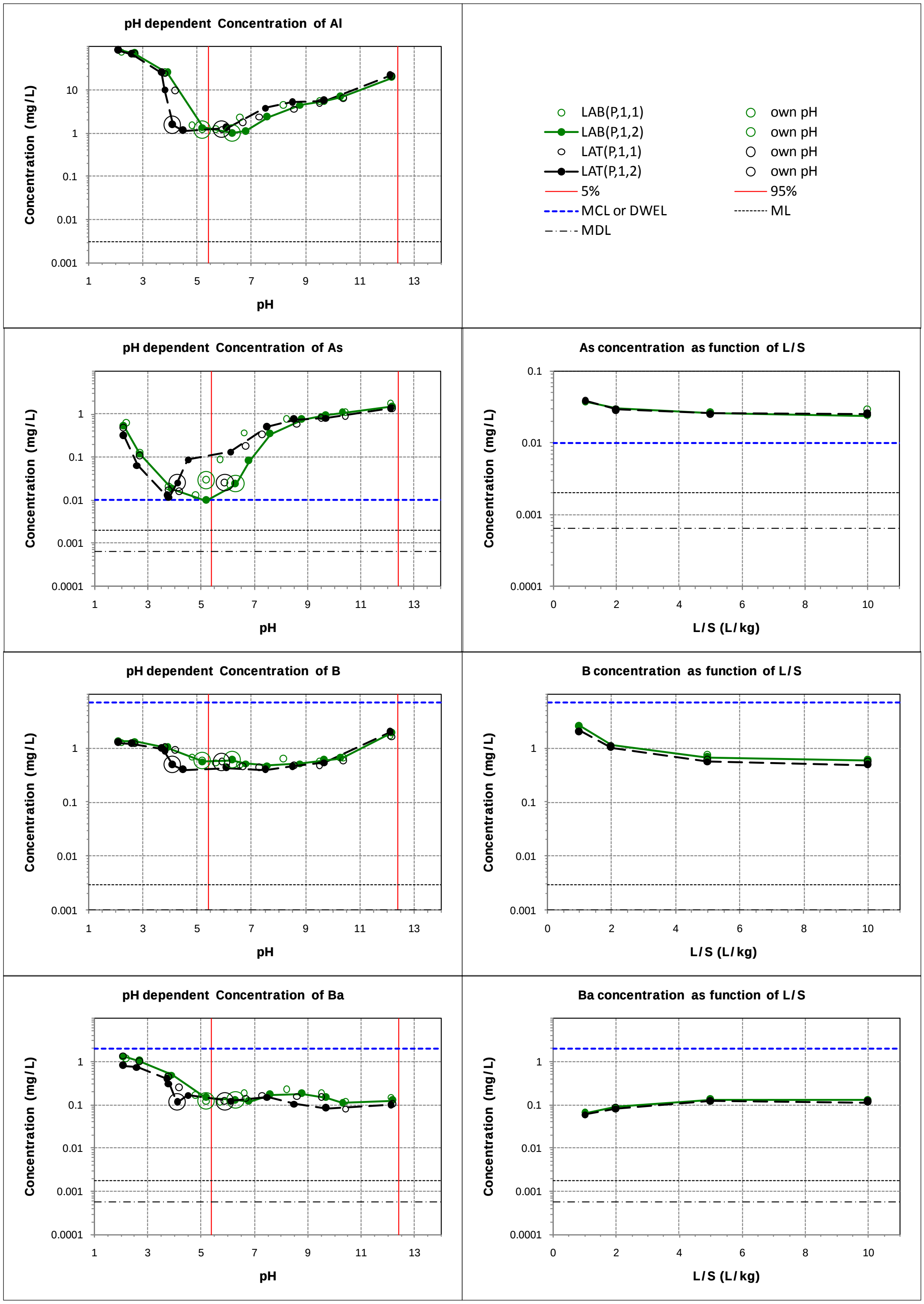
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



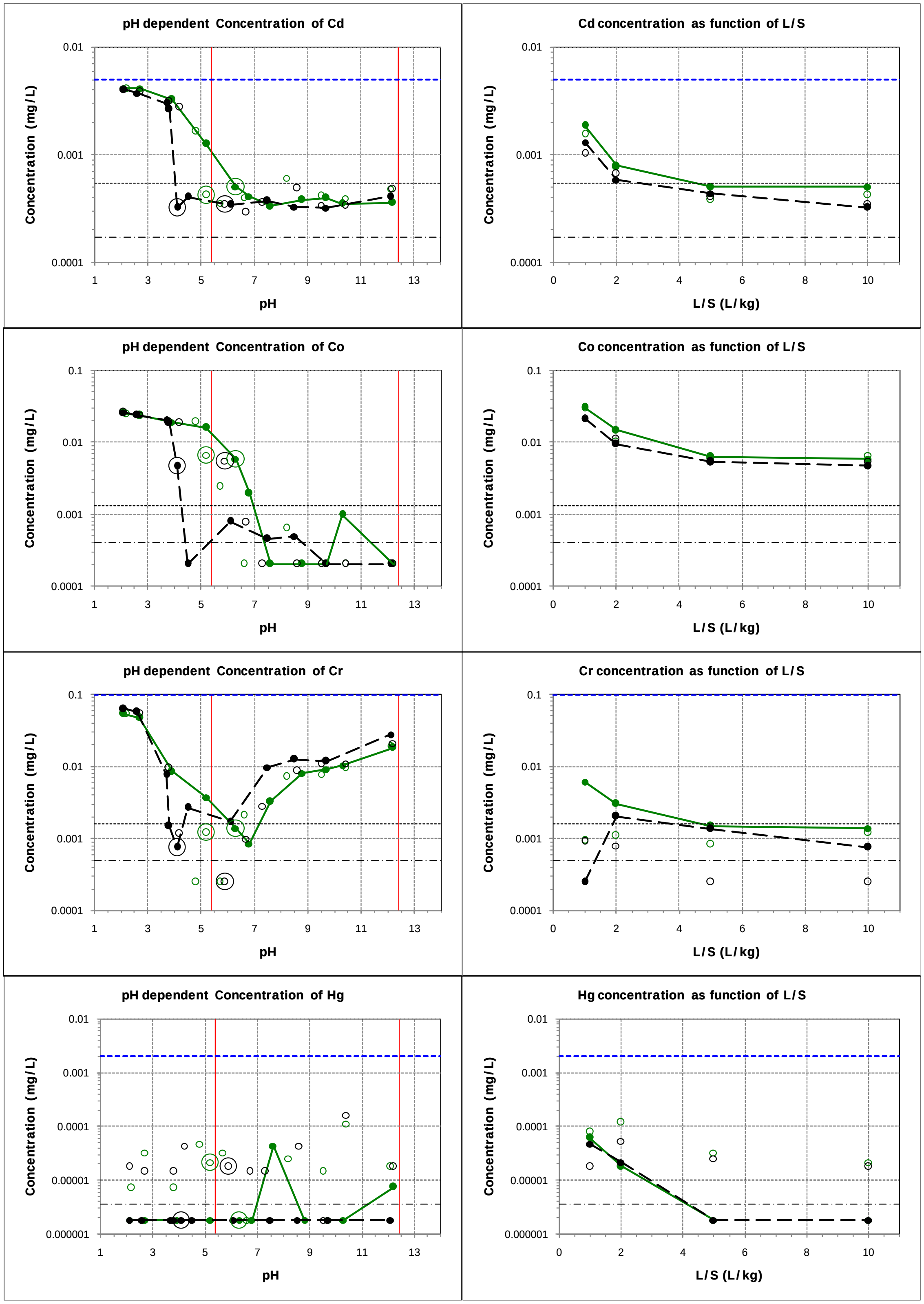
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



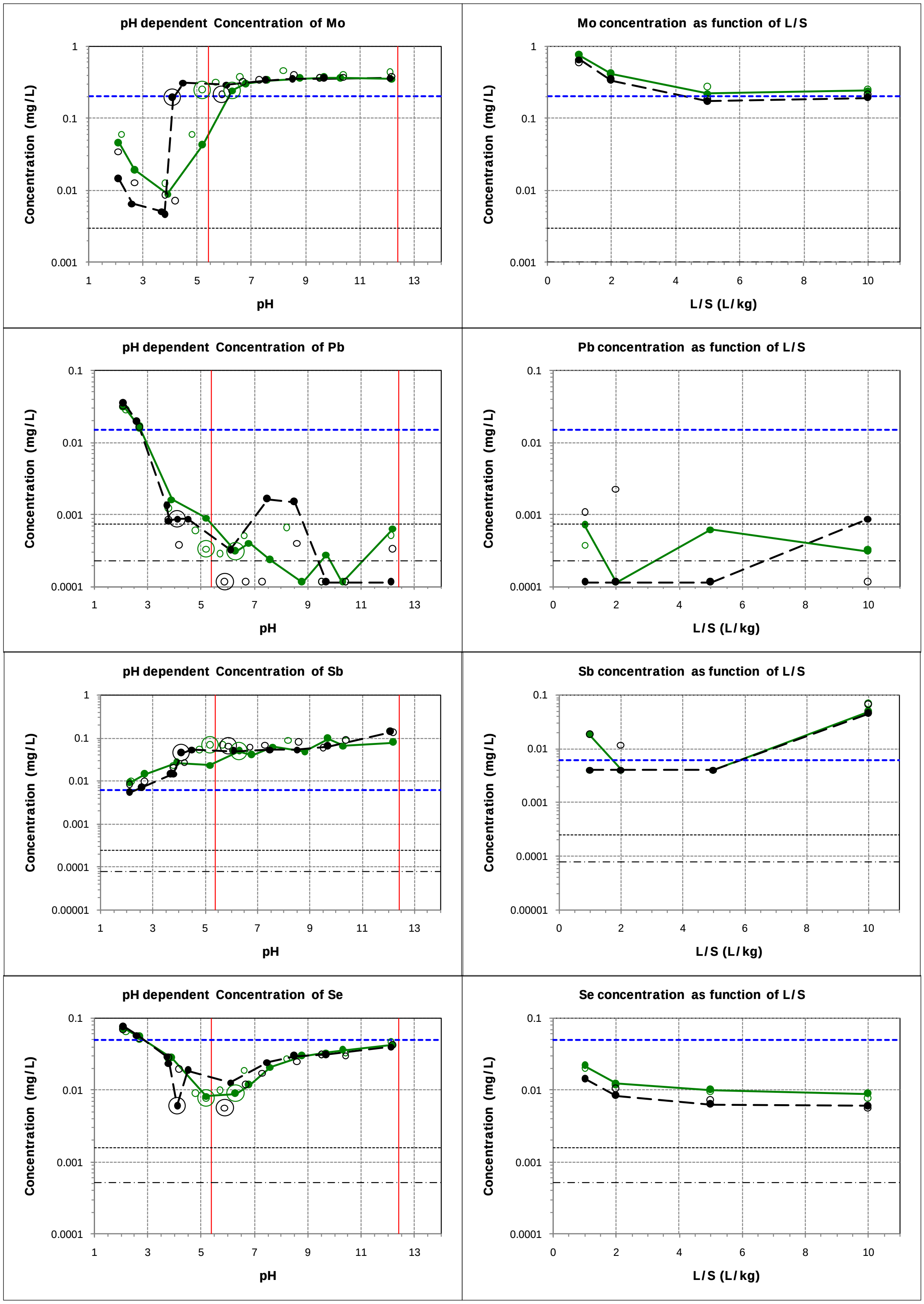
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



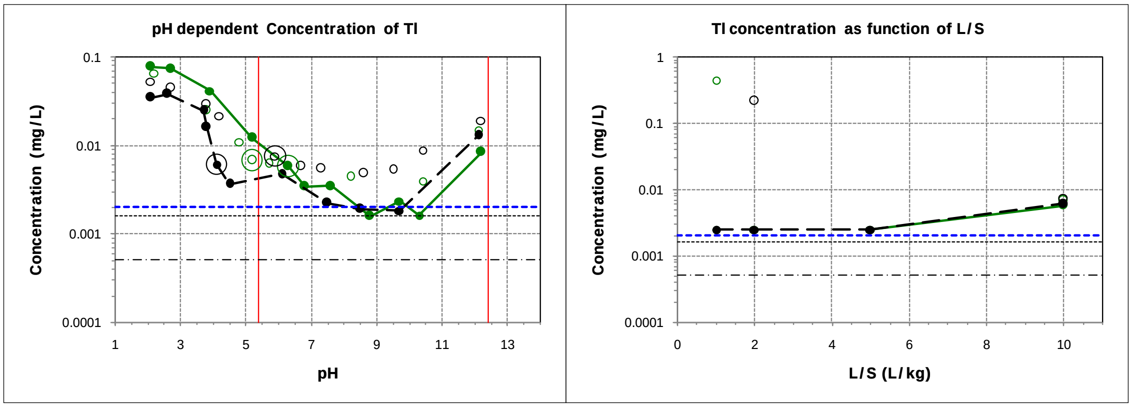
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



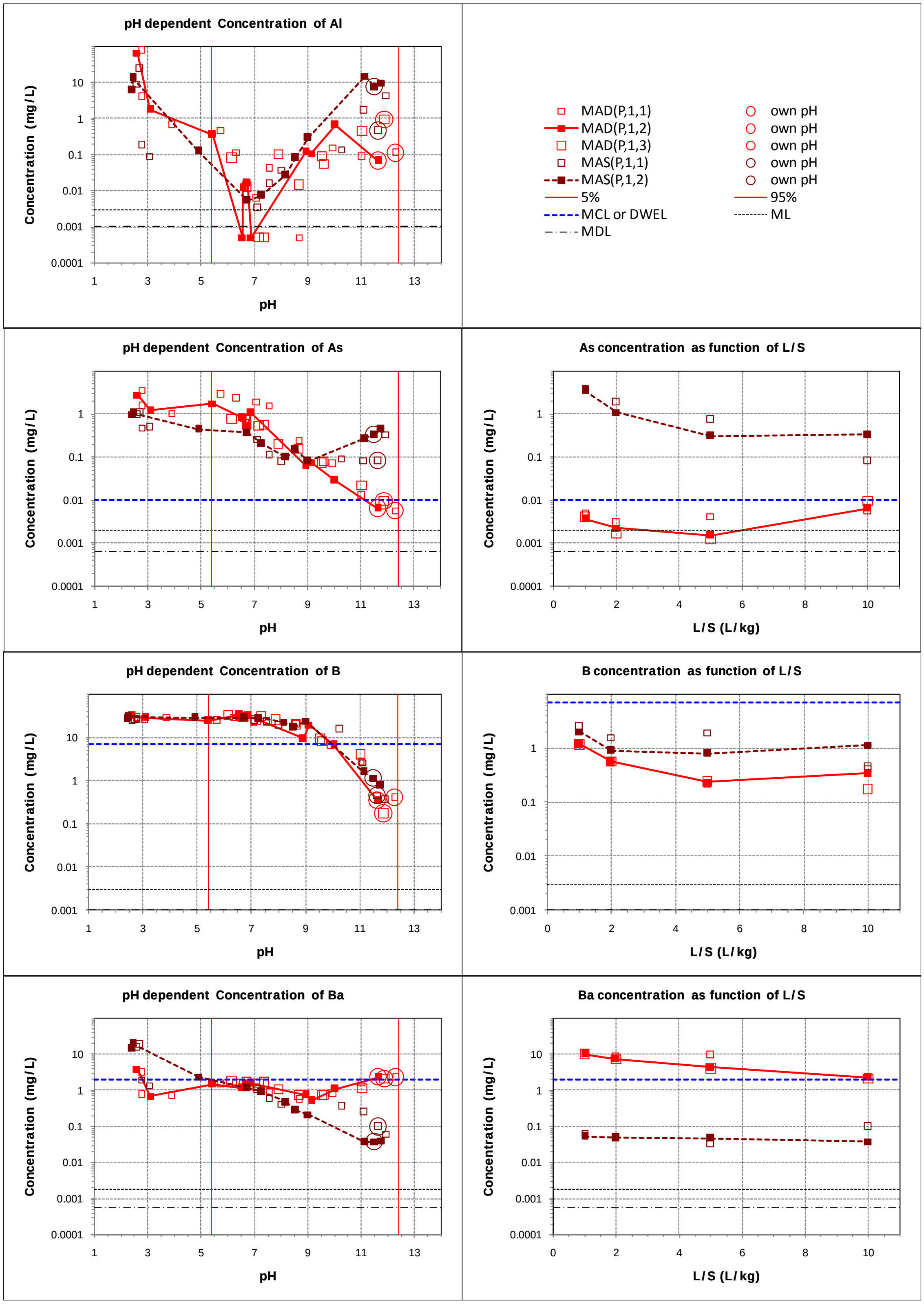
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



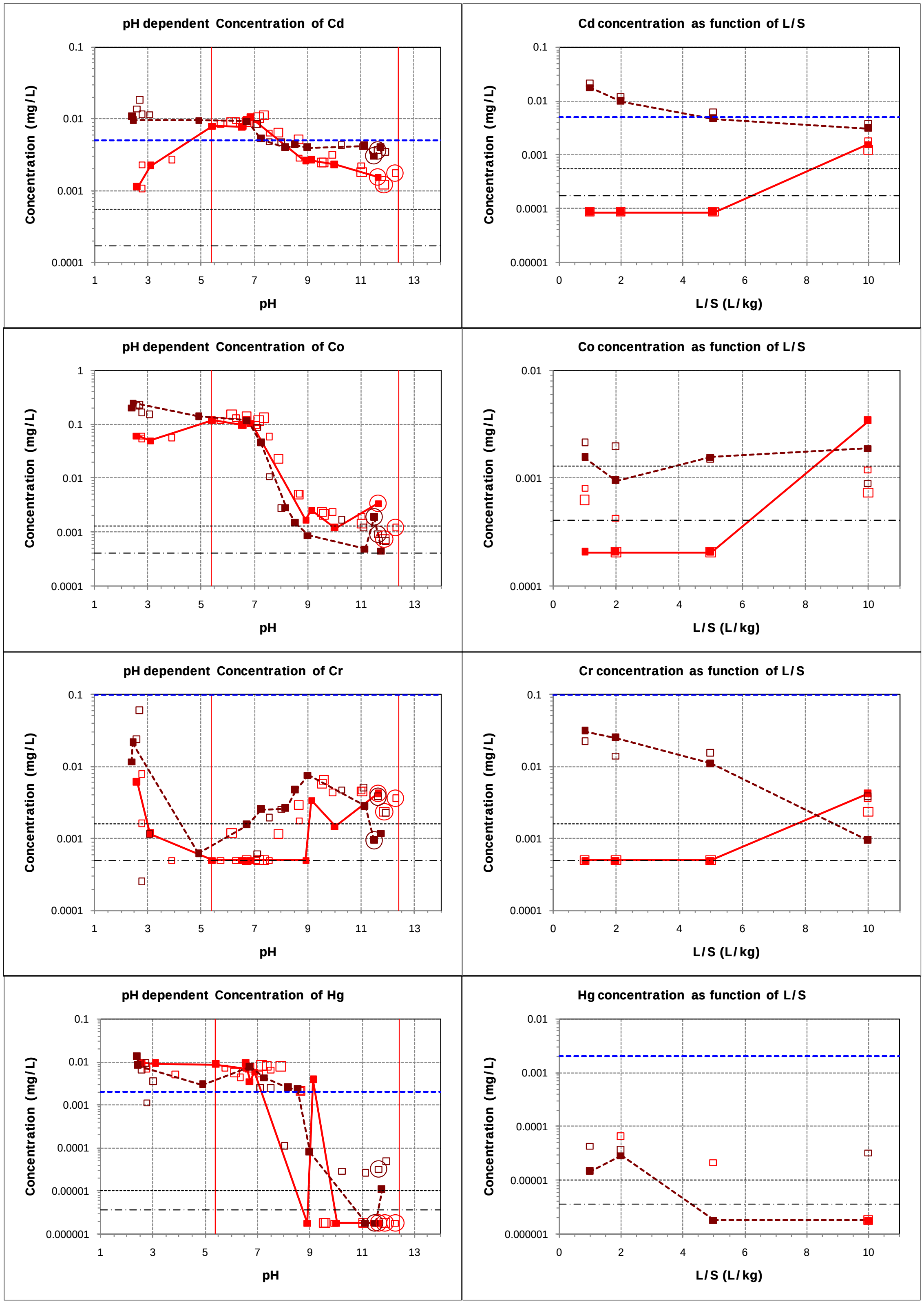
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



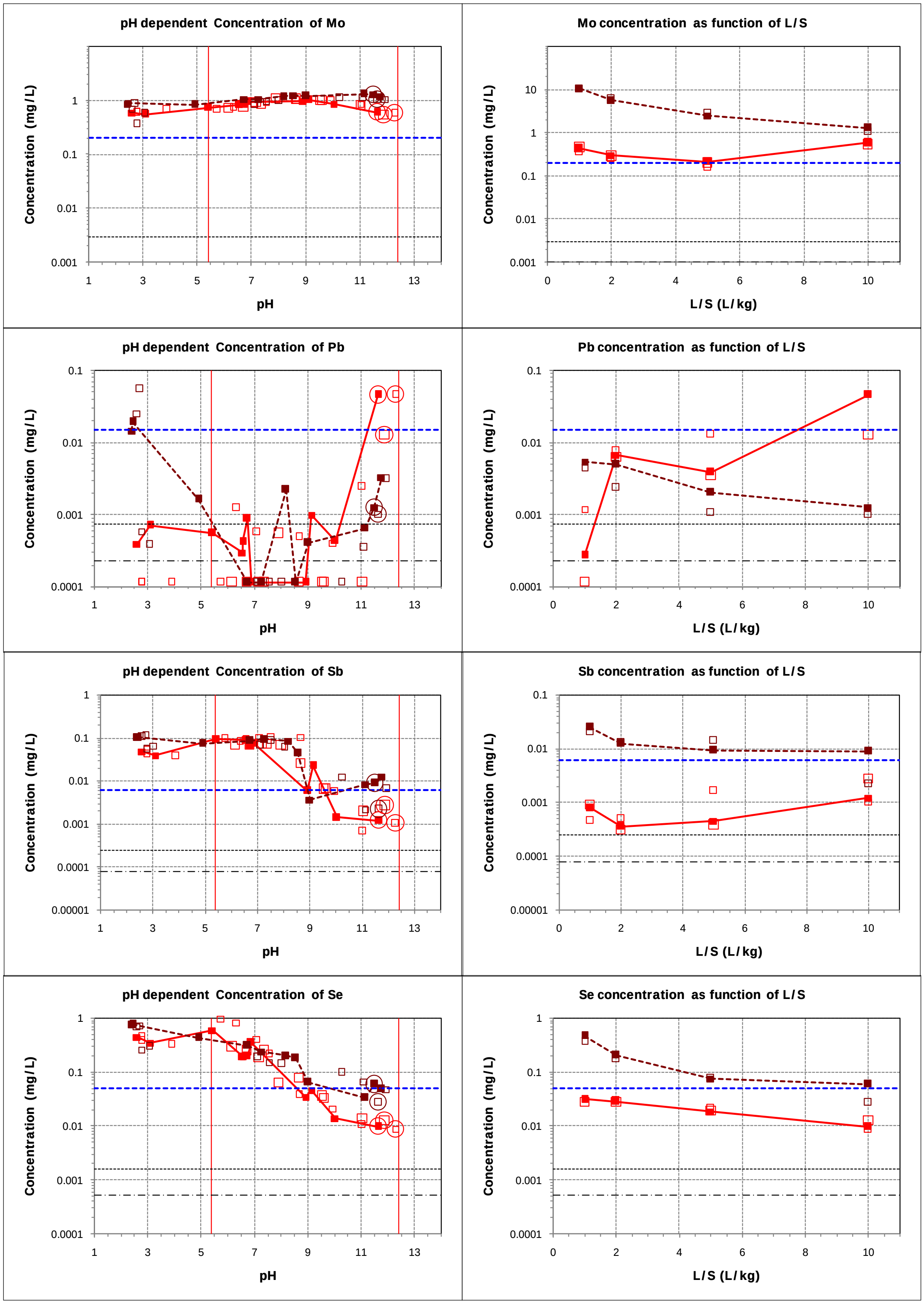
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



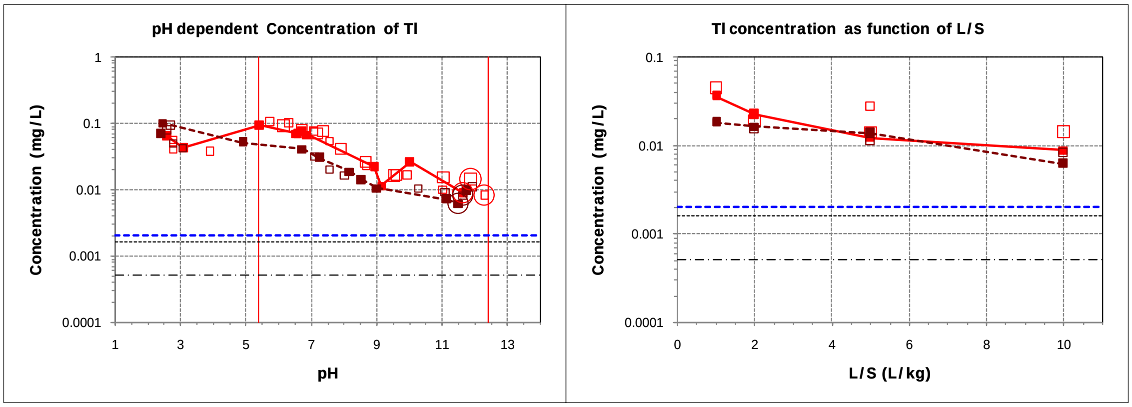
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



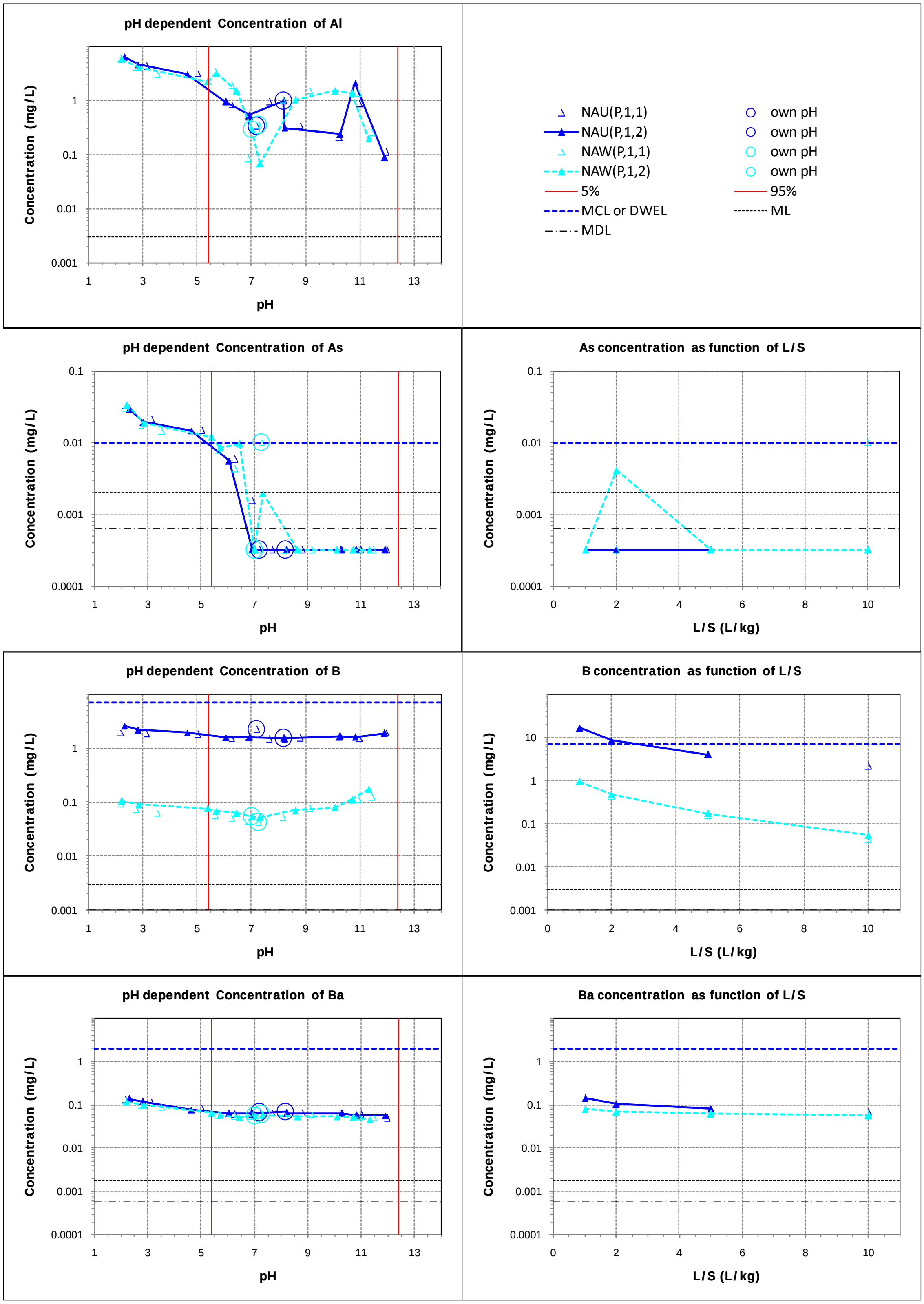
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



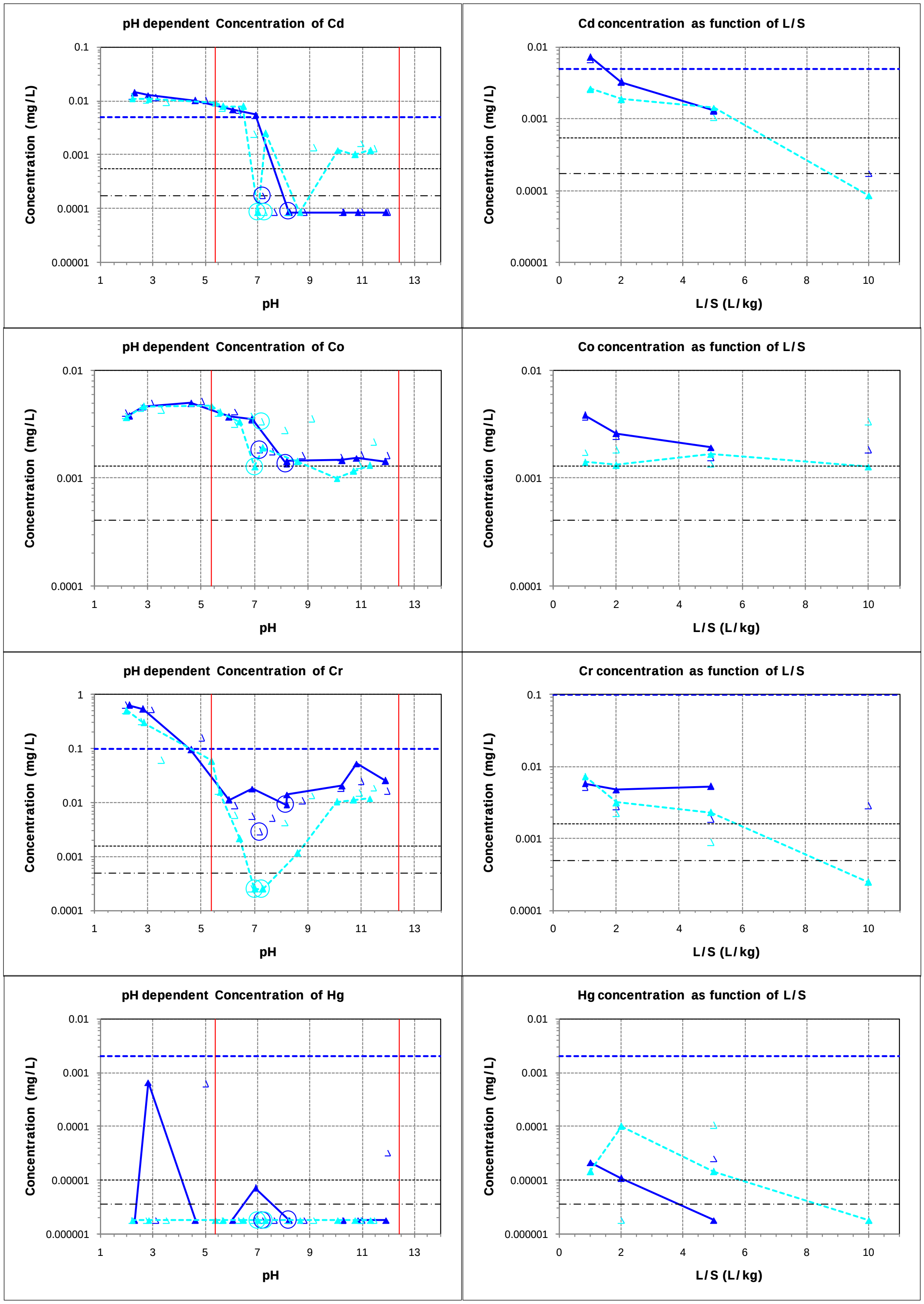
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



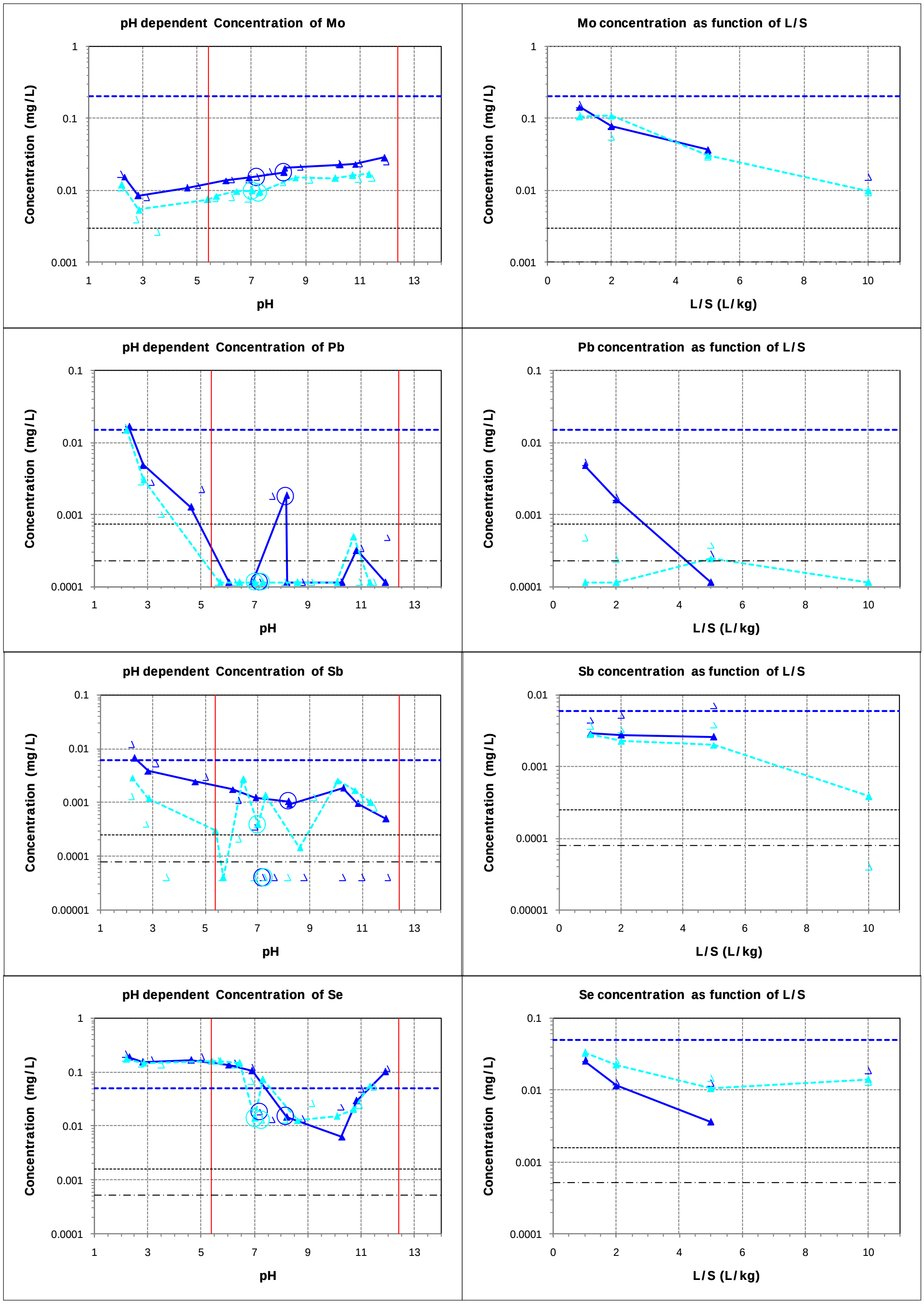
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



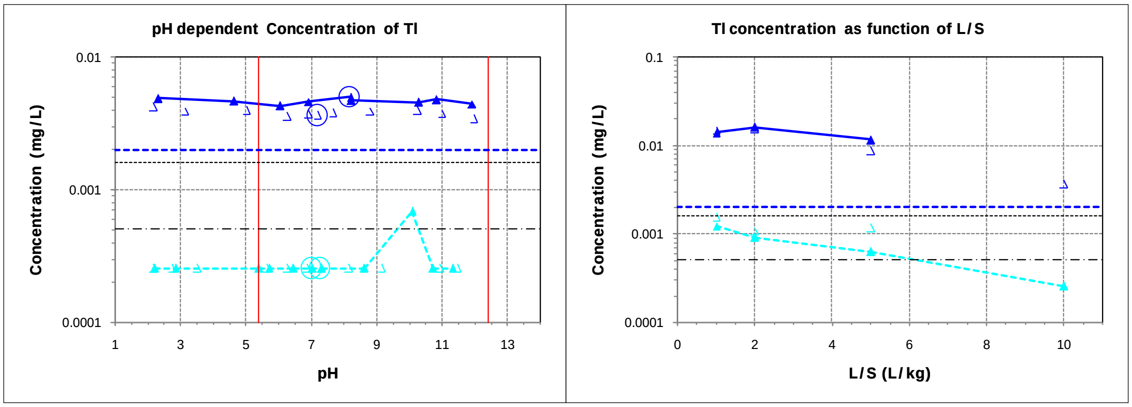
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



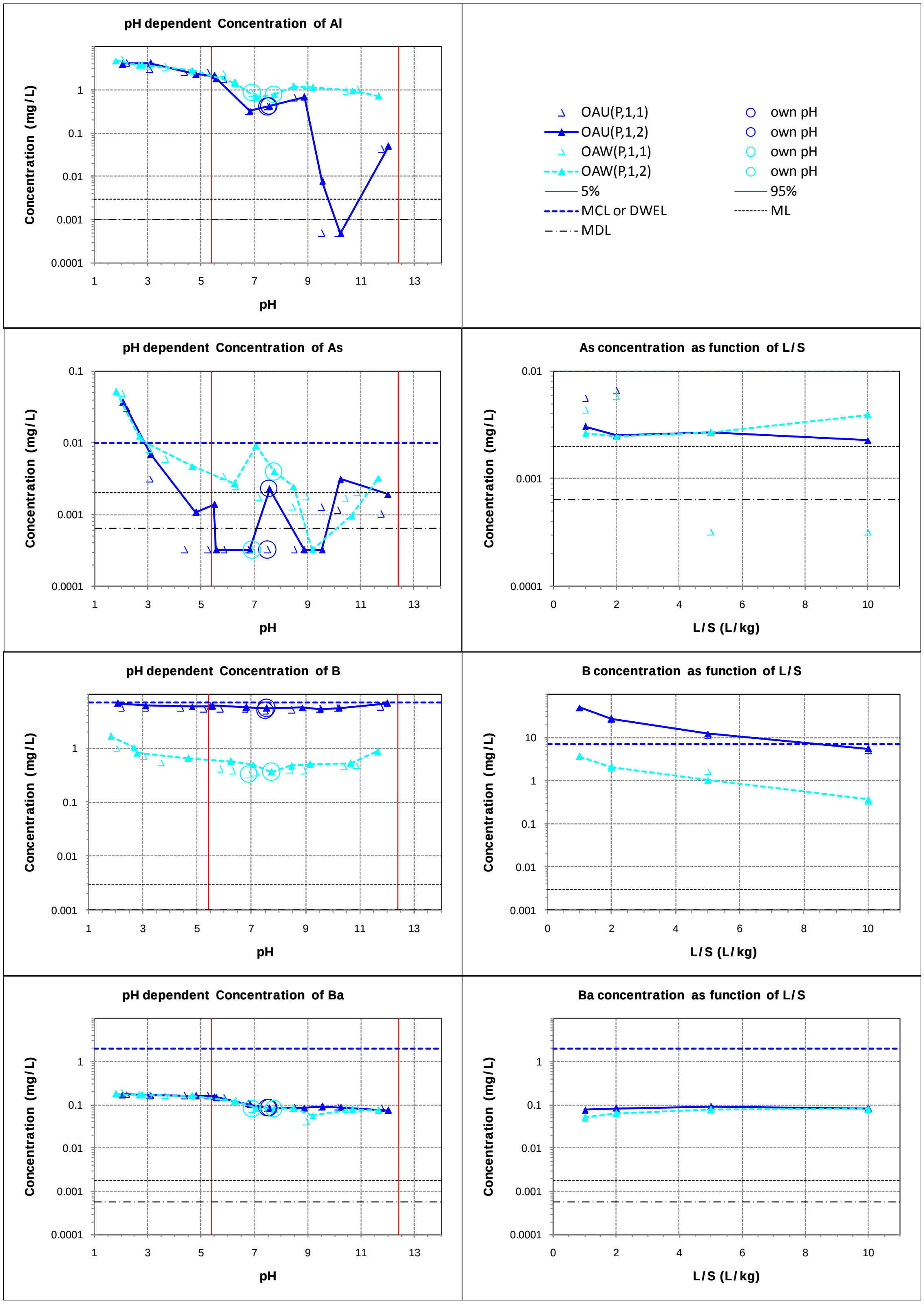
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



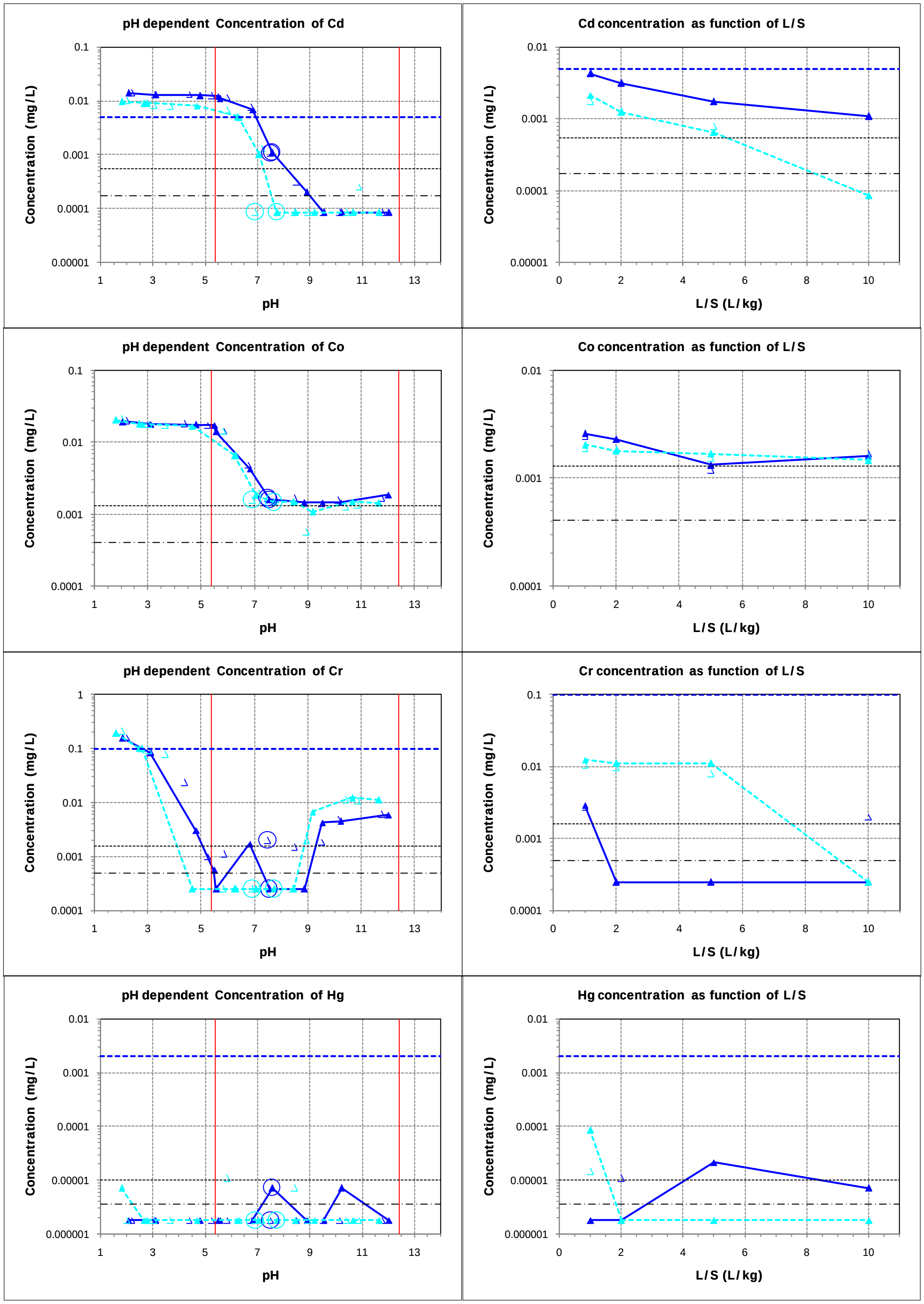
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



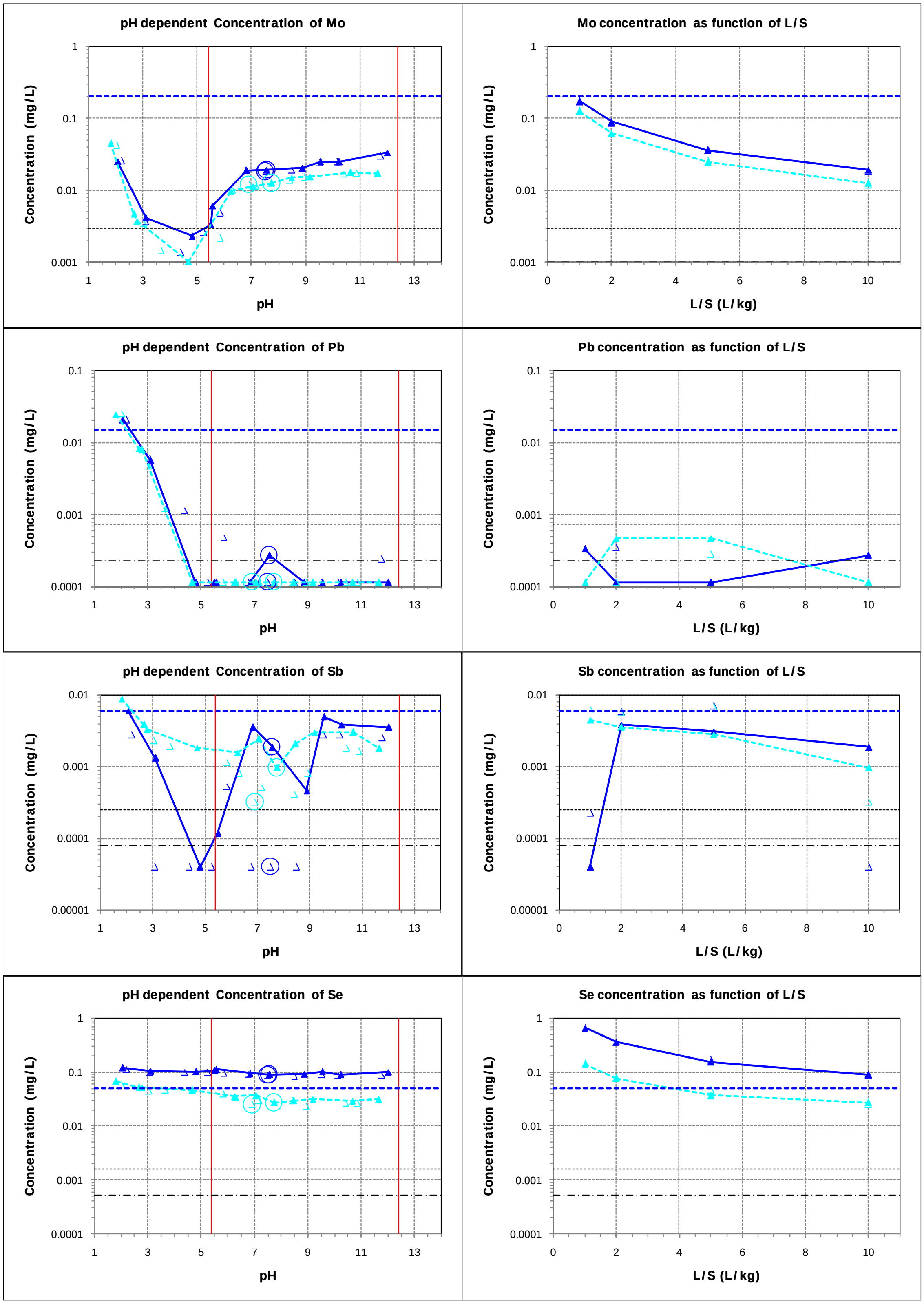
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



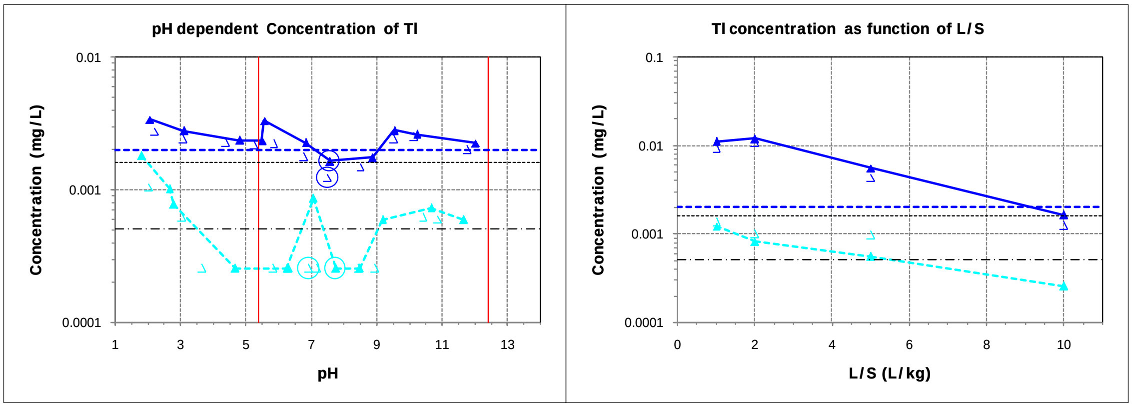
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



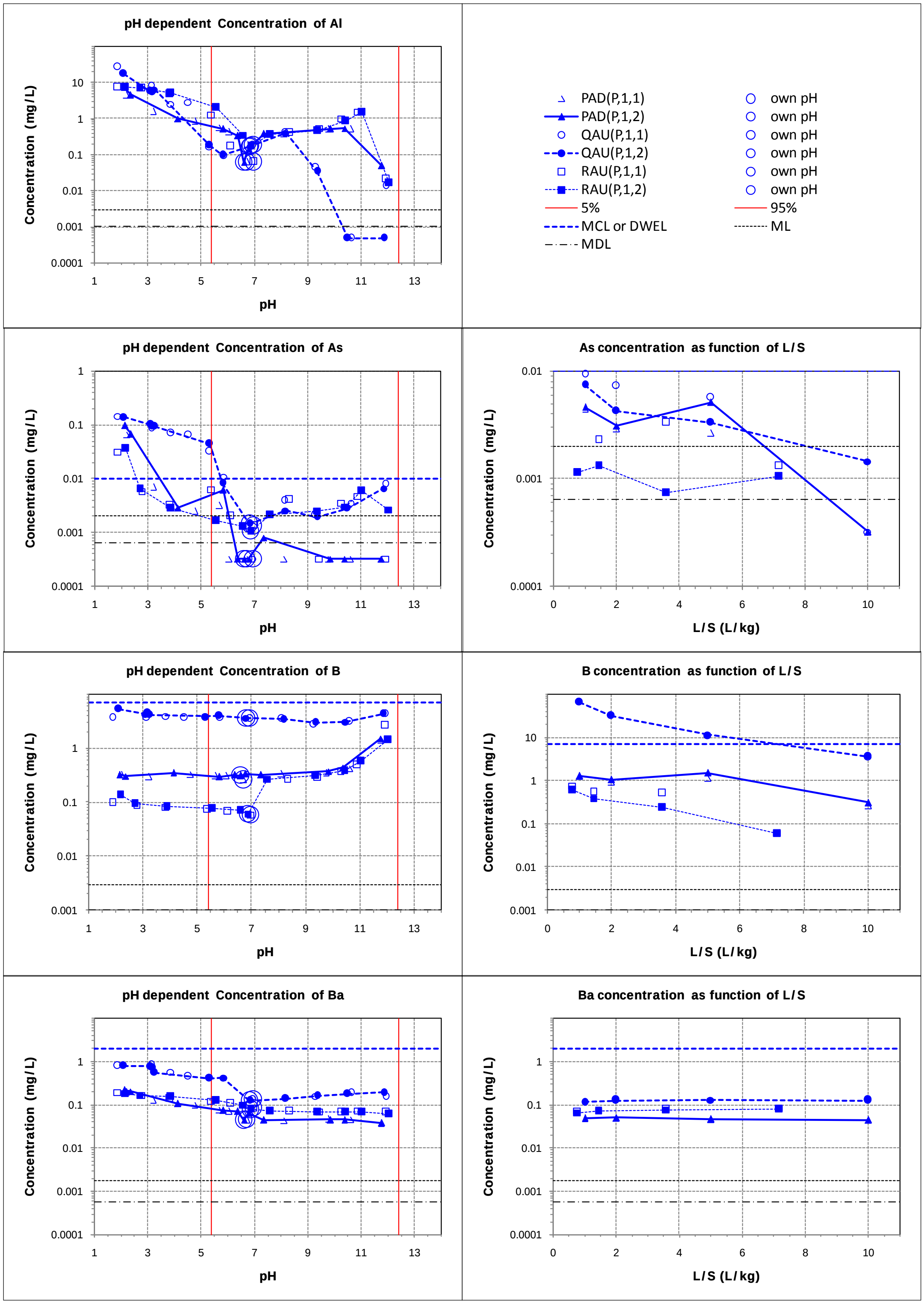
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



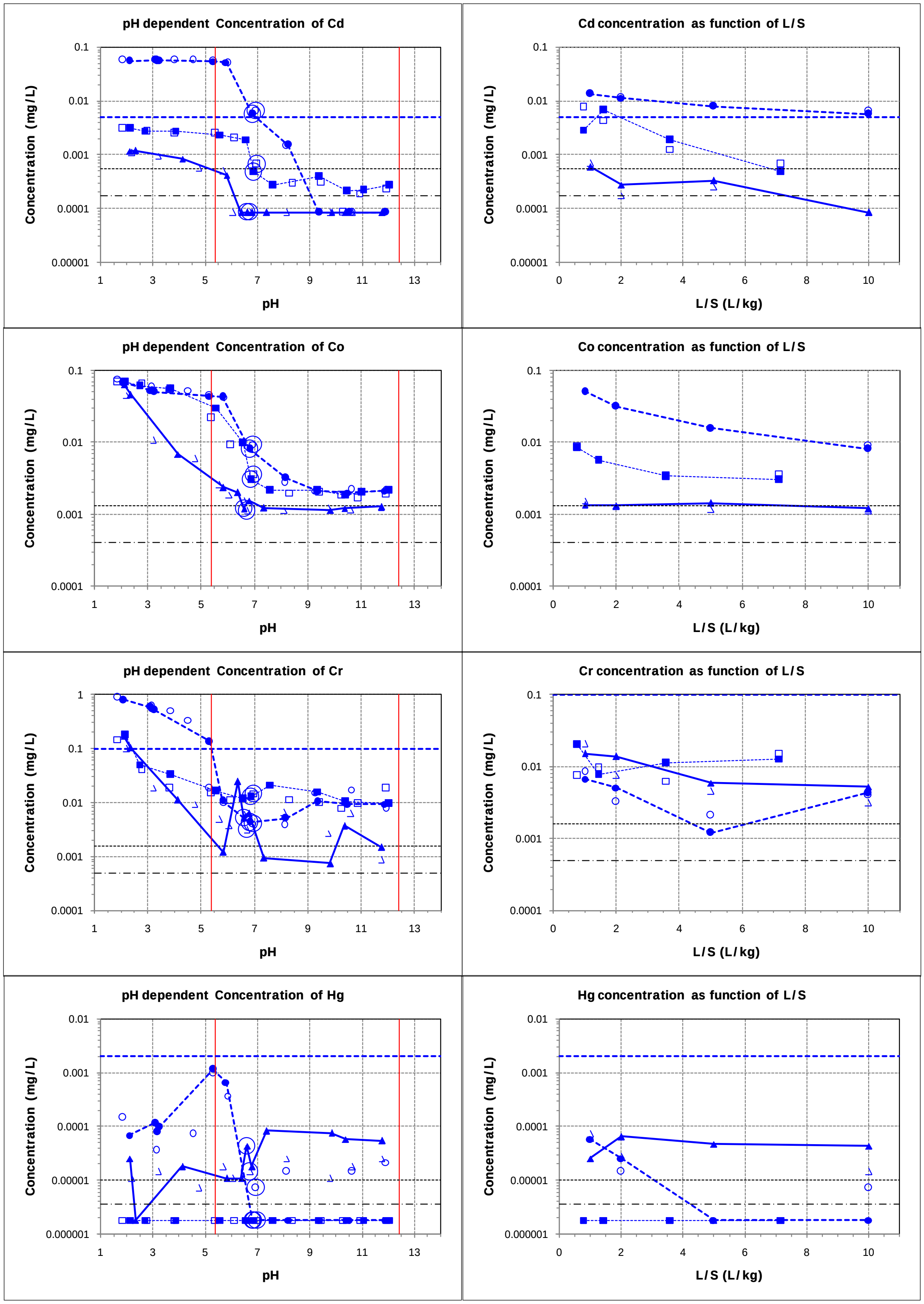
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.

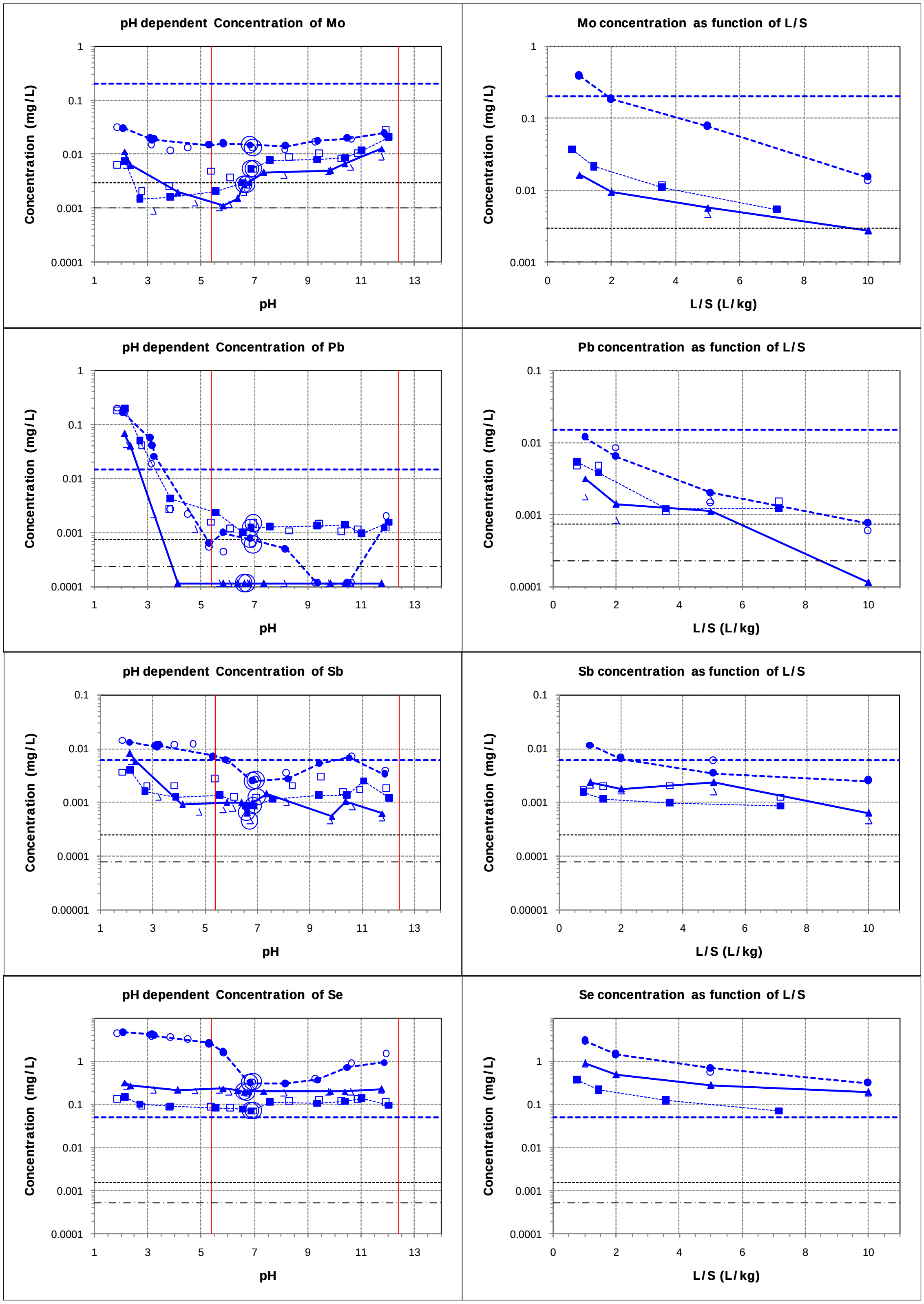


Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.

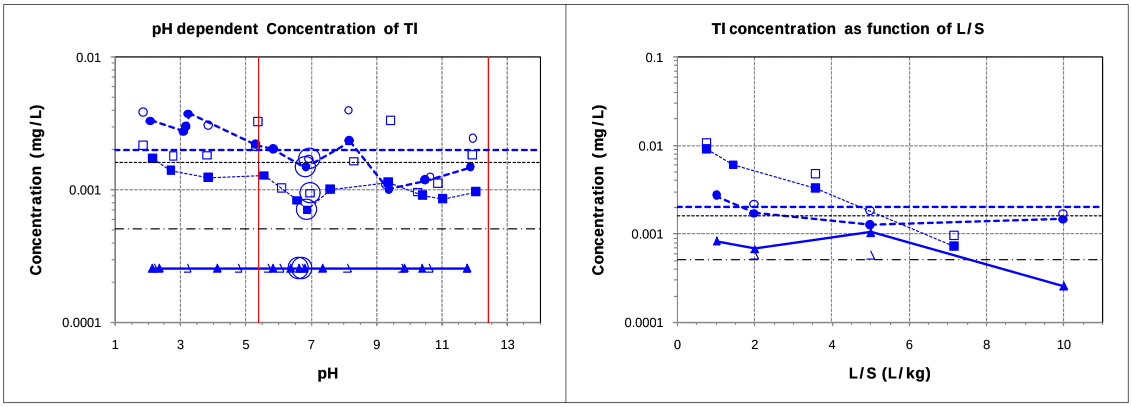


Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.

I/A



Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
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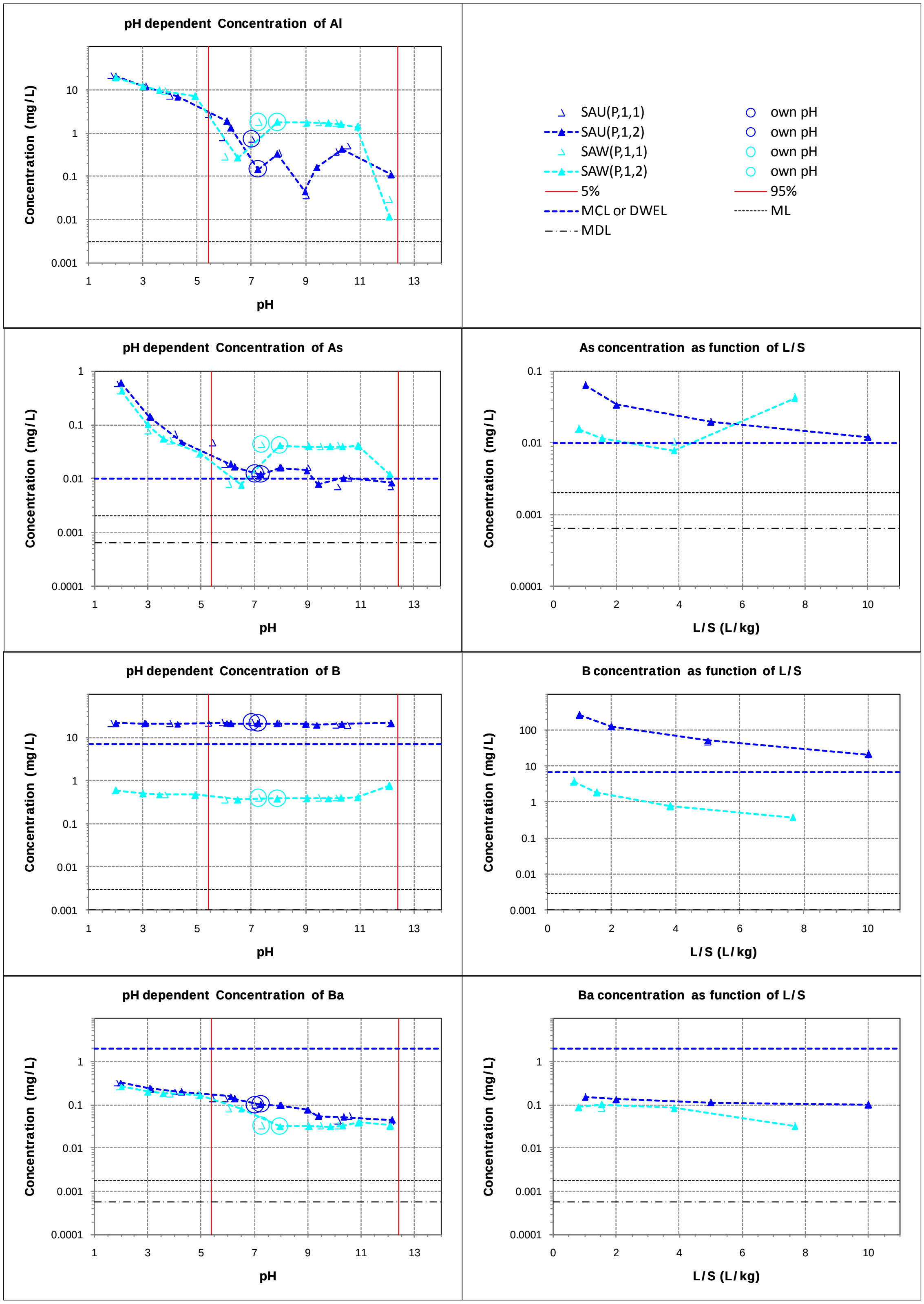
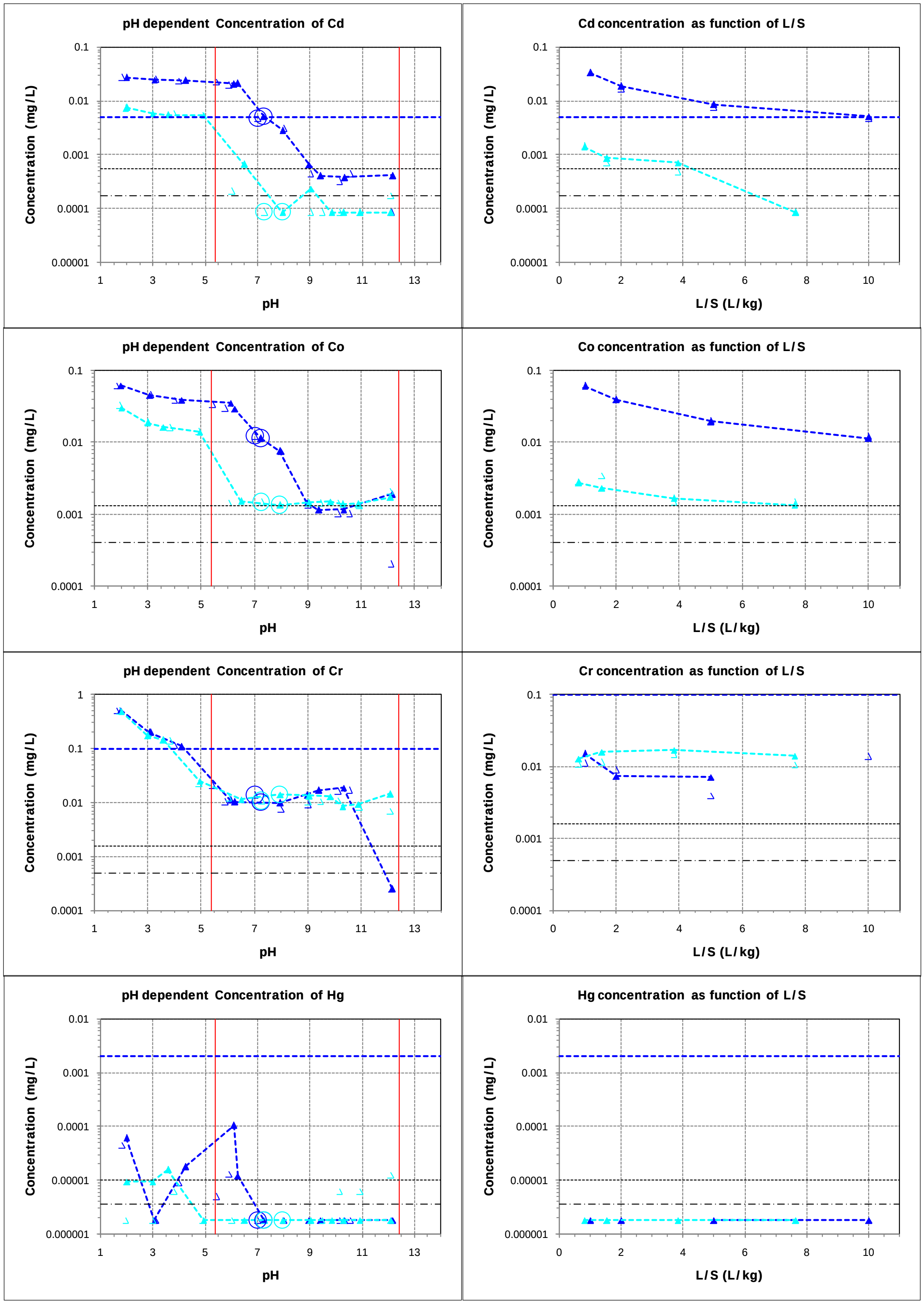
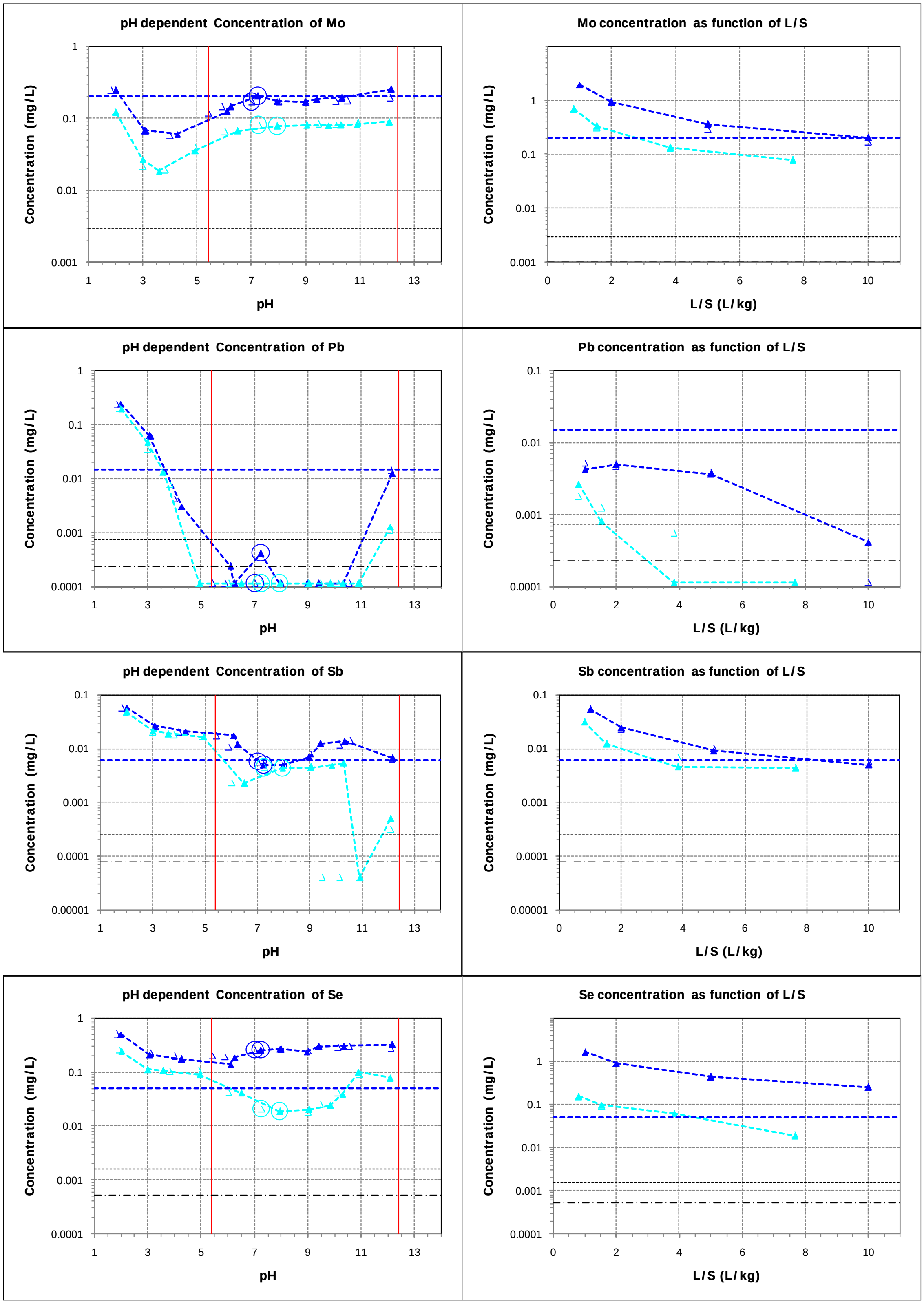
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



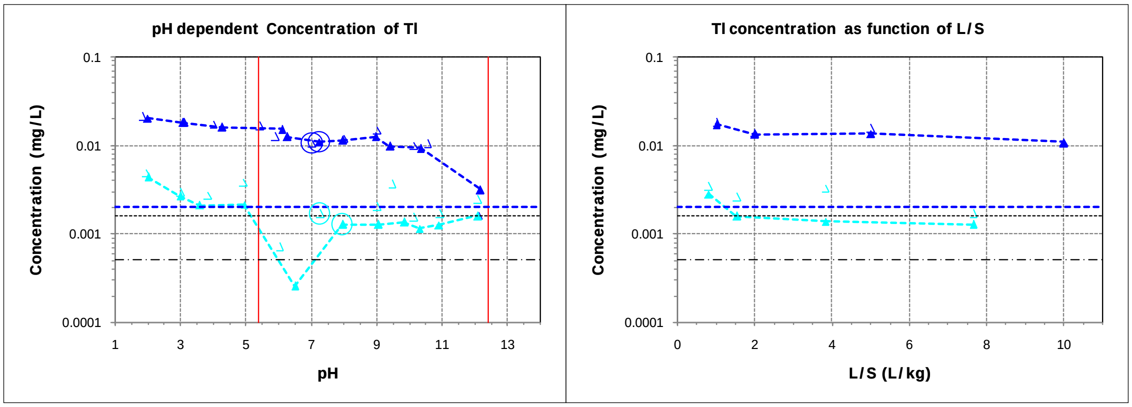
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



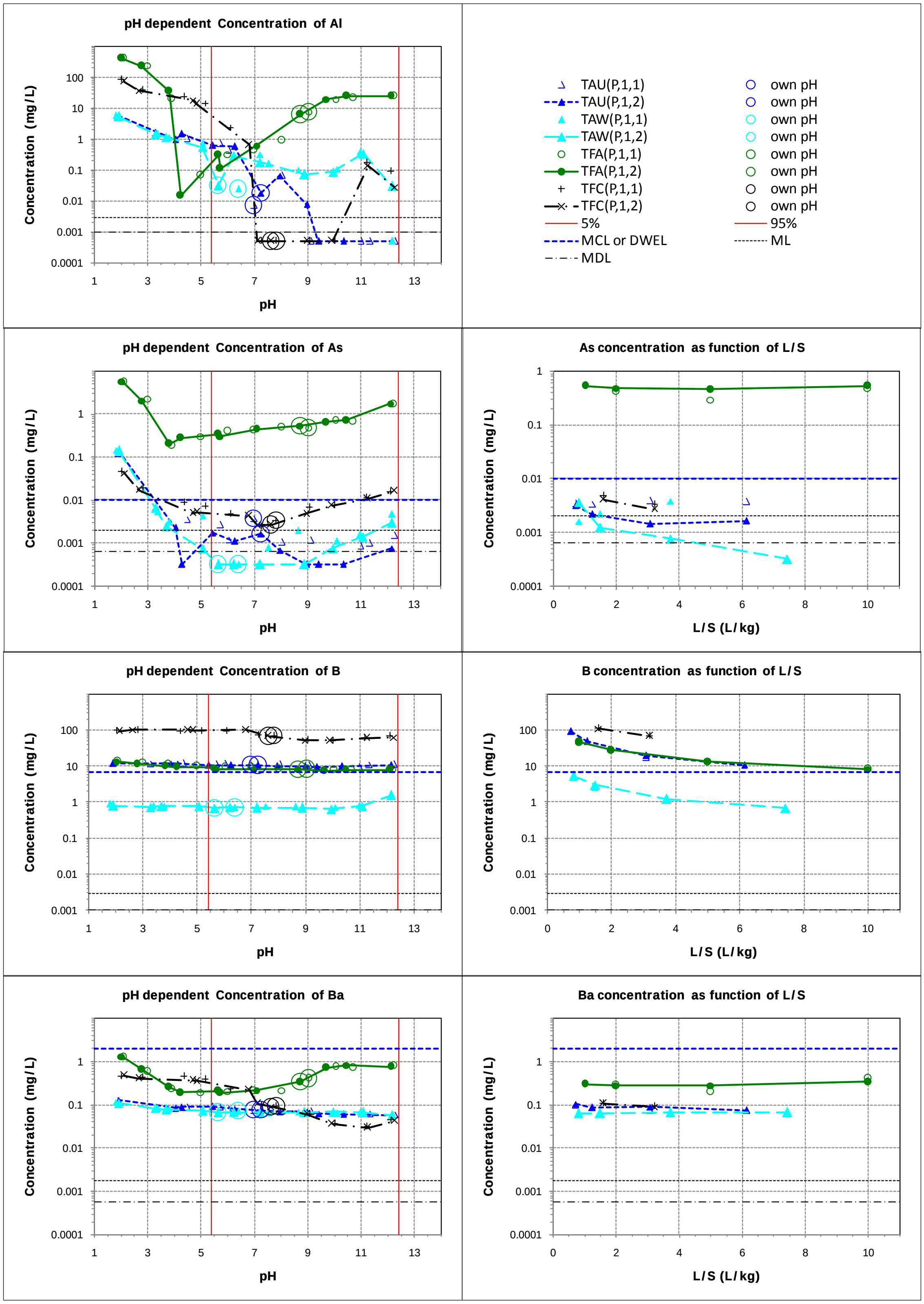
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



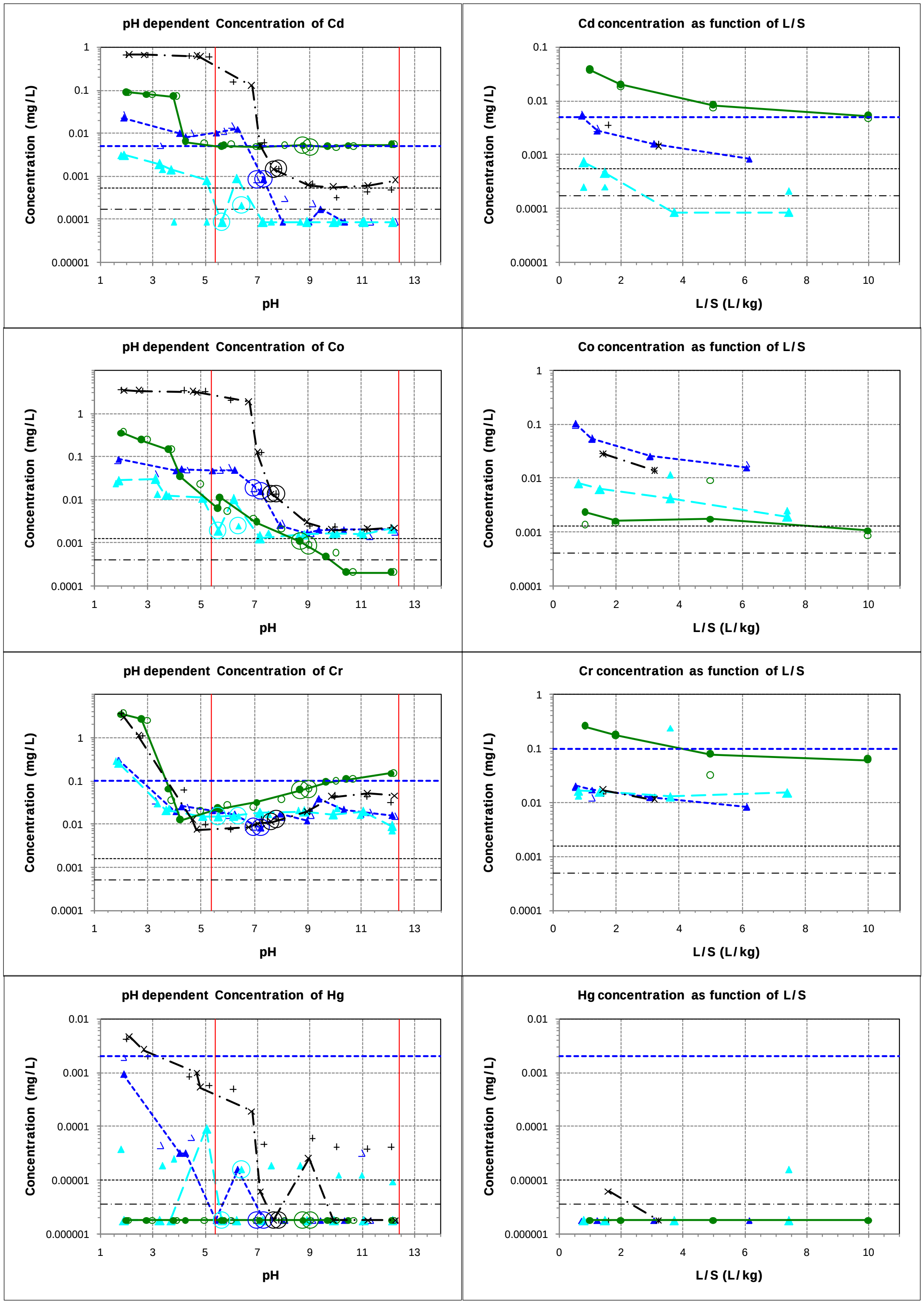
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



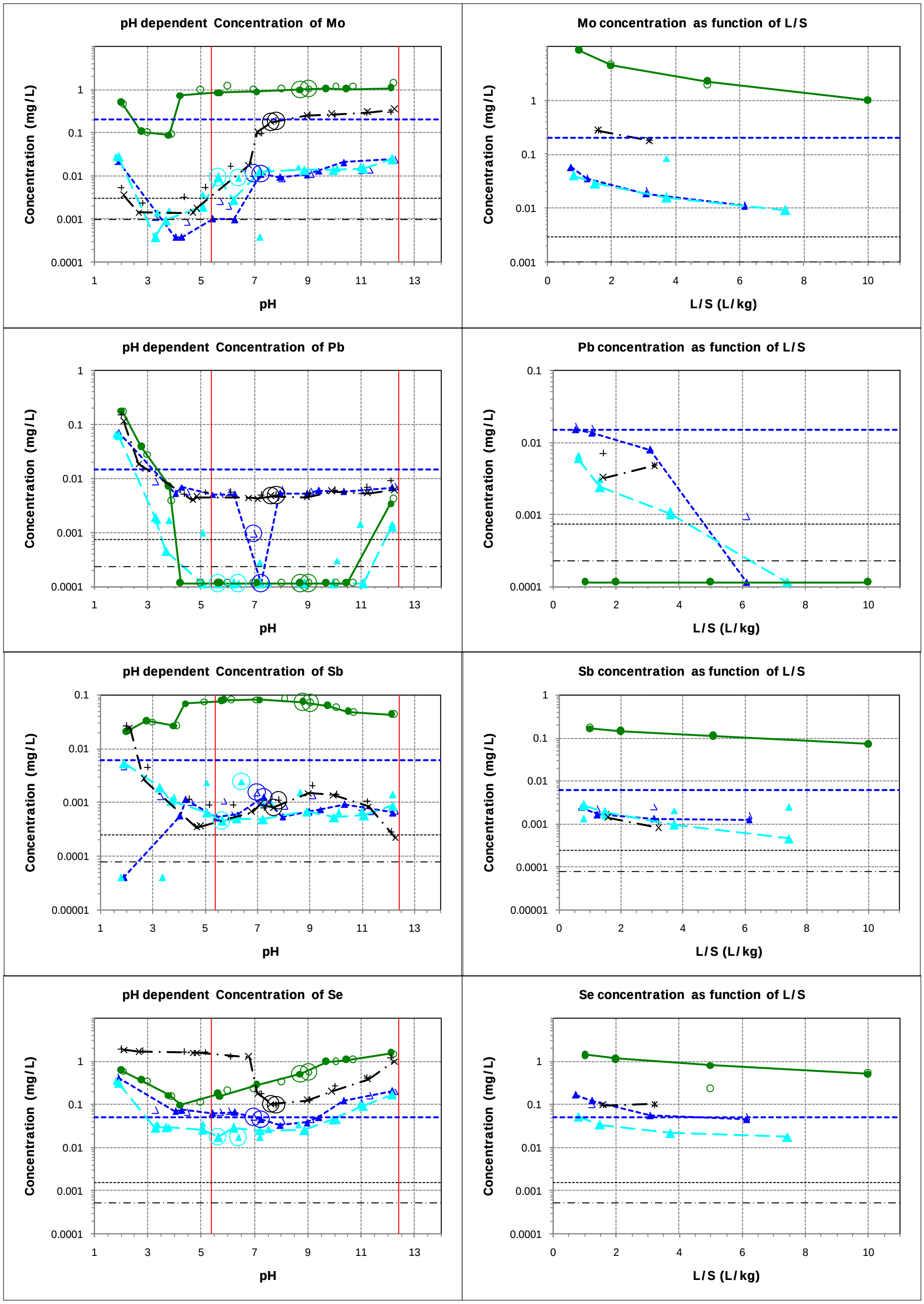
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



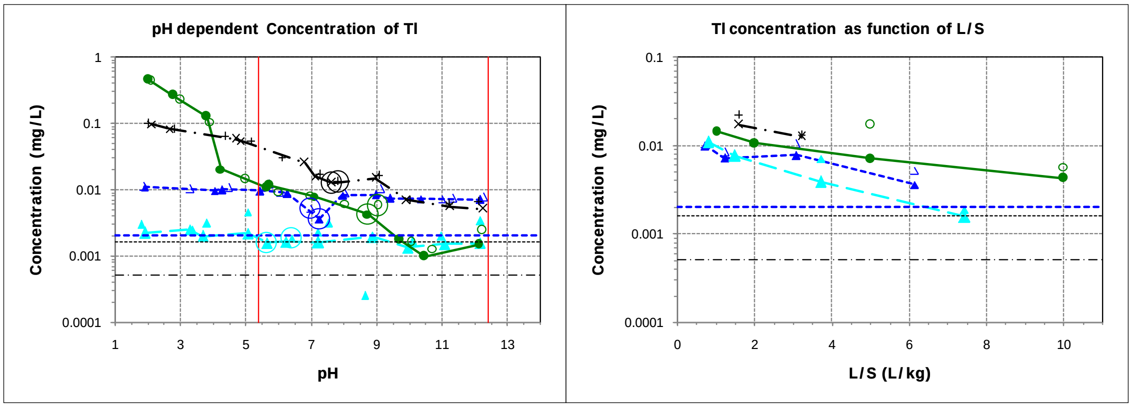
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



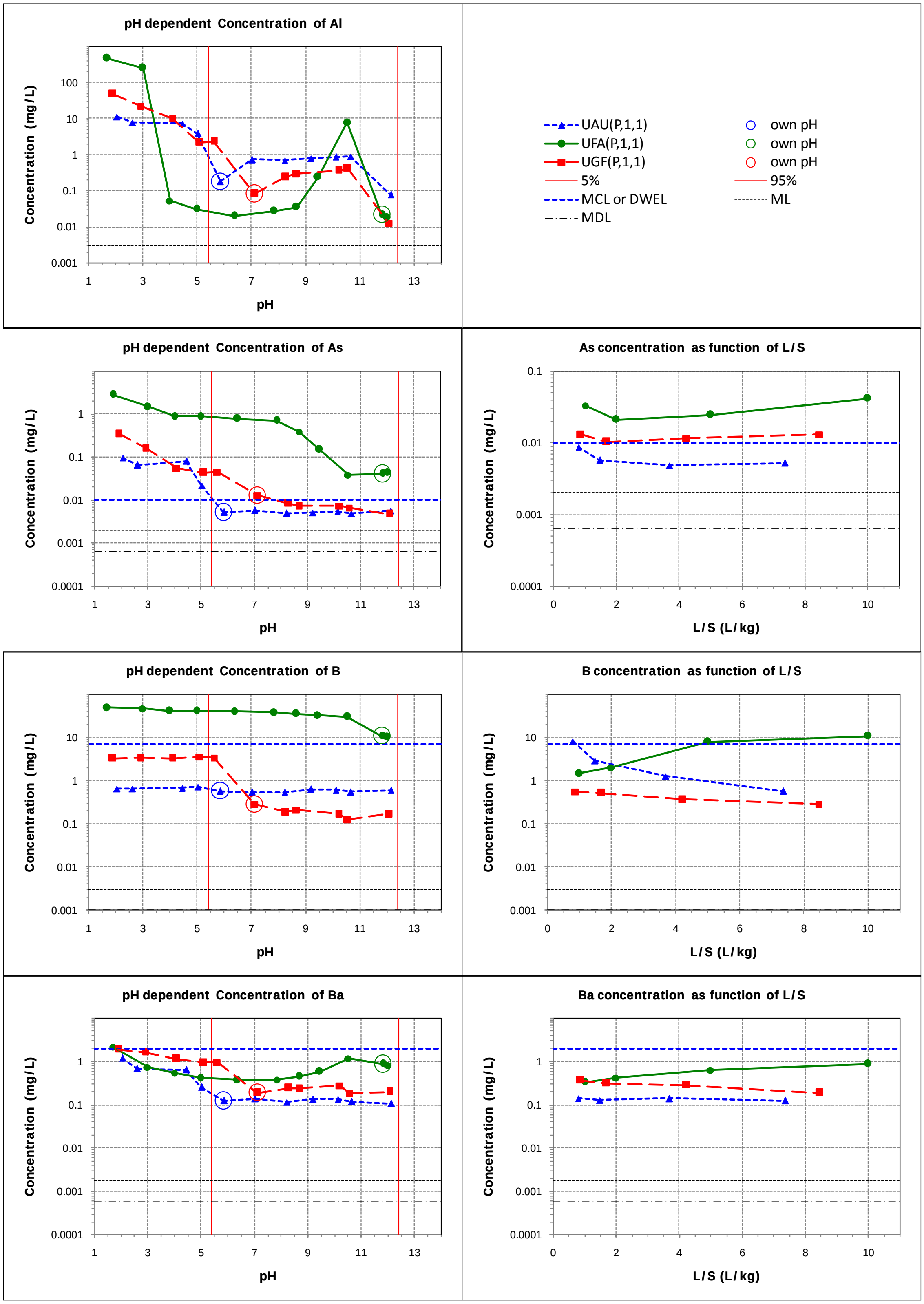
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



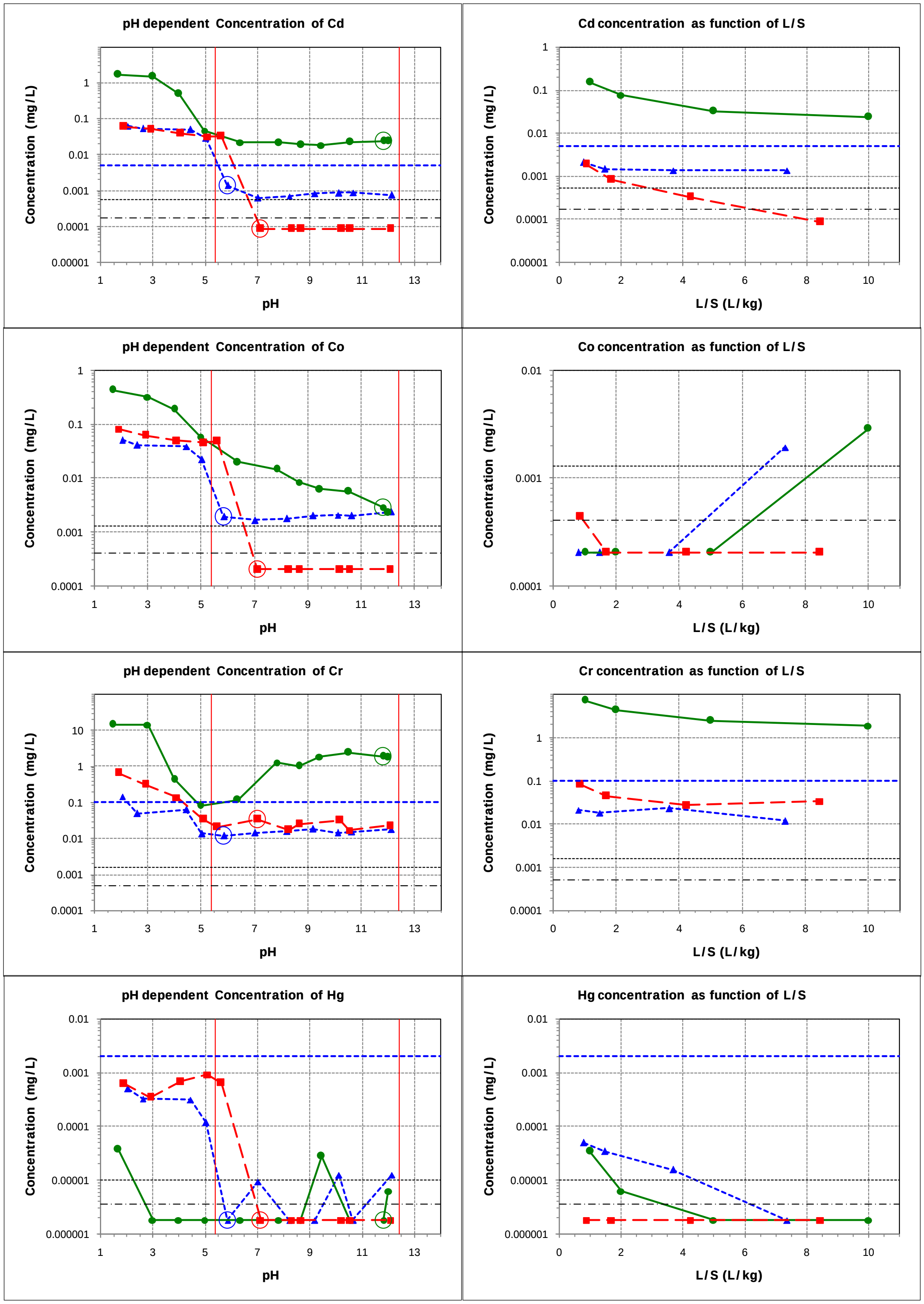
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



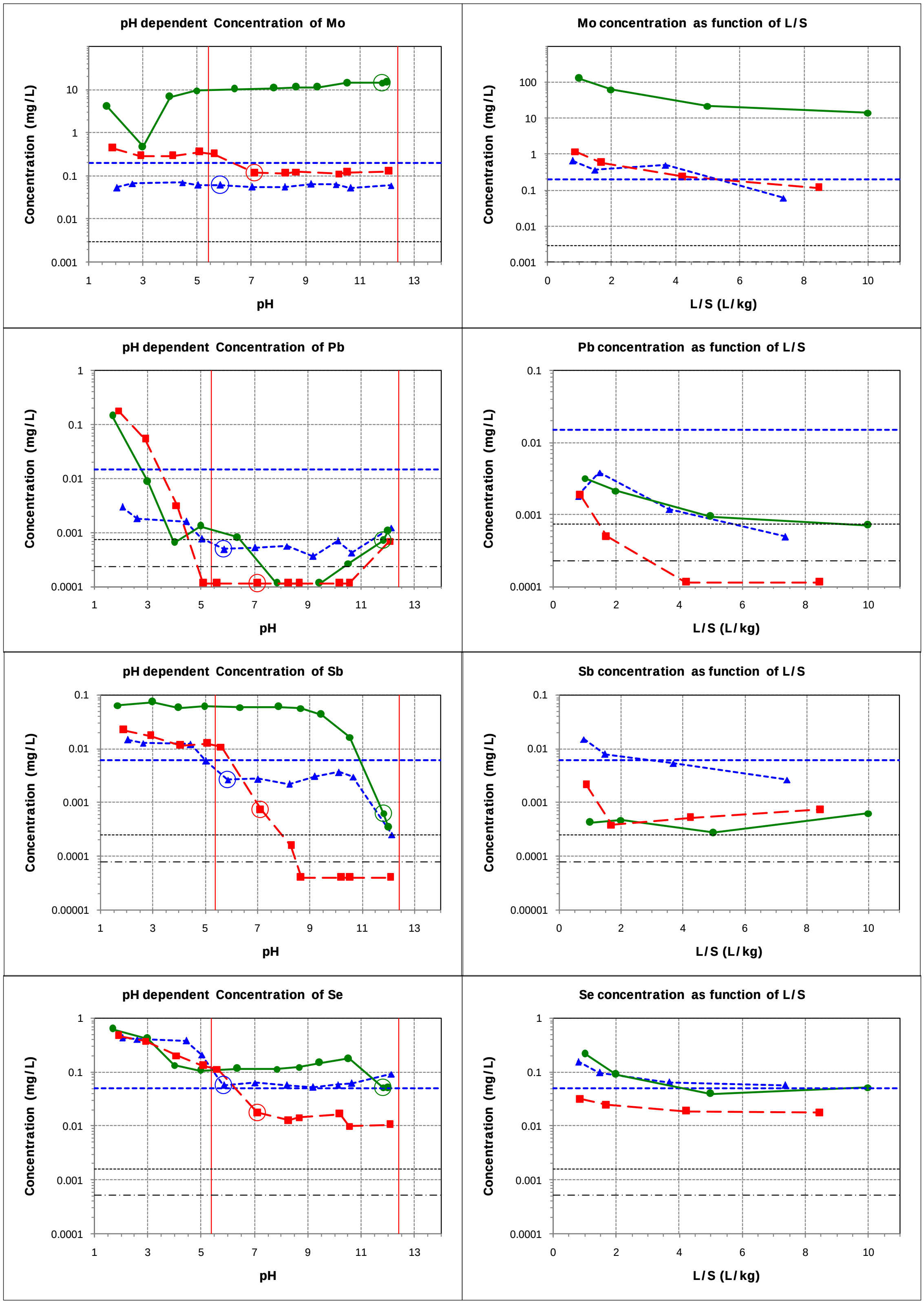
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



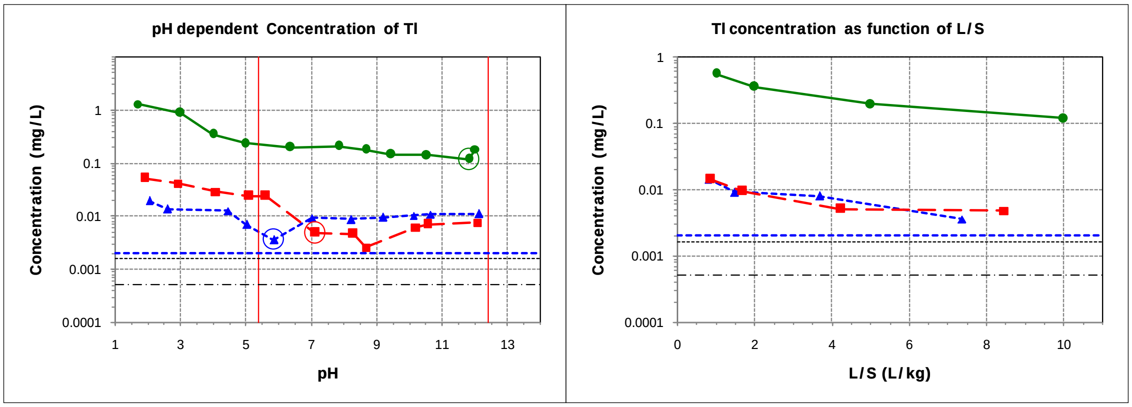
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **UFA** - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



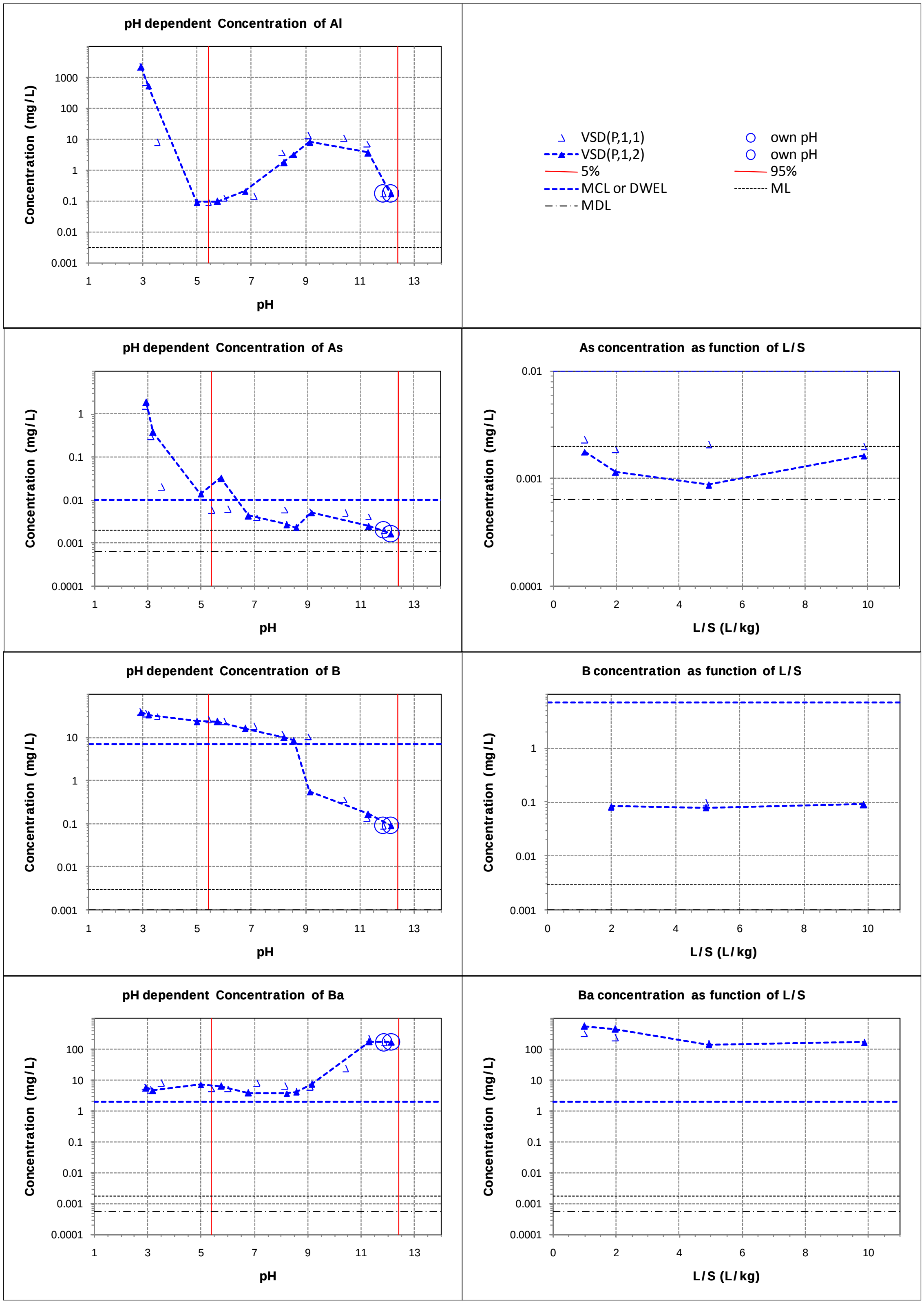
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **UFA** - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



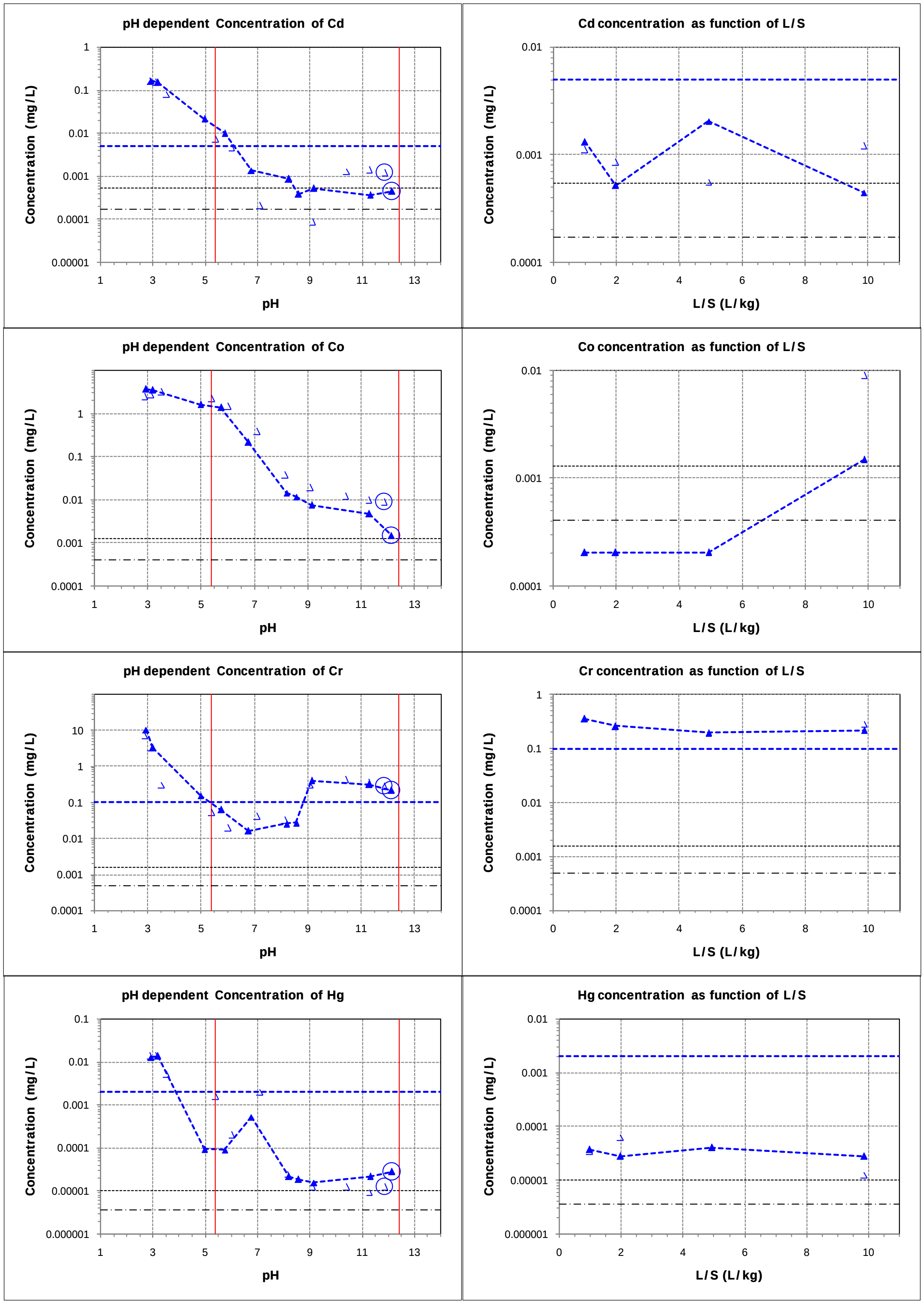
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.


pH dependent Concentration of Cd

Cd concentration as function of L/S

pH dependent Concentration of Co

Co concentration as function of L/S

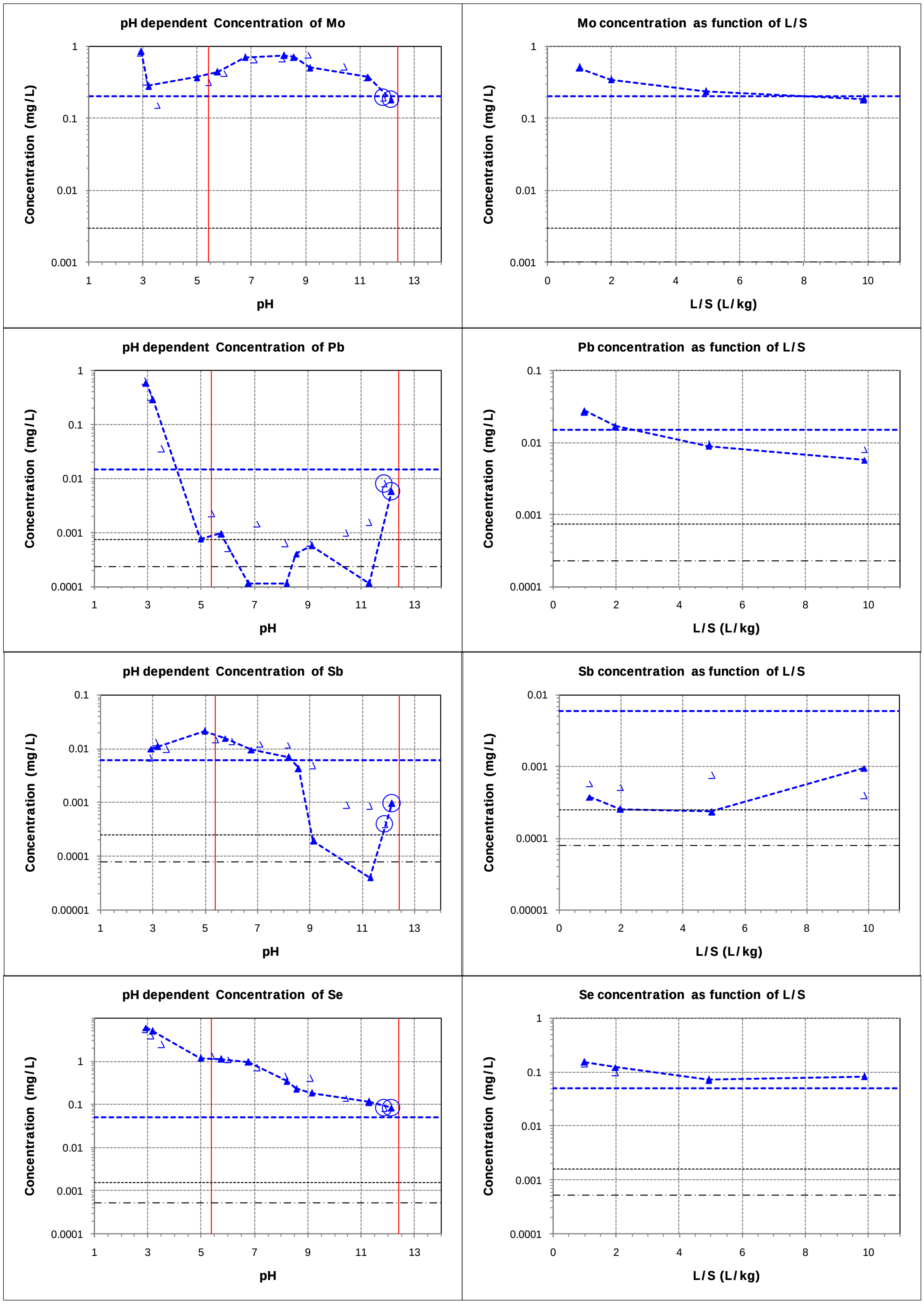
pH dependent Concentration of Cr

Cr concentration as function of L/S

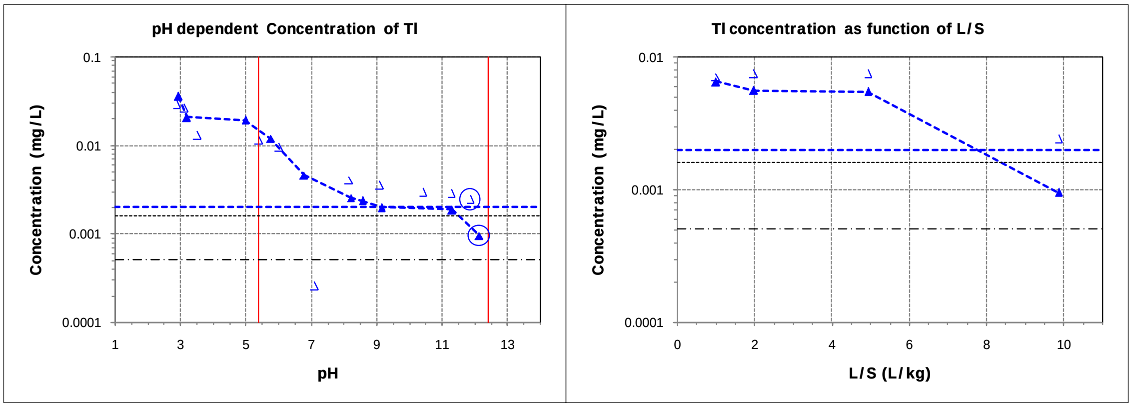
pH dependent Concentration of Hg

Hg concentration as function of L/S

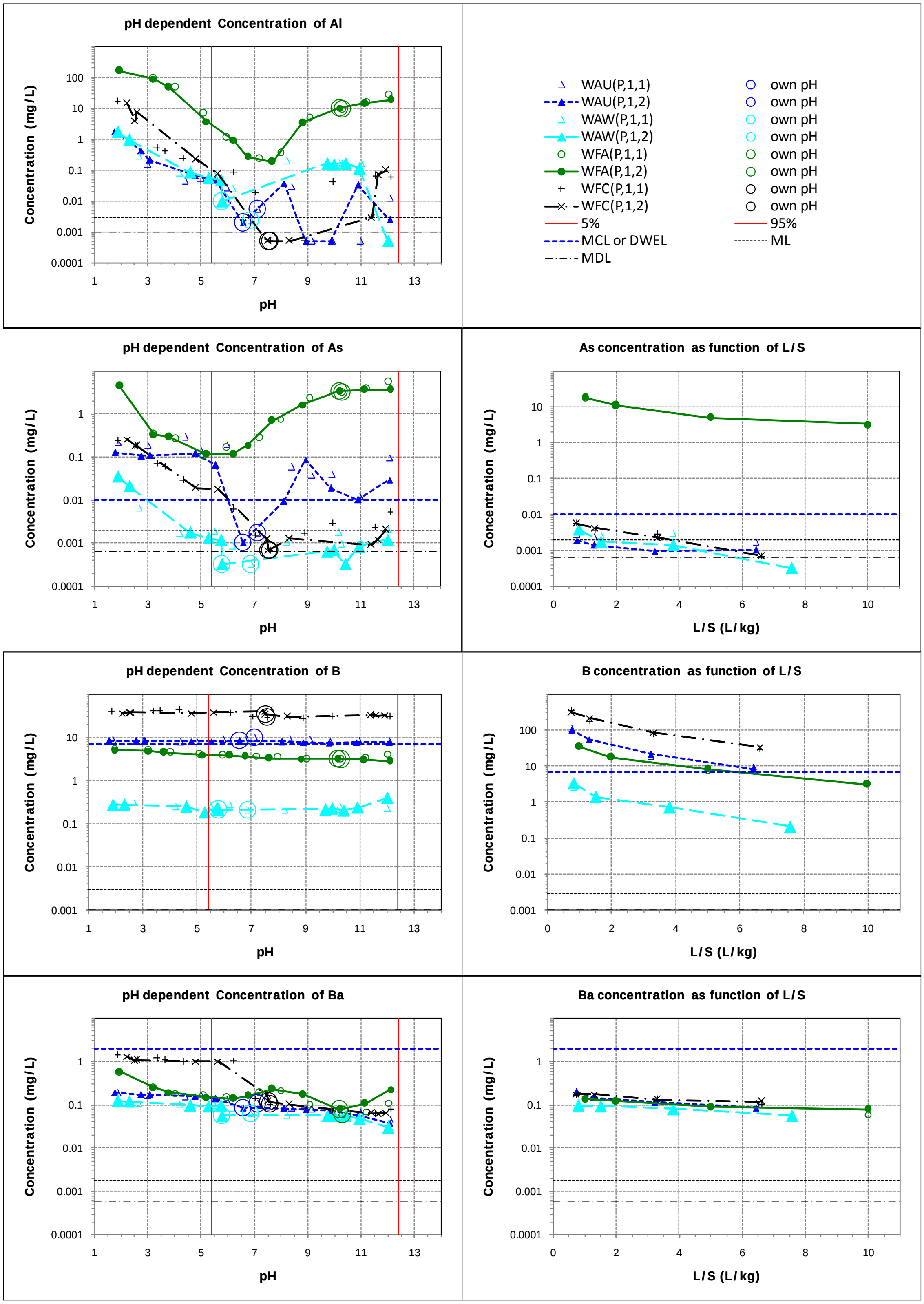
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



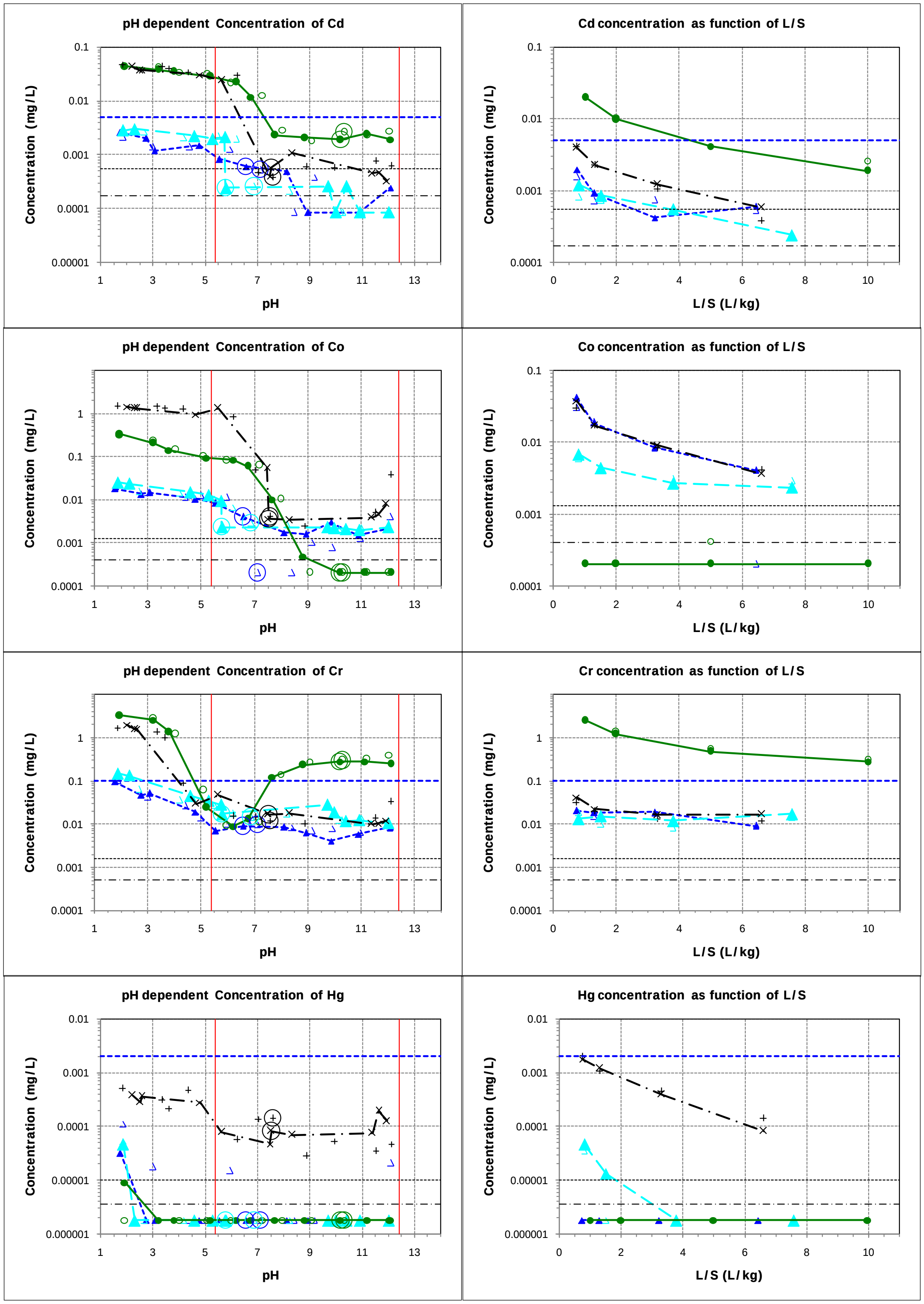
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



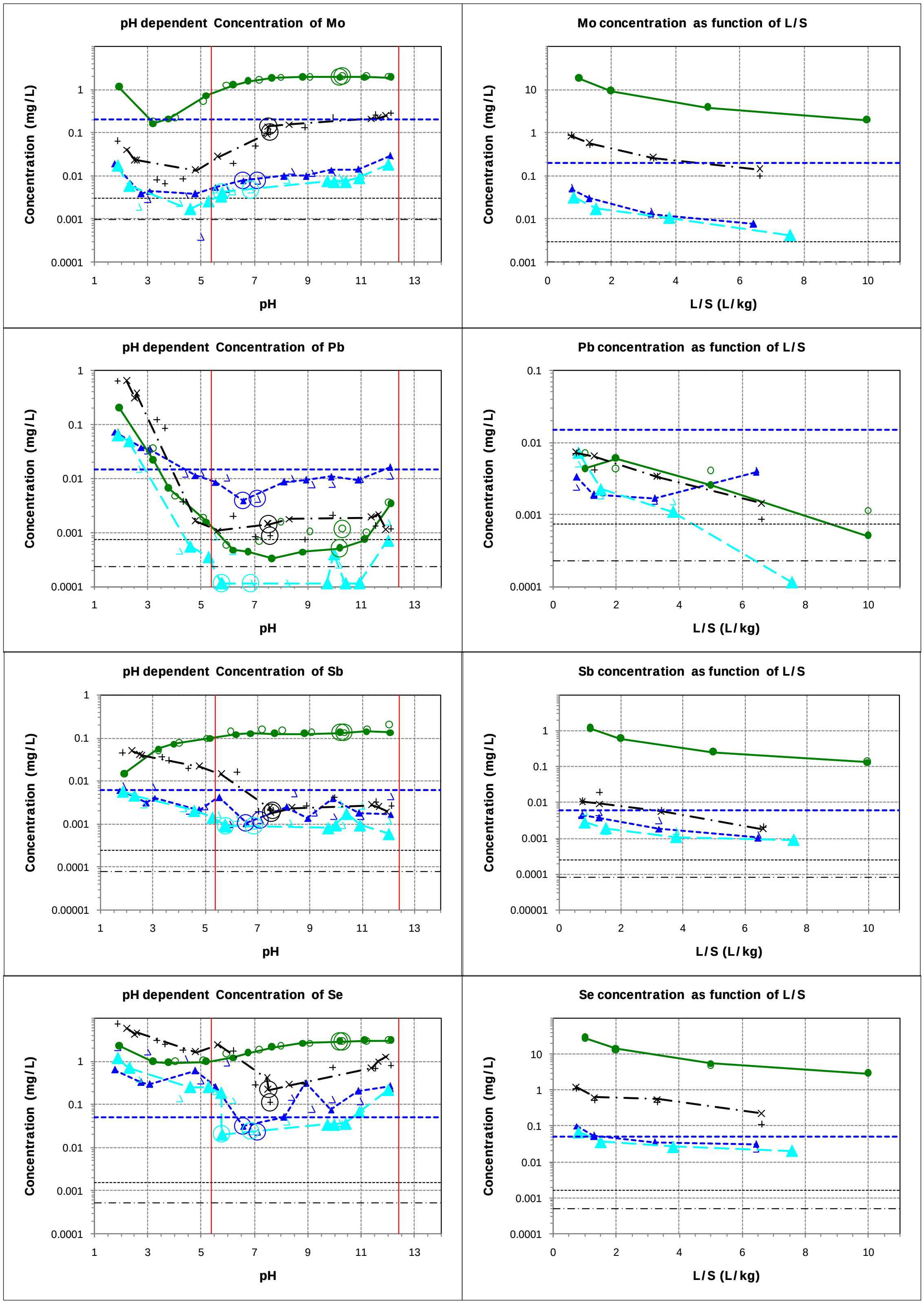
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD -** spray dryer ash.



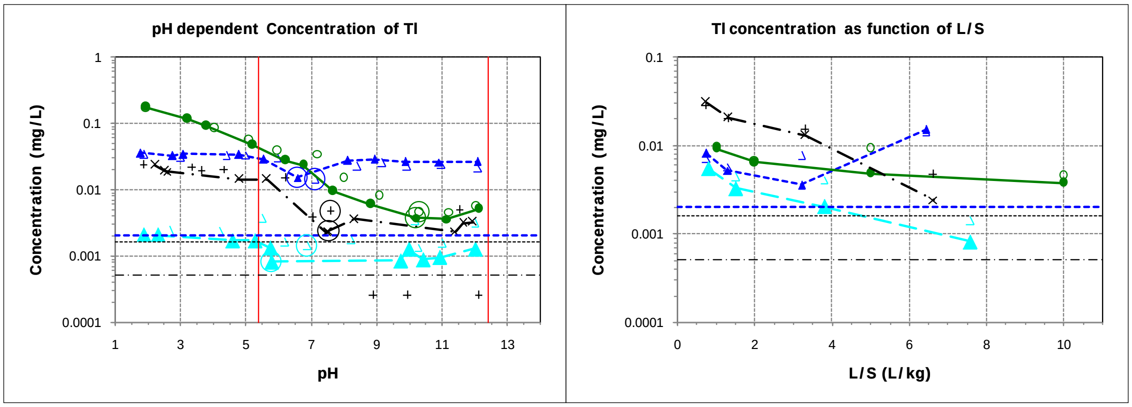
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



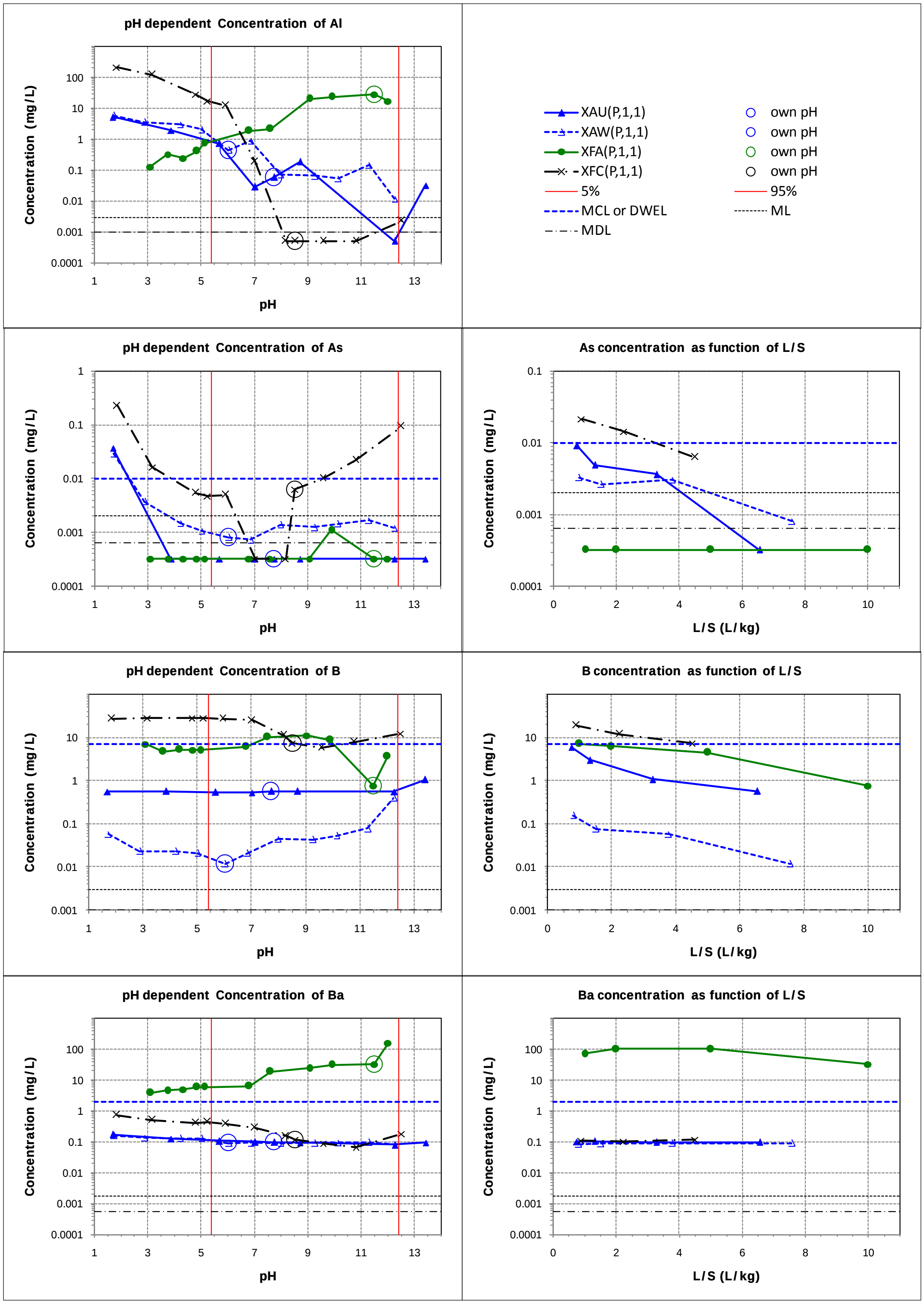
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



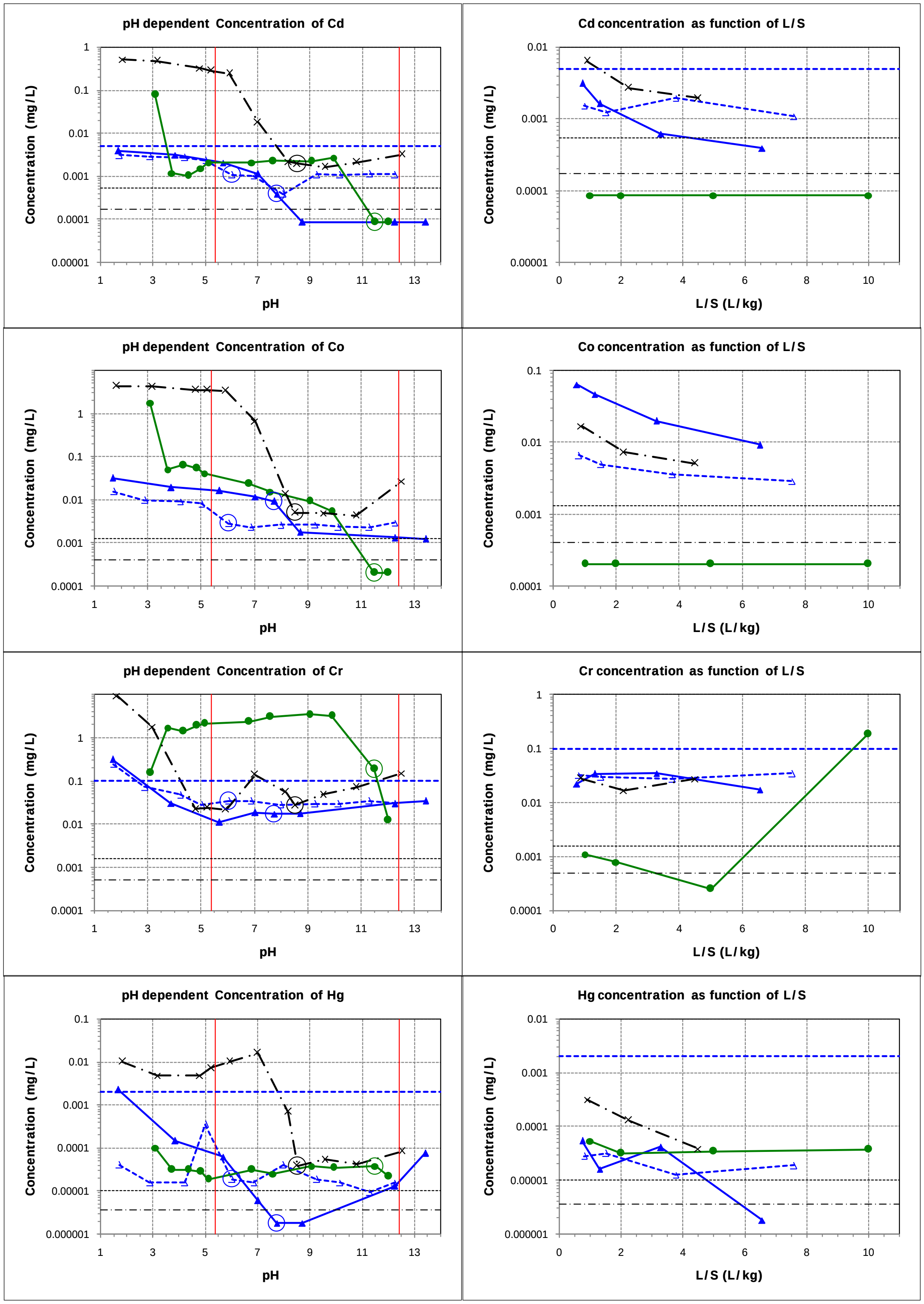
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



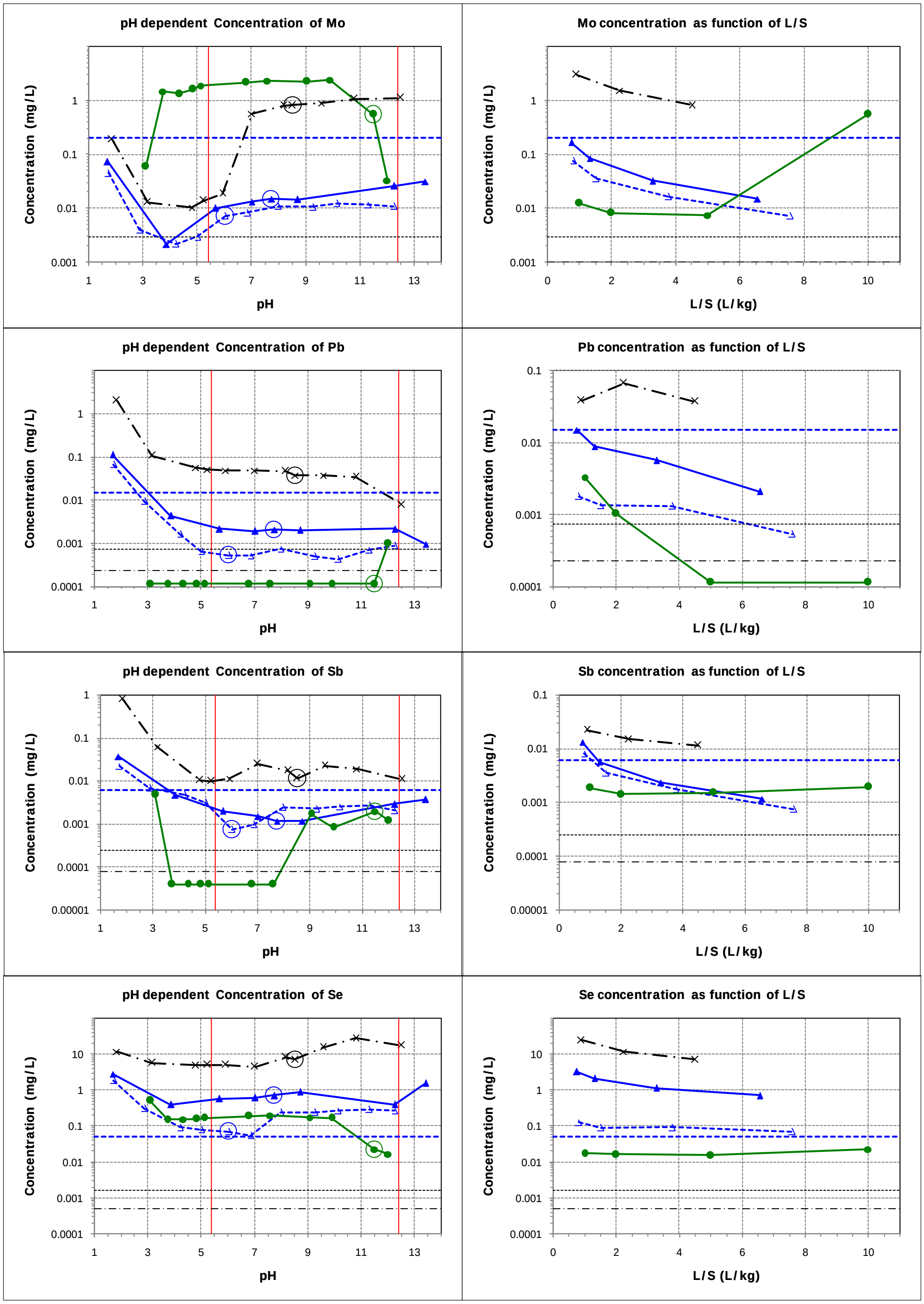
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



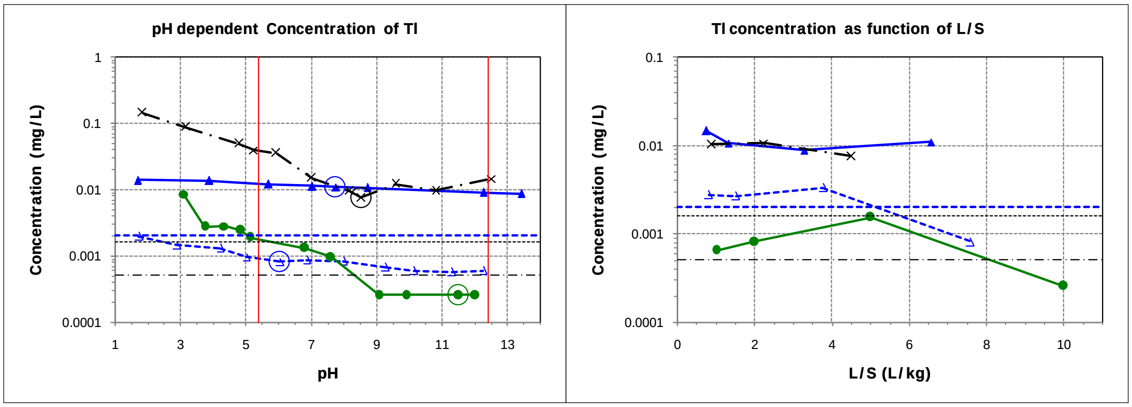
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



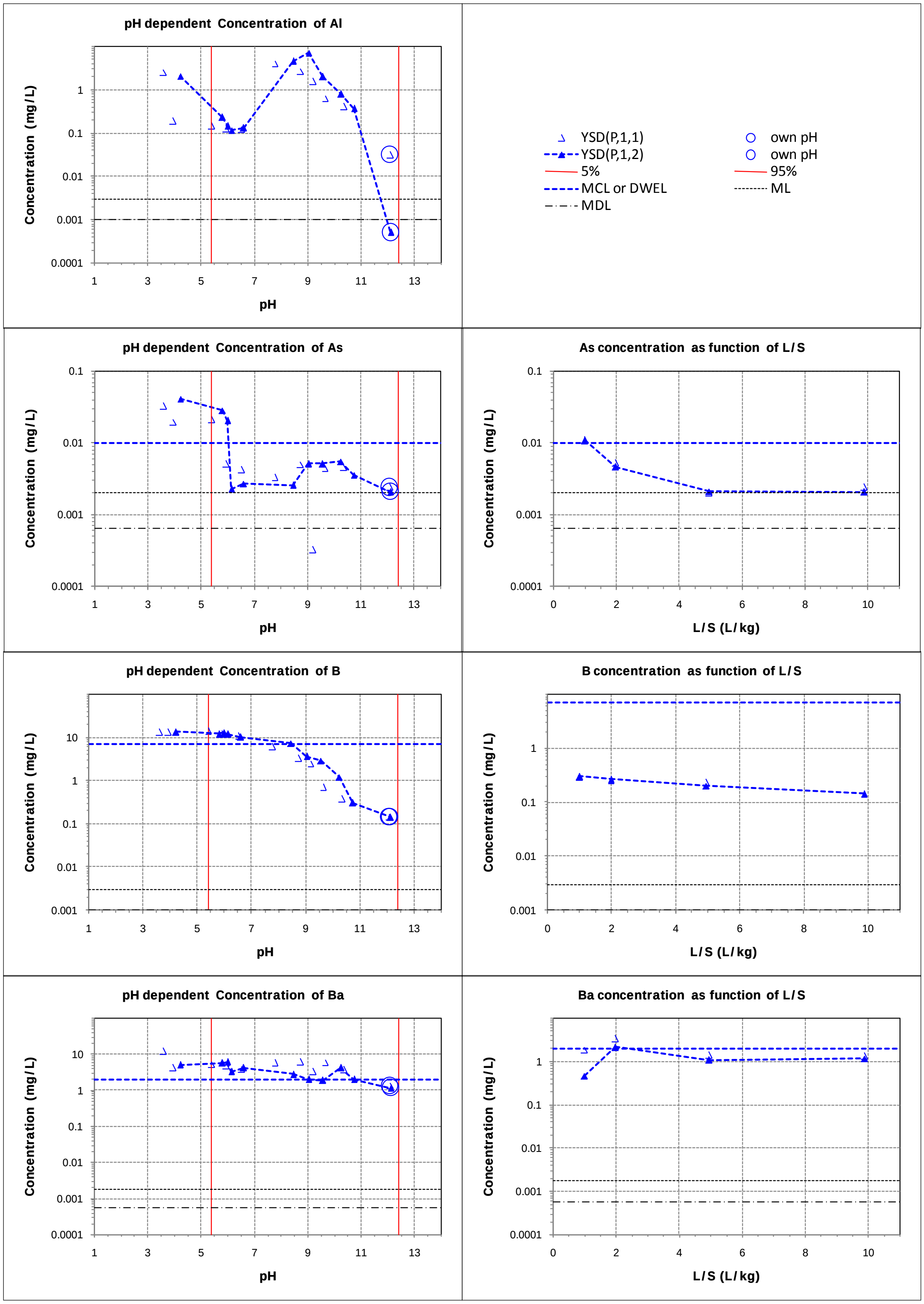
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



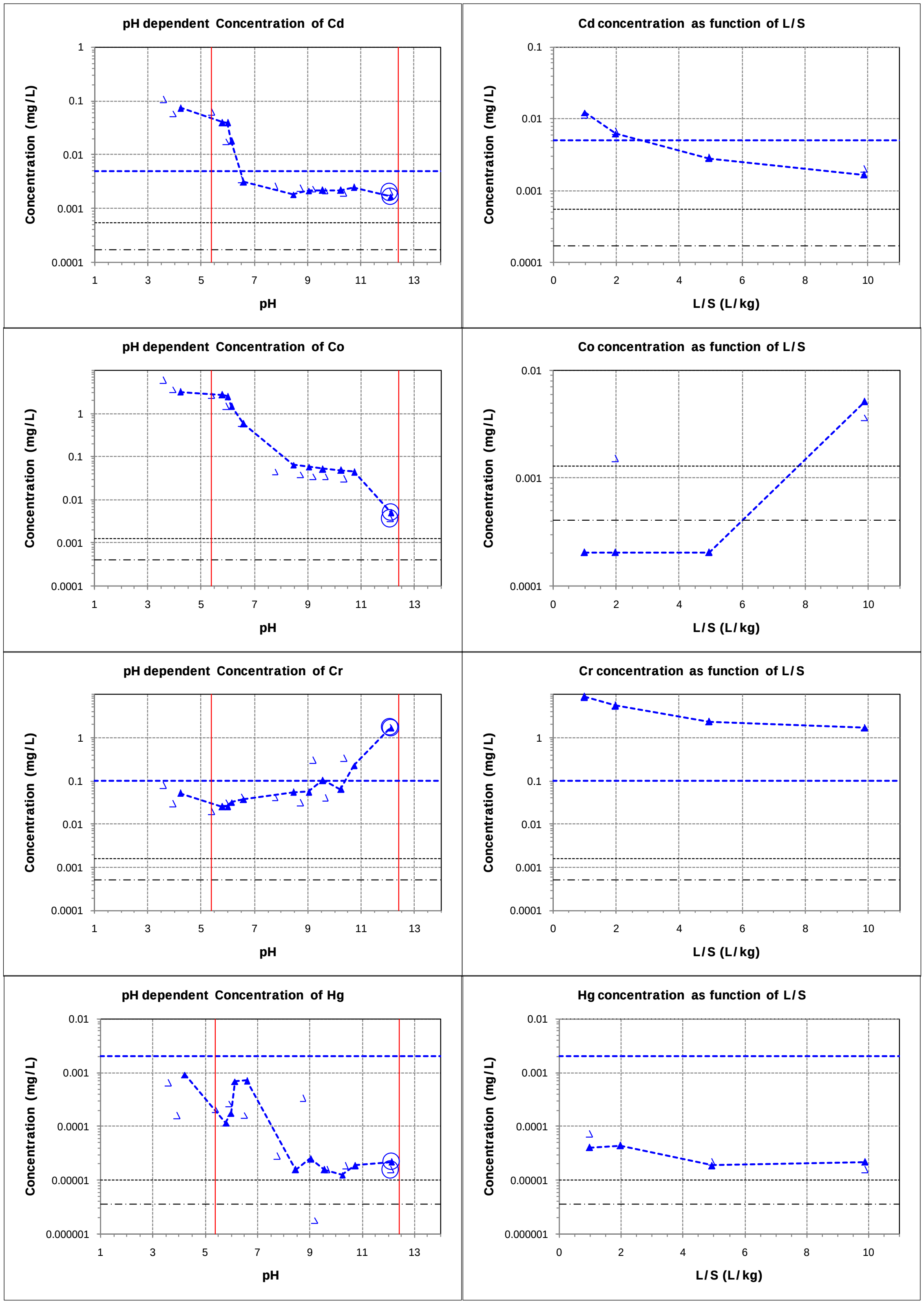
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



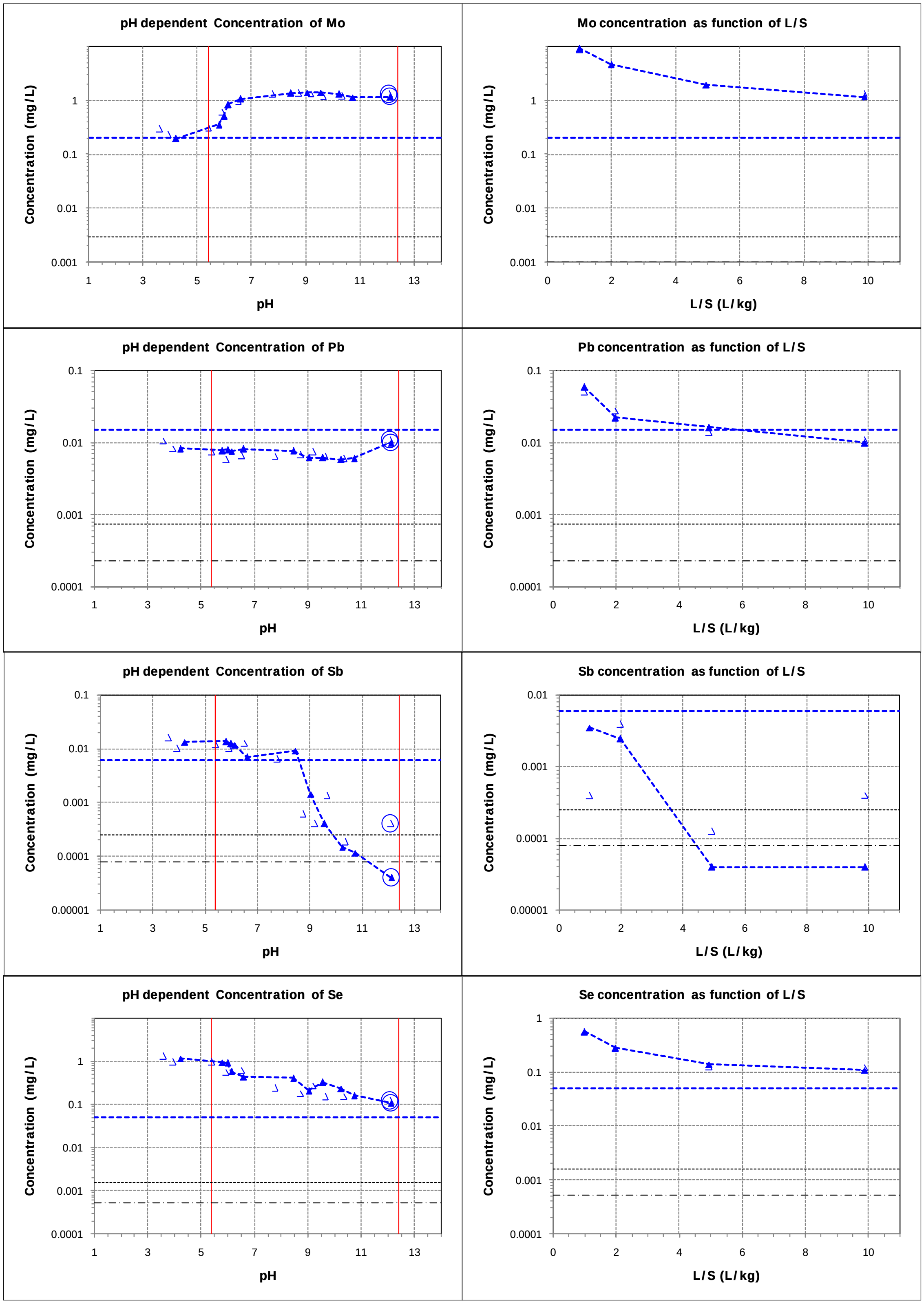
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



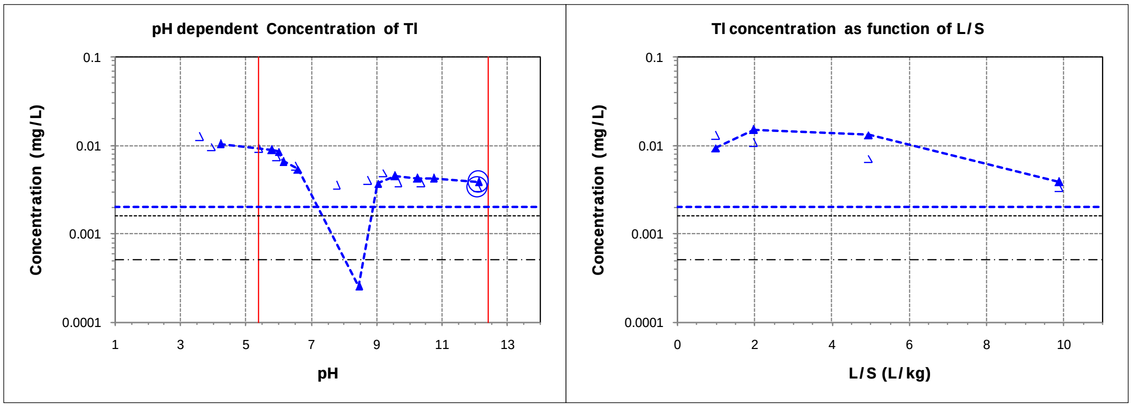
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD -** spray dryer ash.



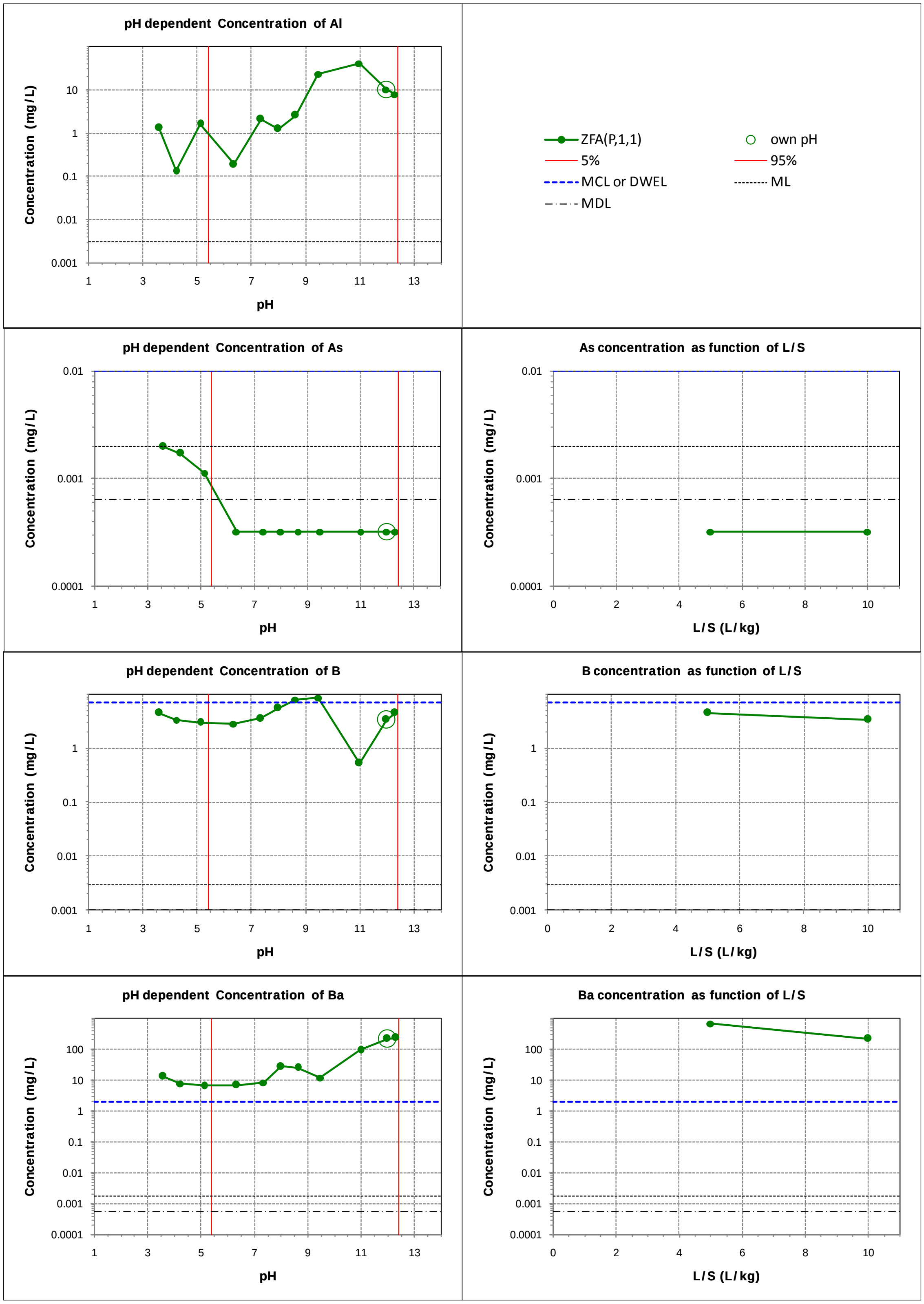
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



pH dependent Concentration of Al

As concentration as function of L/S

pH dependent Concentration of As

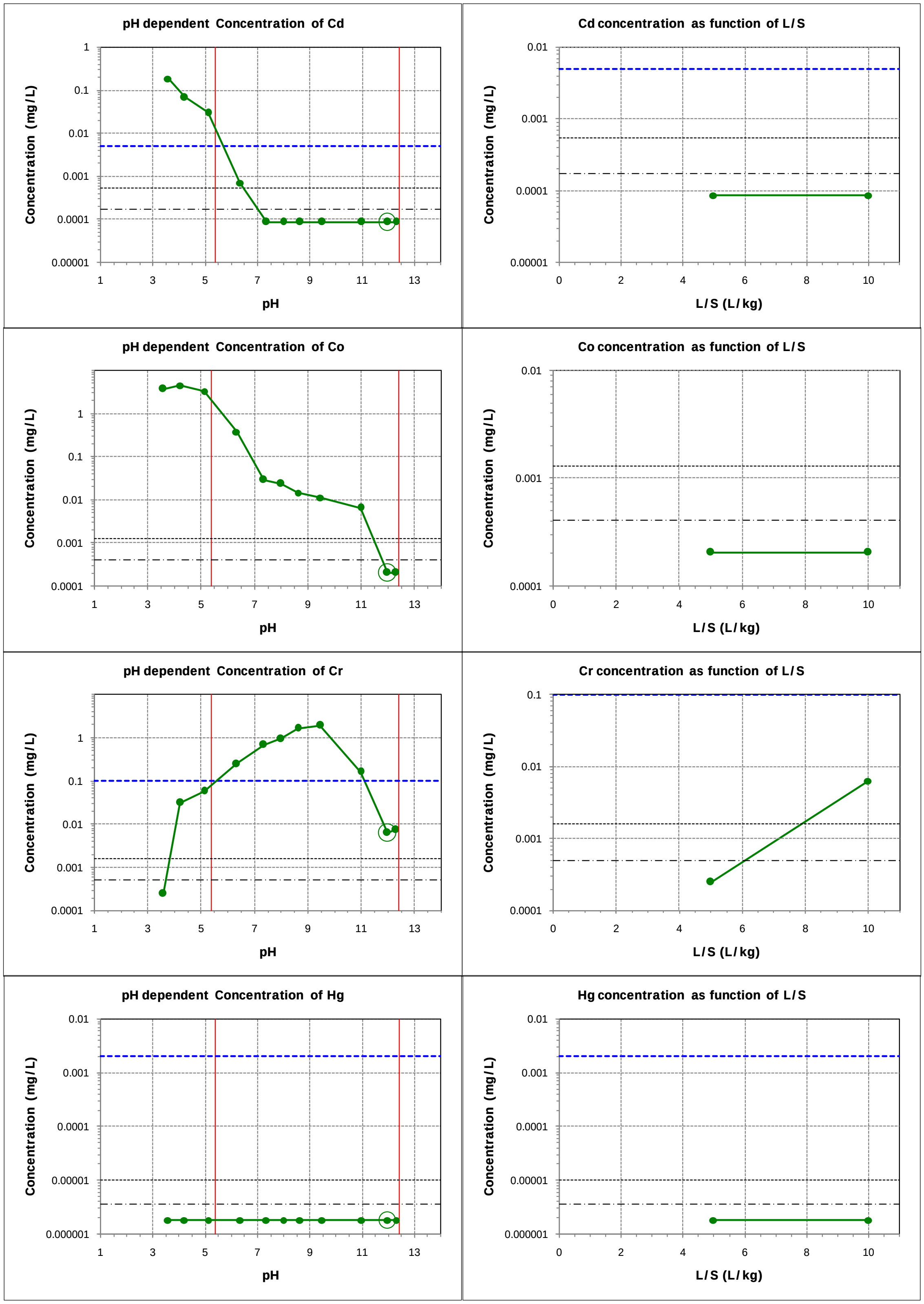
B concentration as function of L/S

pH dependent Concentration of B

Ba concentration as function of L/S

pH dependent Concentration of Ba

Facility Z (PRB, CS-ESP). **ZFA** - fly ash.


pH dependent Concentration of Cd

Cd concentration as function of L/S

pH dependent Concentration of Co

Co concentration as function of L/S

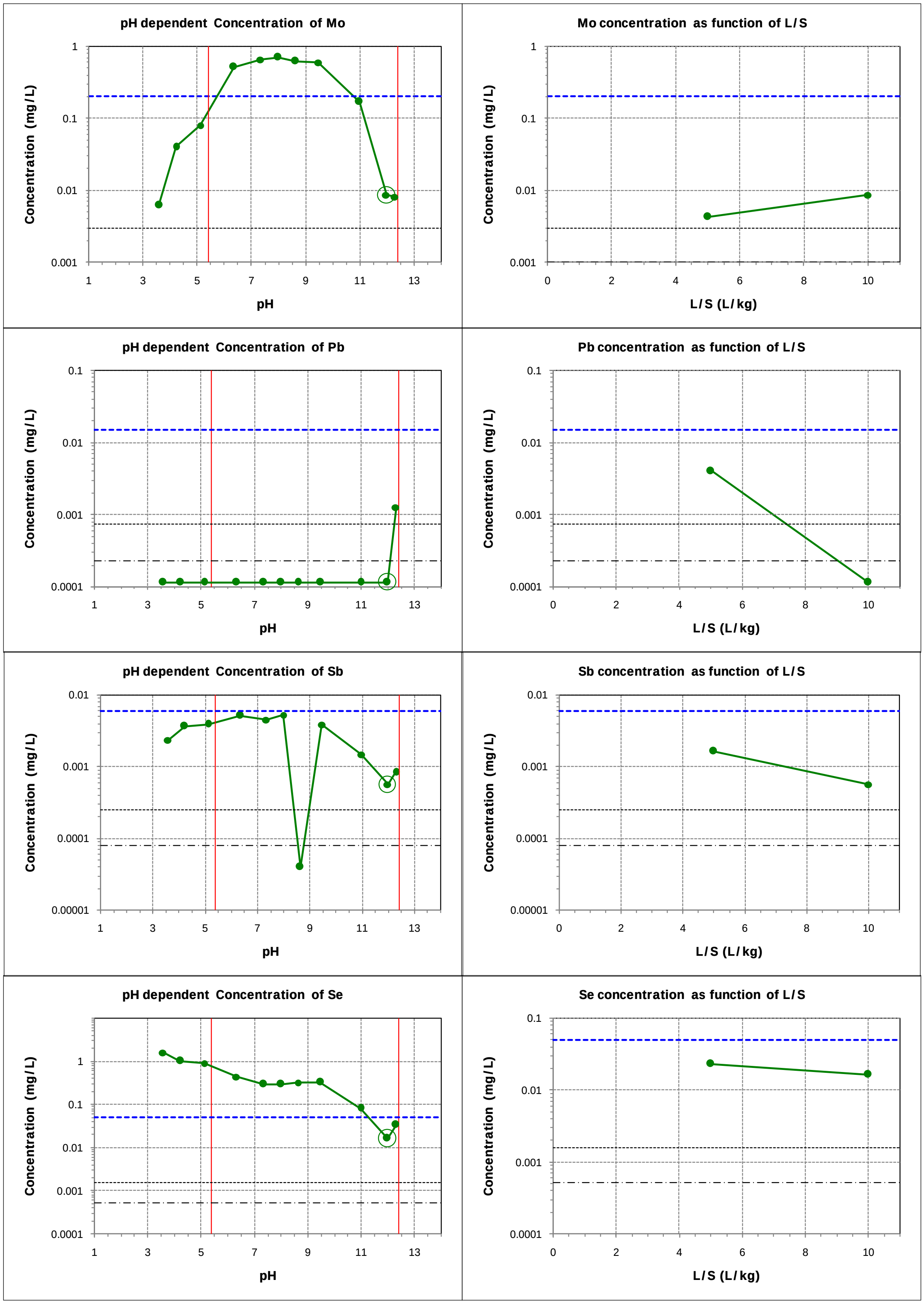
pH dependent Concentration of Cr

Cr concentration as function of L/S

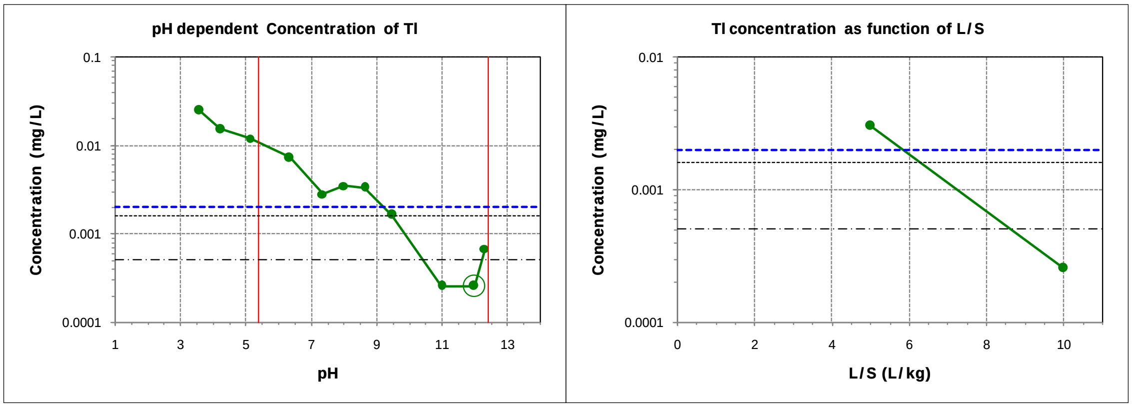
pH dependent Concentration of Hg

Hg concentration as function of L/S

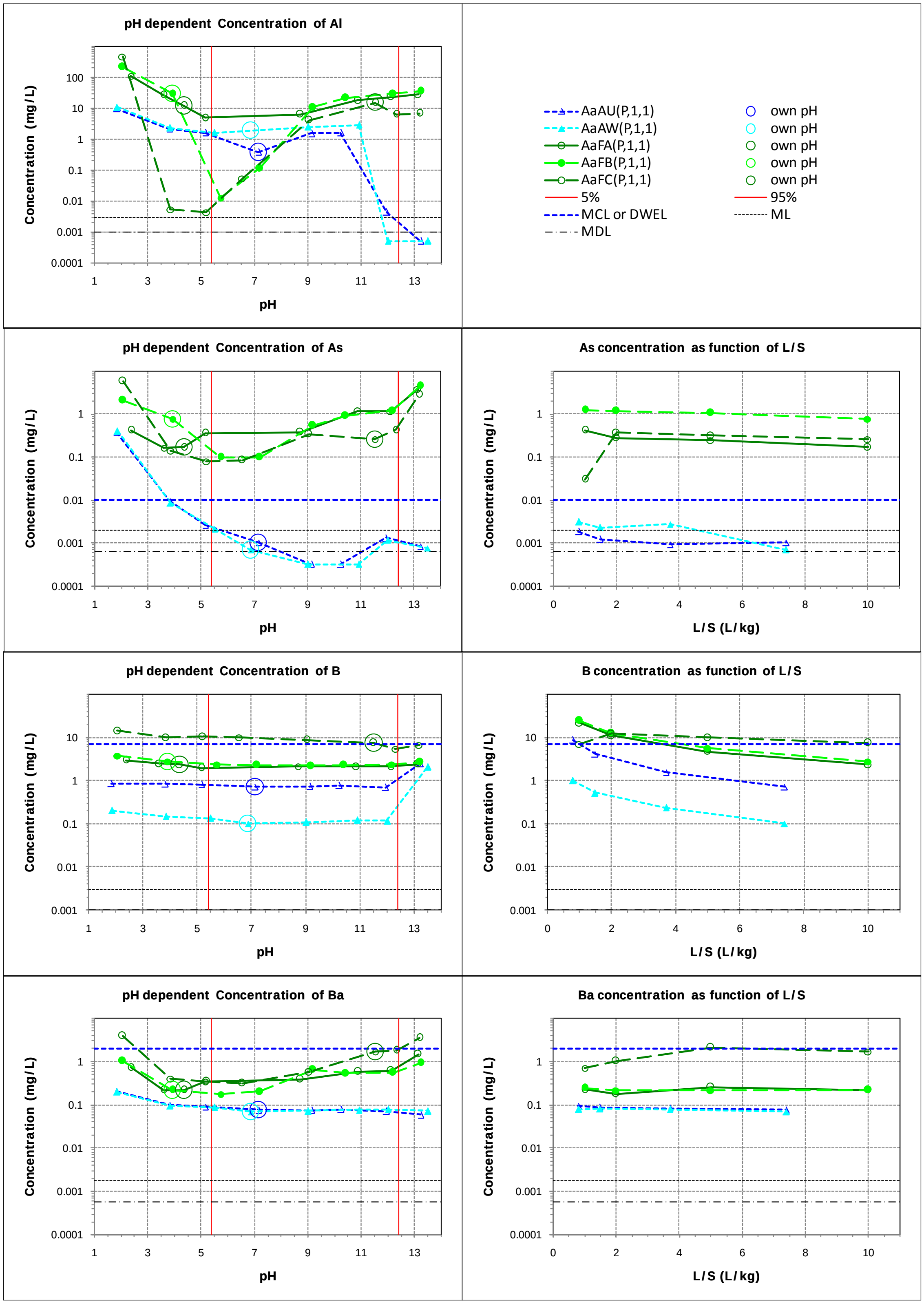
Facility Z (PRB, CS-ESP). **ZFA** - fly ash.



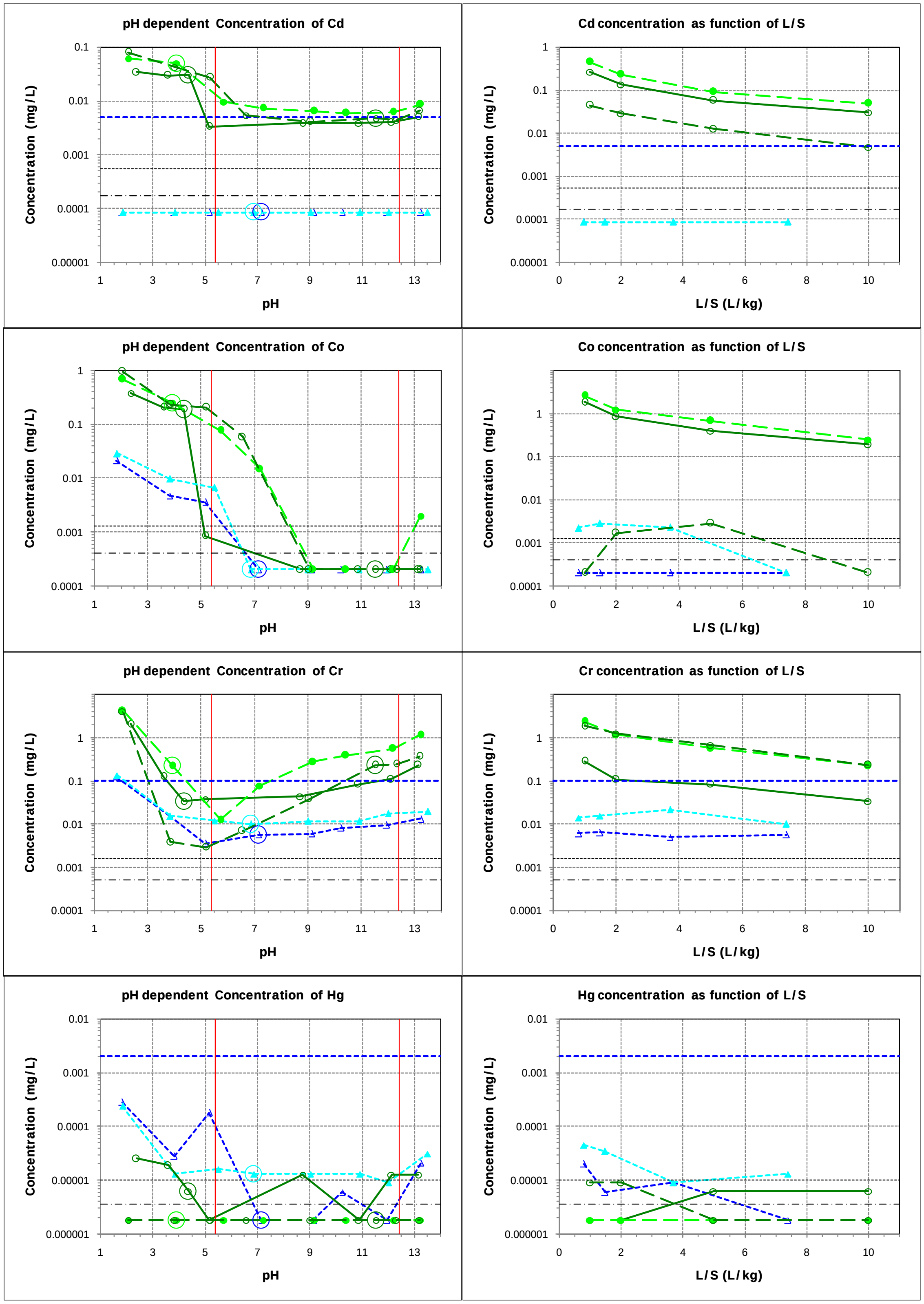
Facility Z (PRB, CS-ESP). **ZFA** - fly ash.



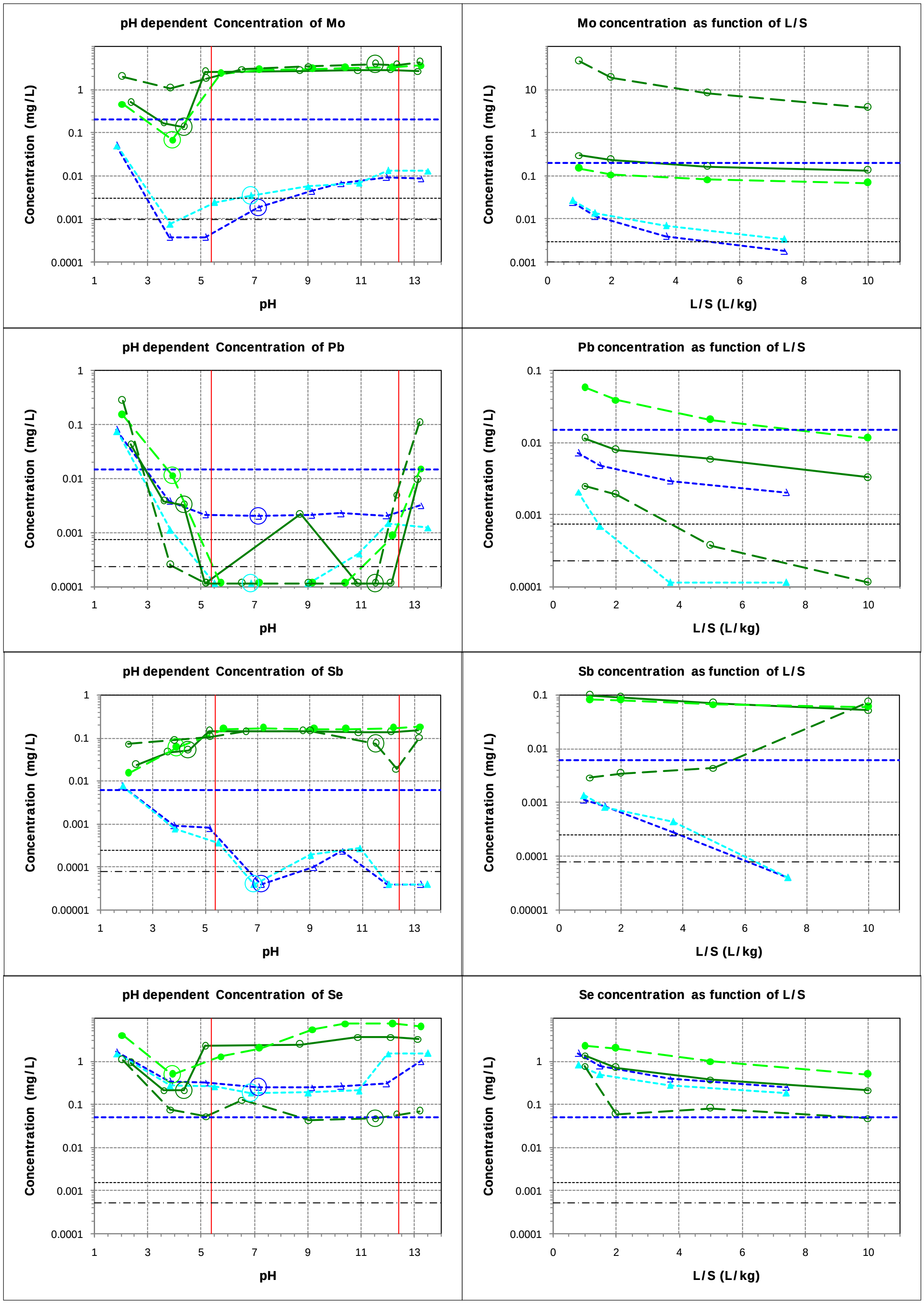
Facility Z (PRB, CS-ESP). **ZFA** - fly ash.



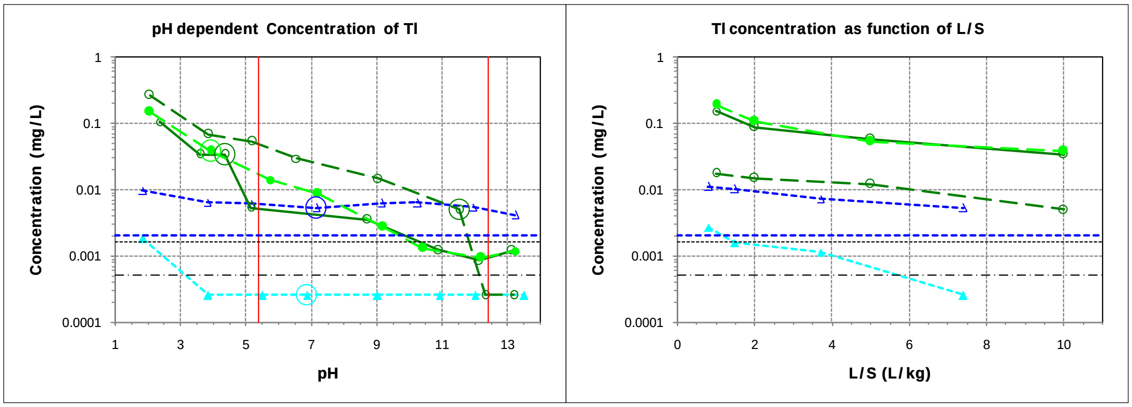
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP)**;**
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



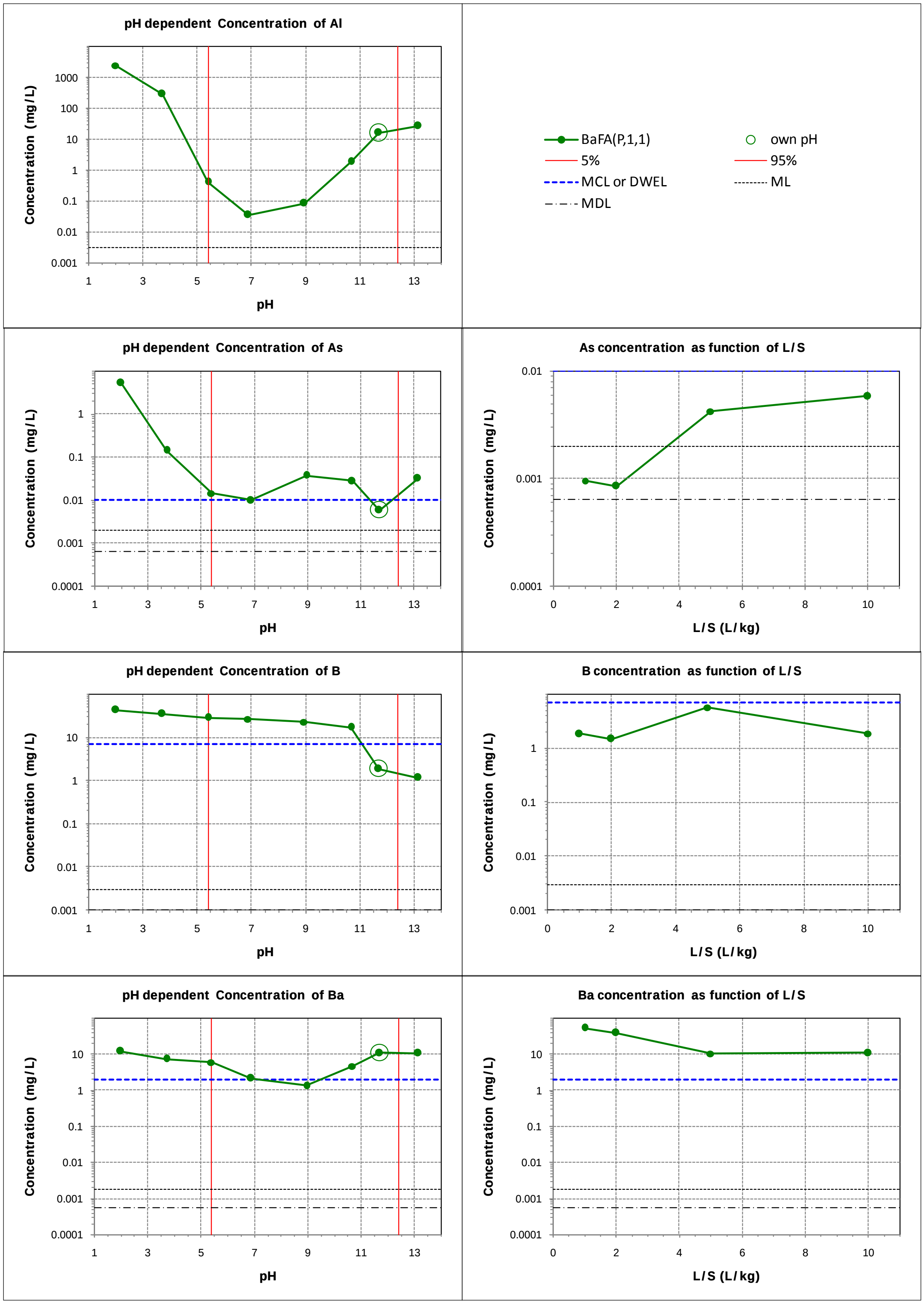
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP)**;**
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



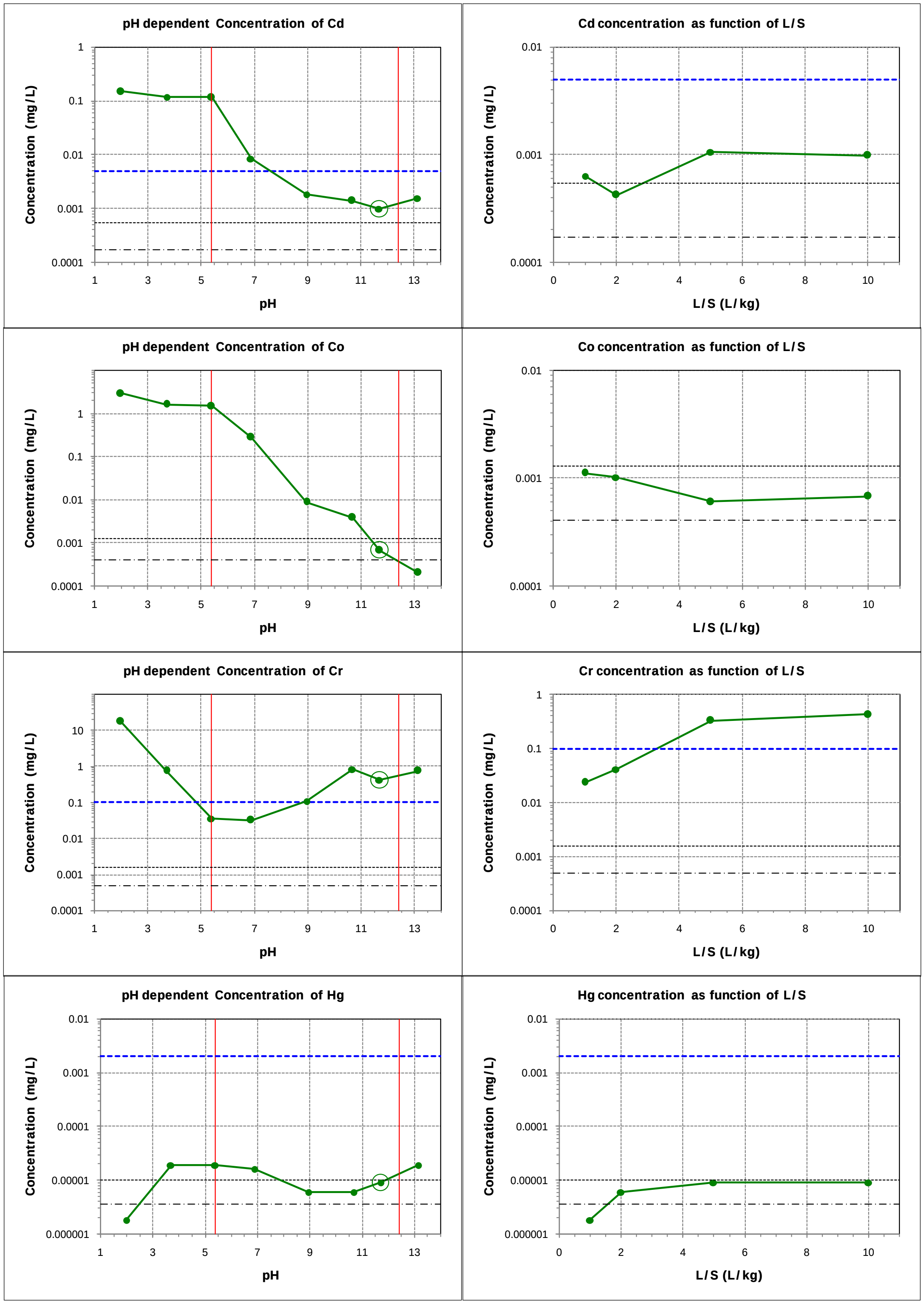
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP)**;**
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



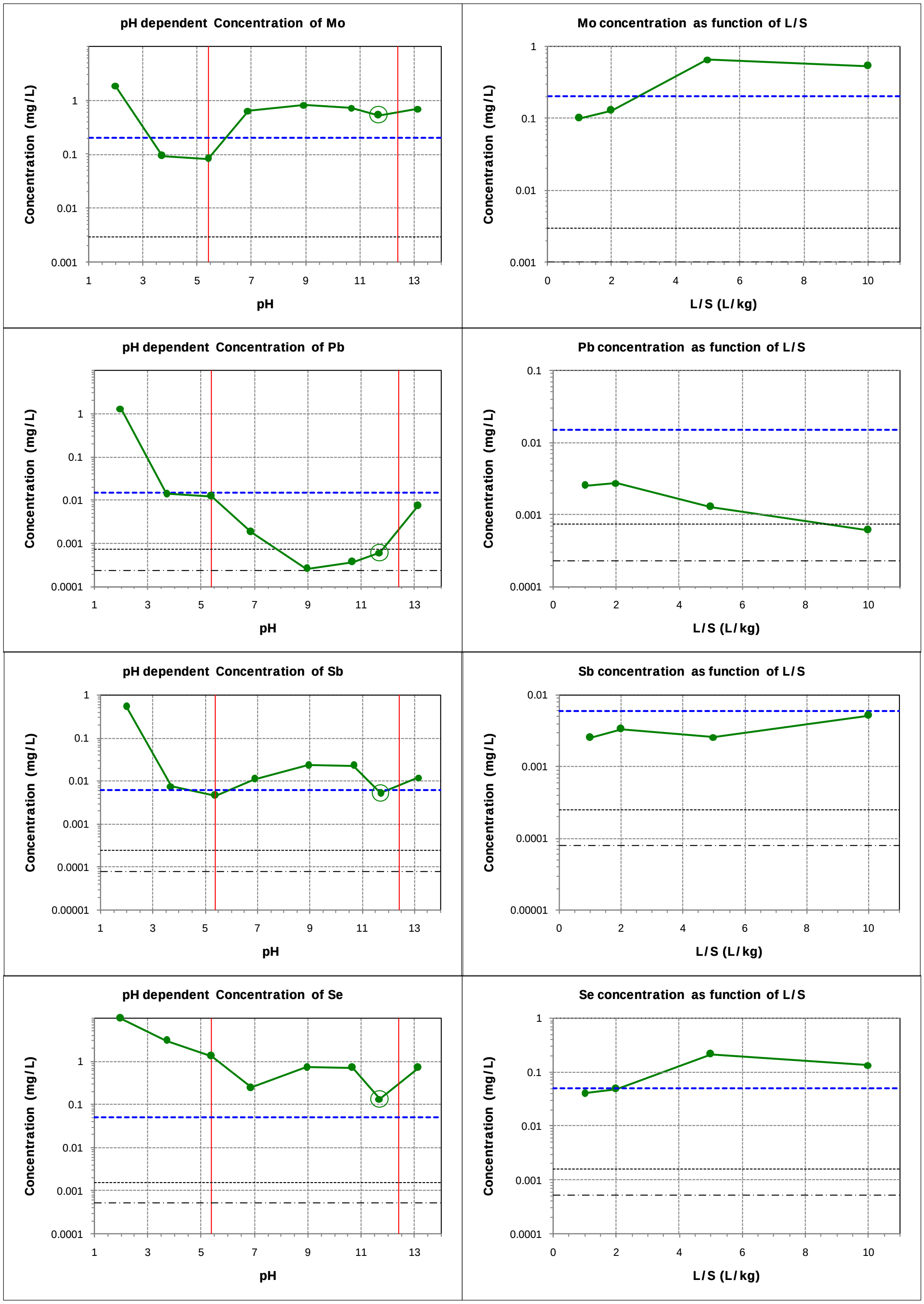
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP)**;**
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



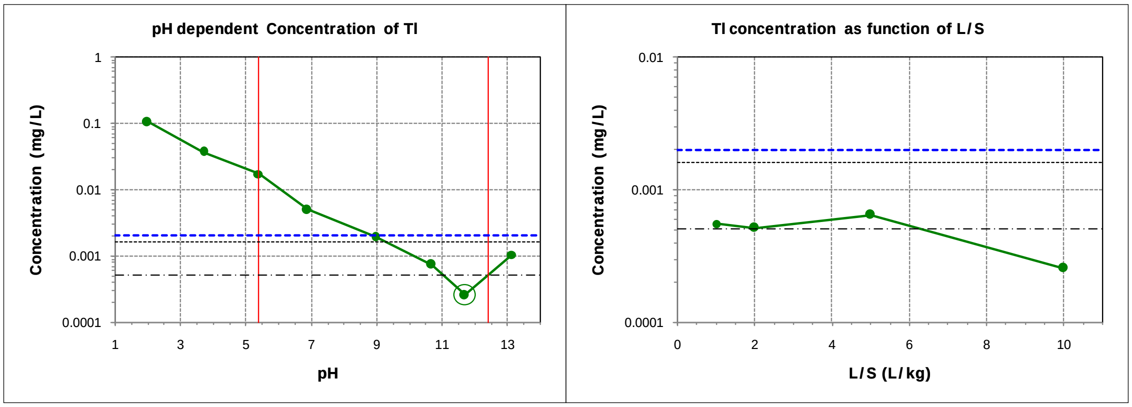
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



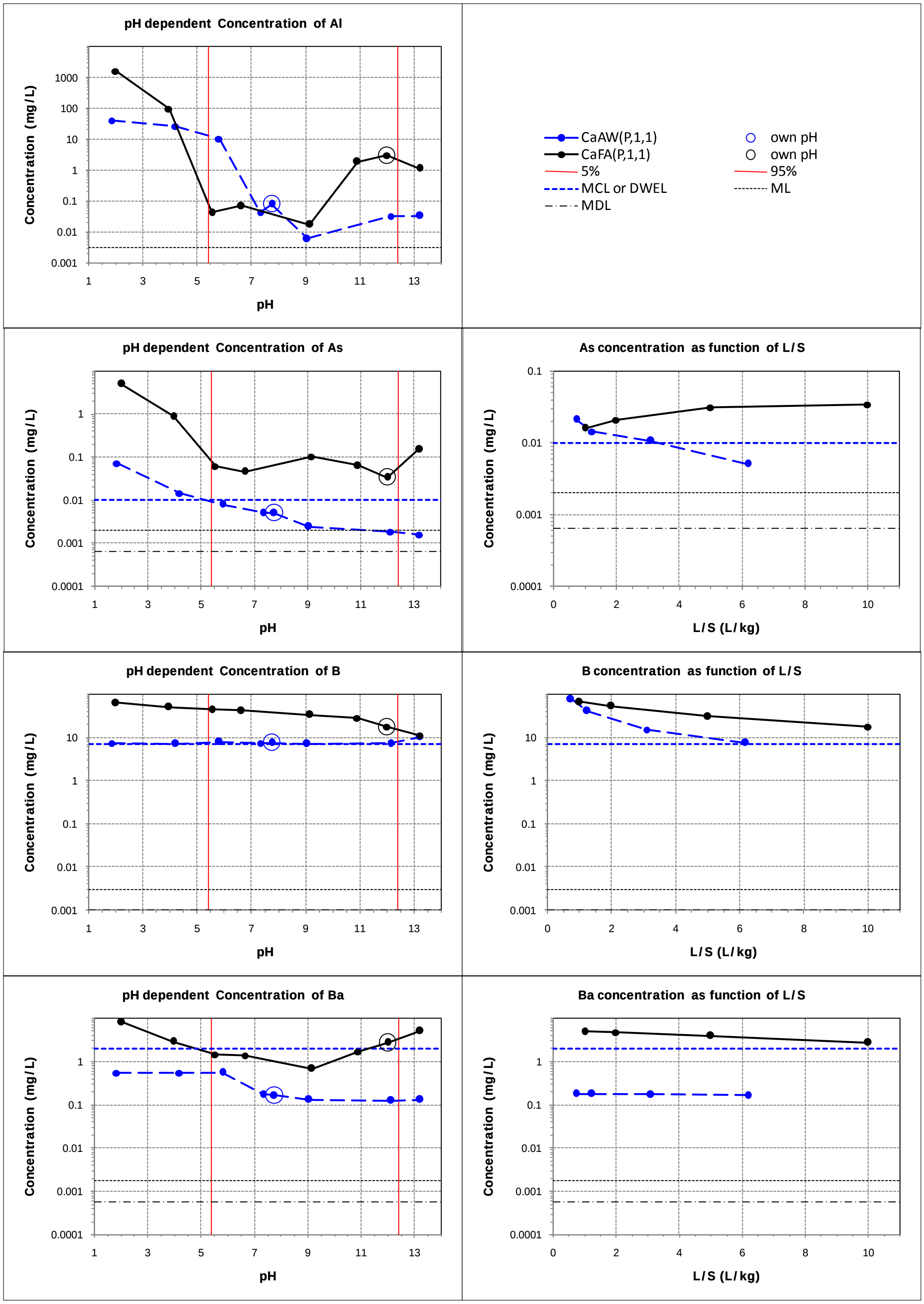
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



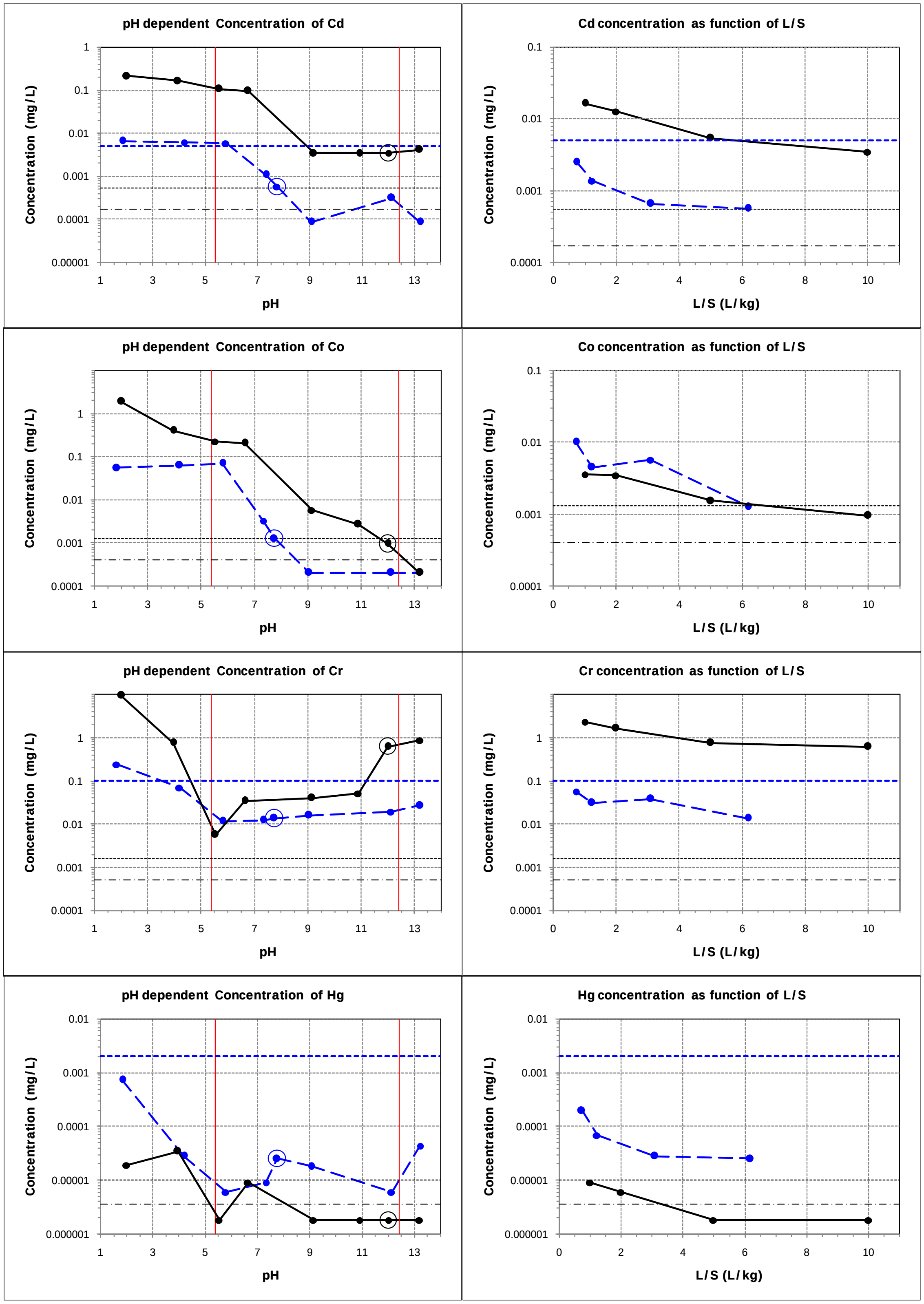
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



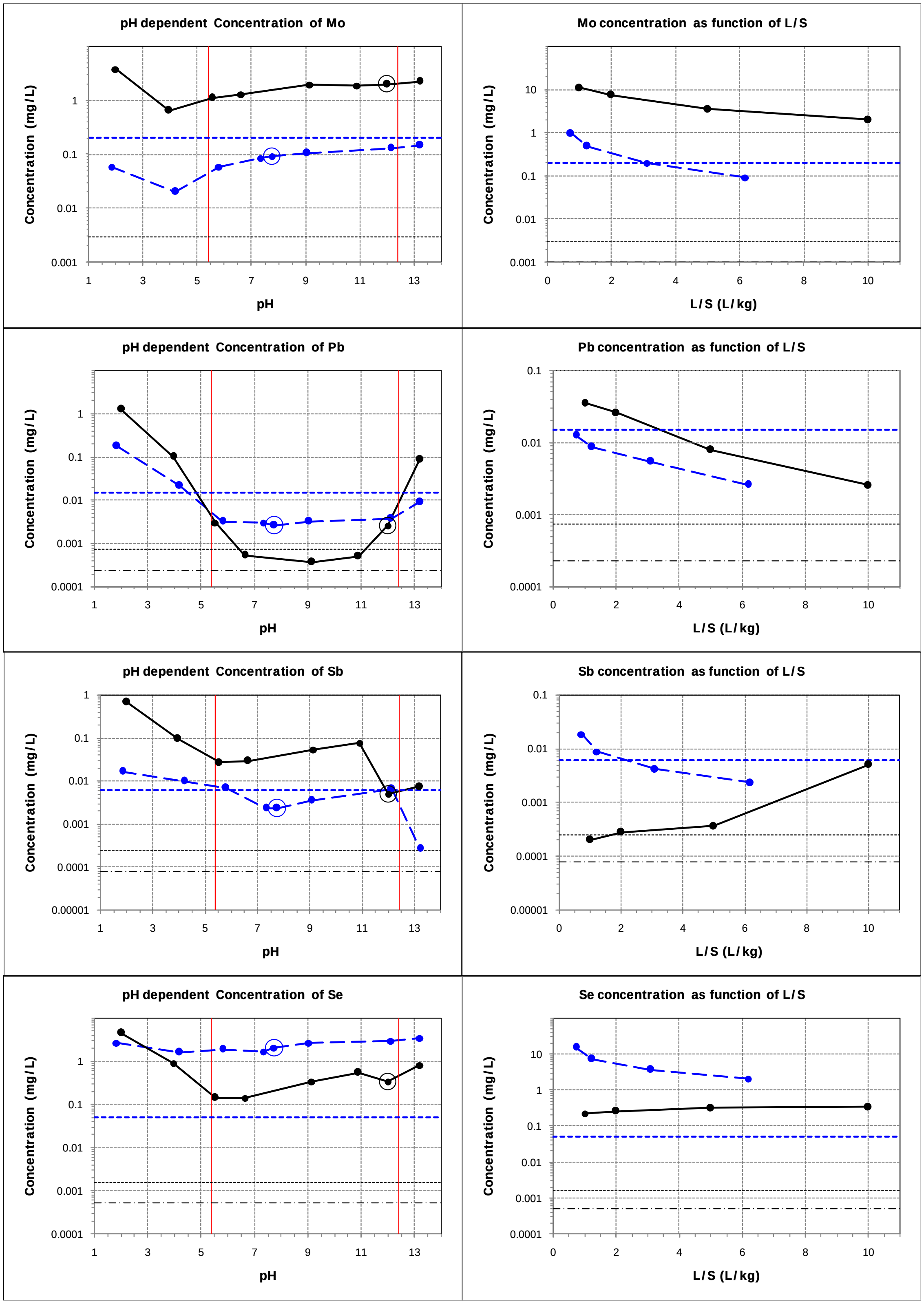
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



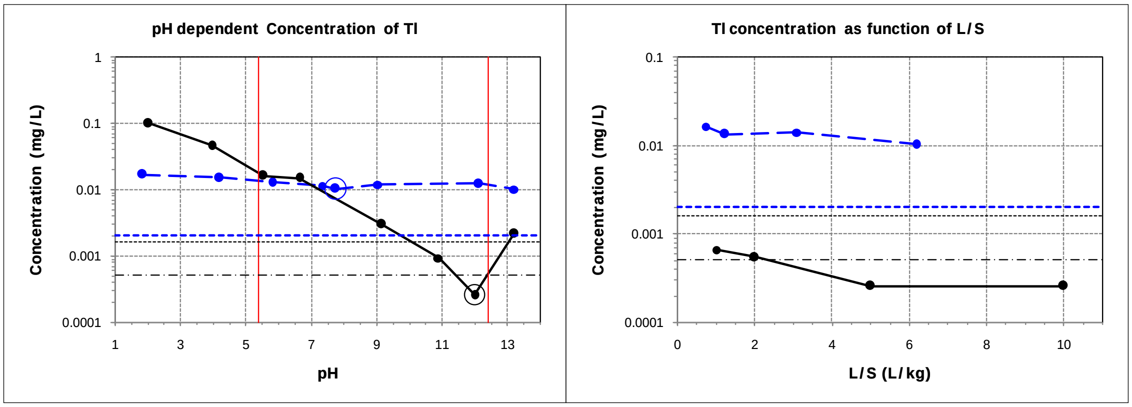
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



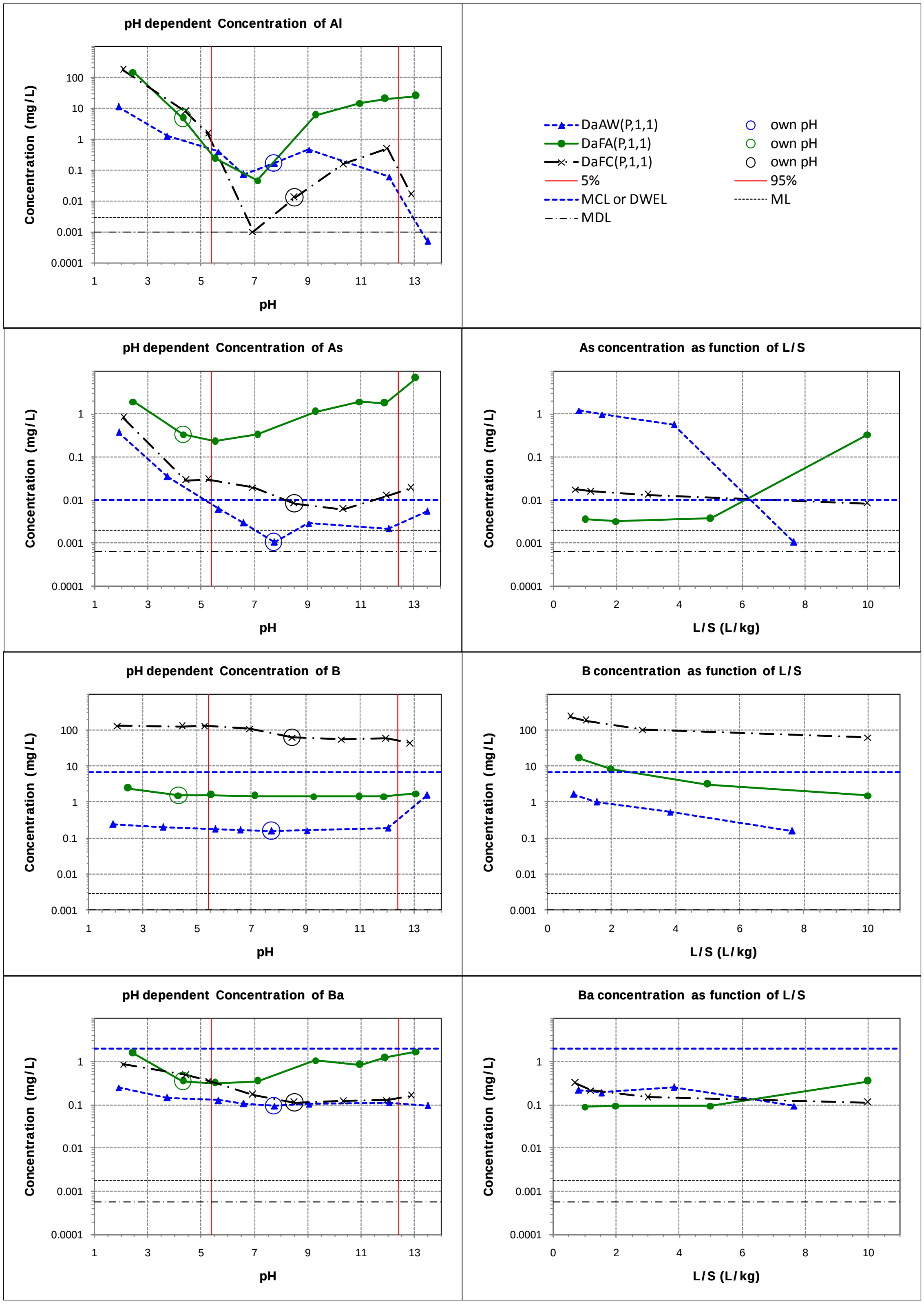
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



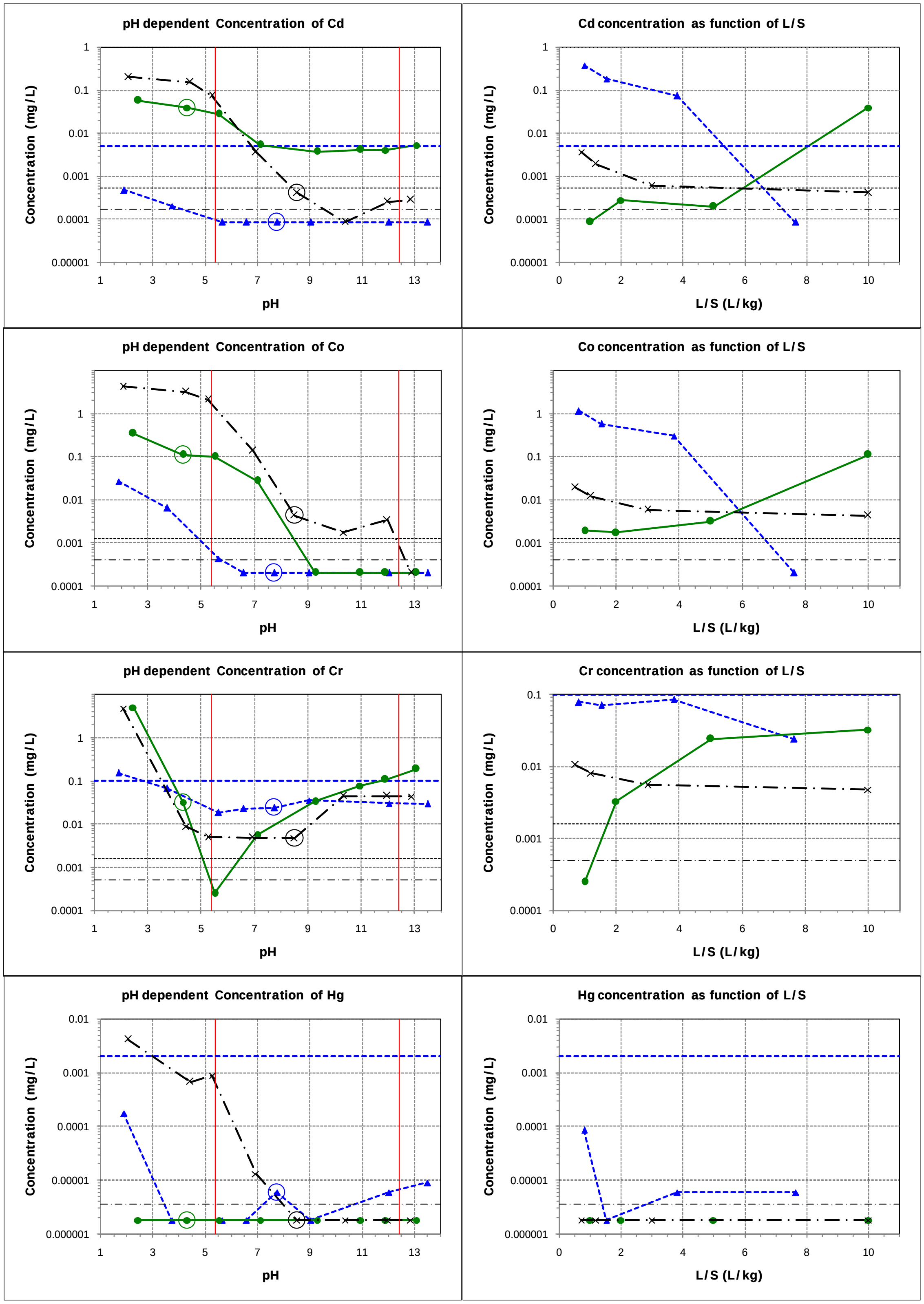
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



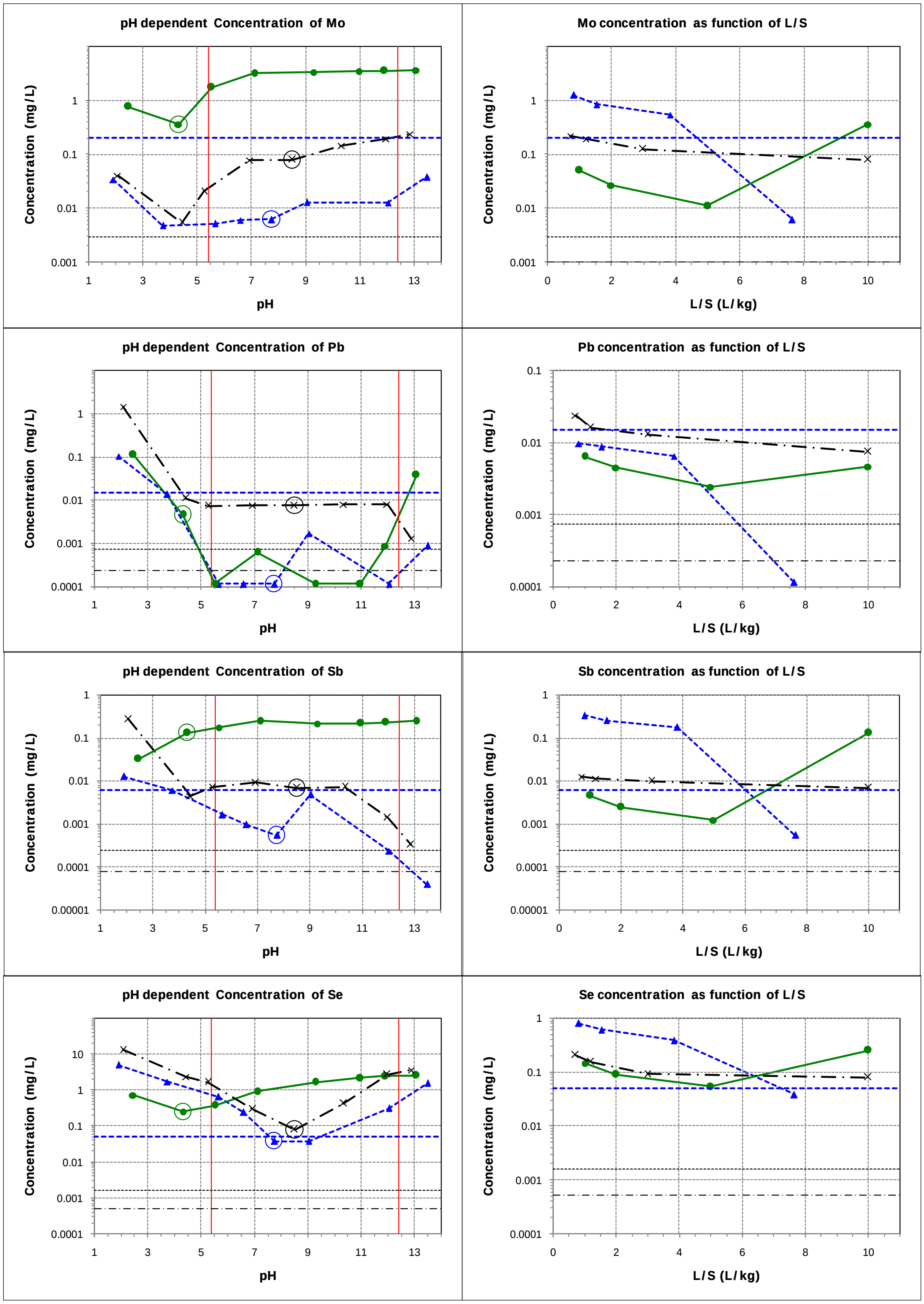
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



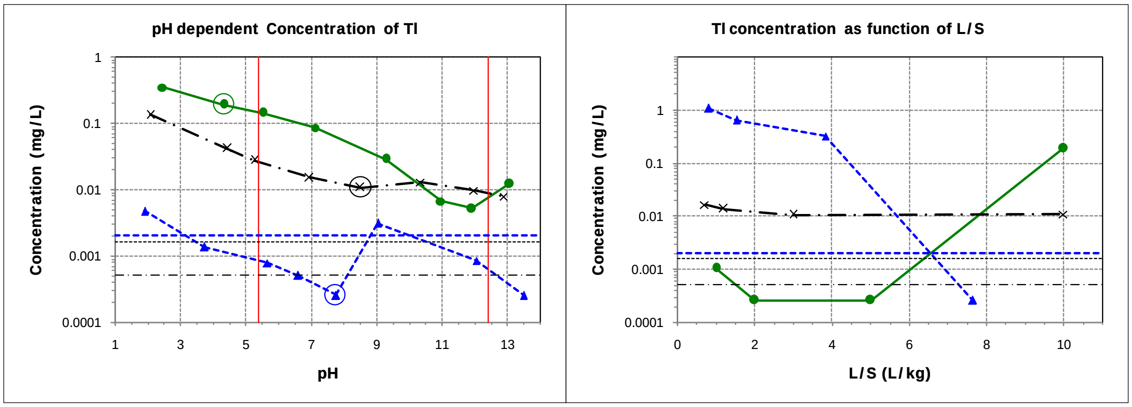
Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.



Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.

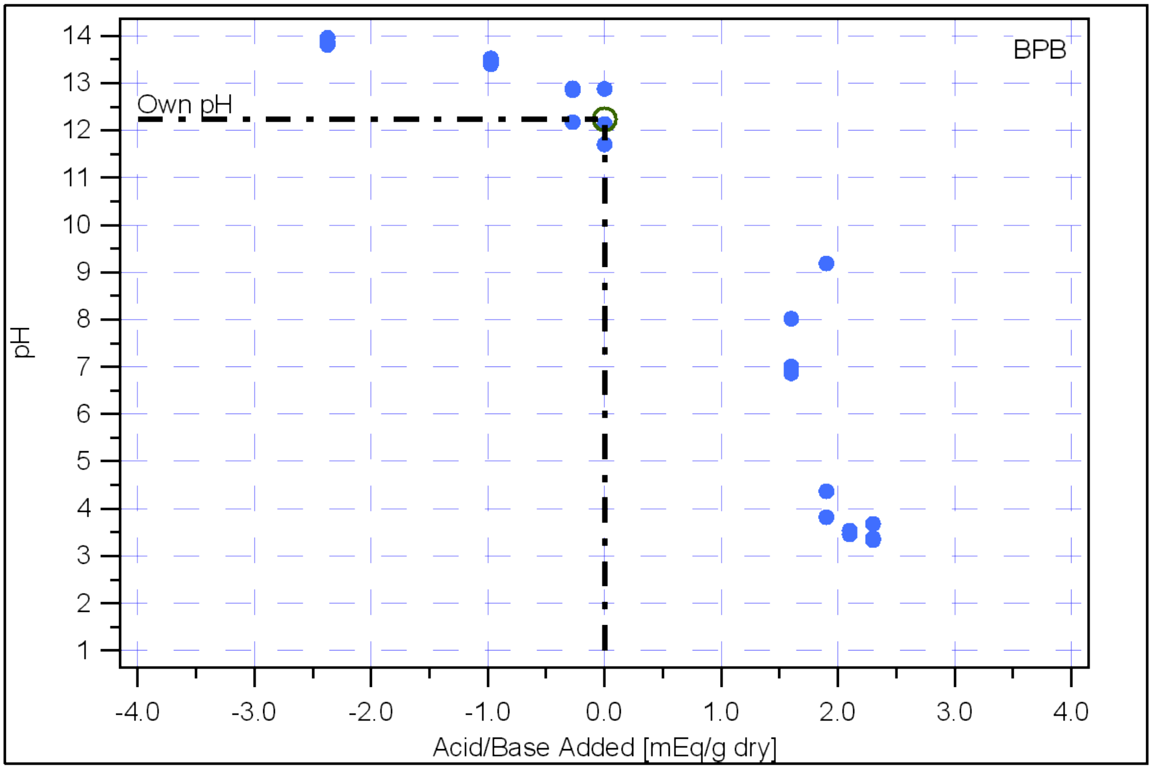


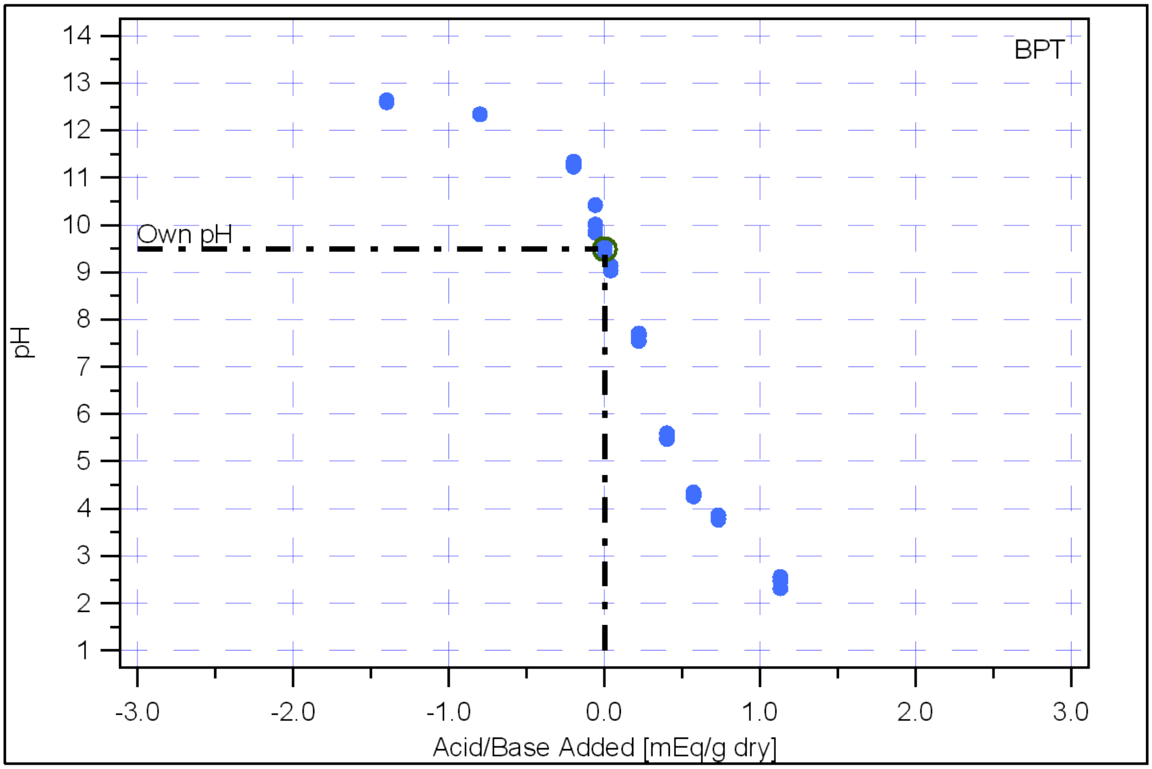
Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.



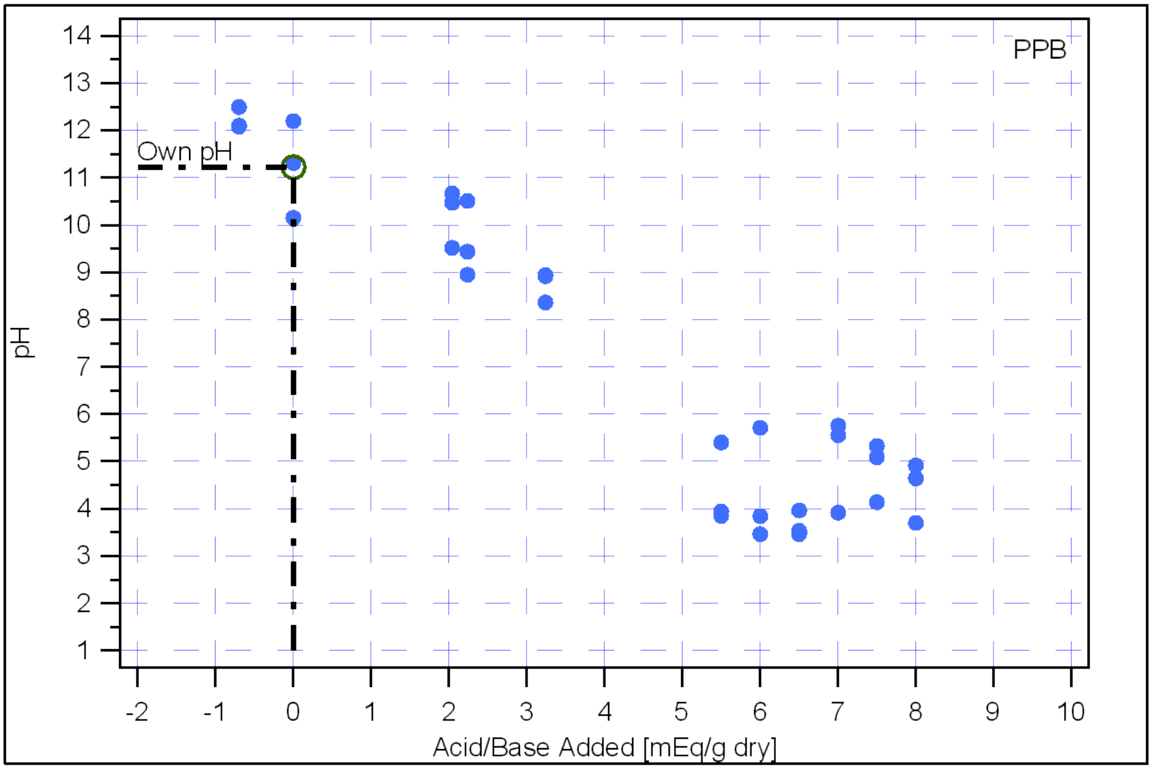
Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.

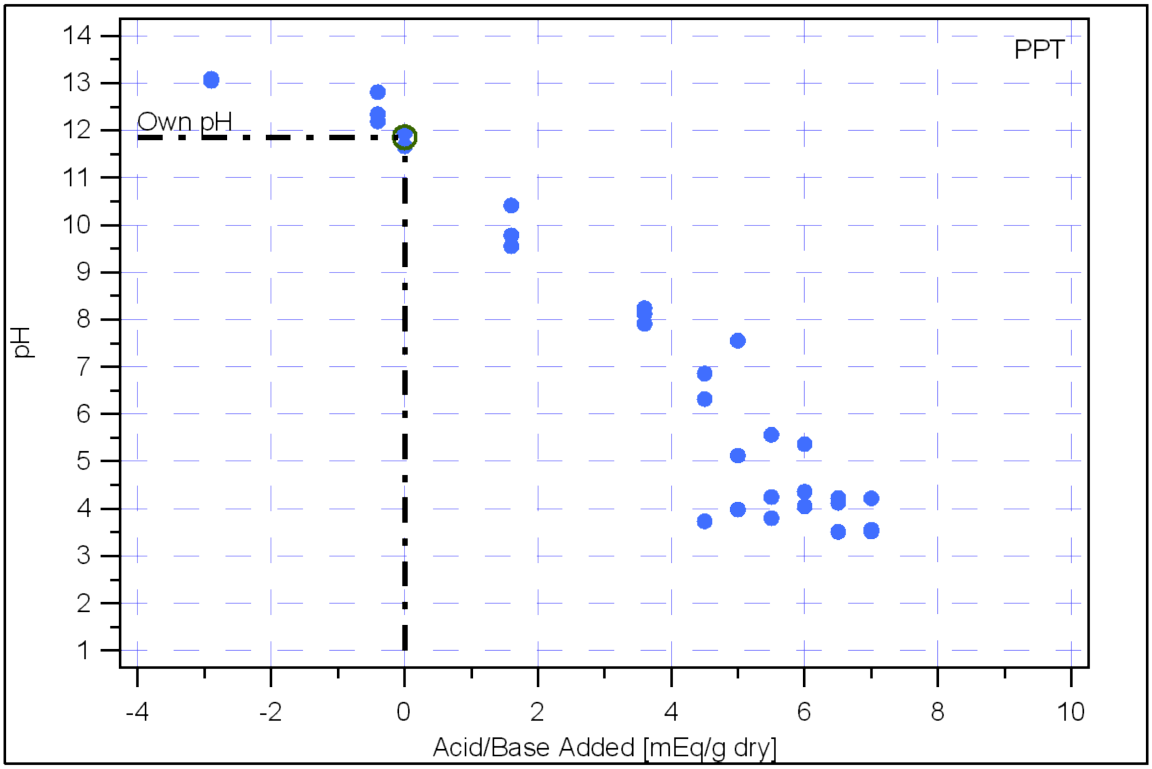
Appendix G
CCR pH Titration Curves



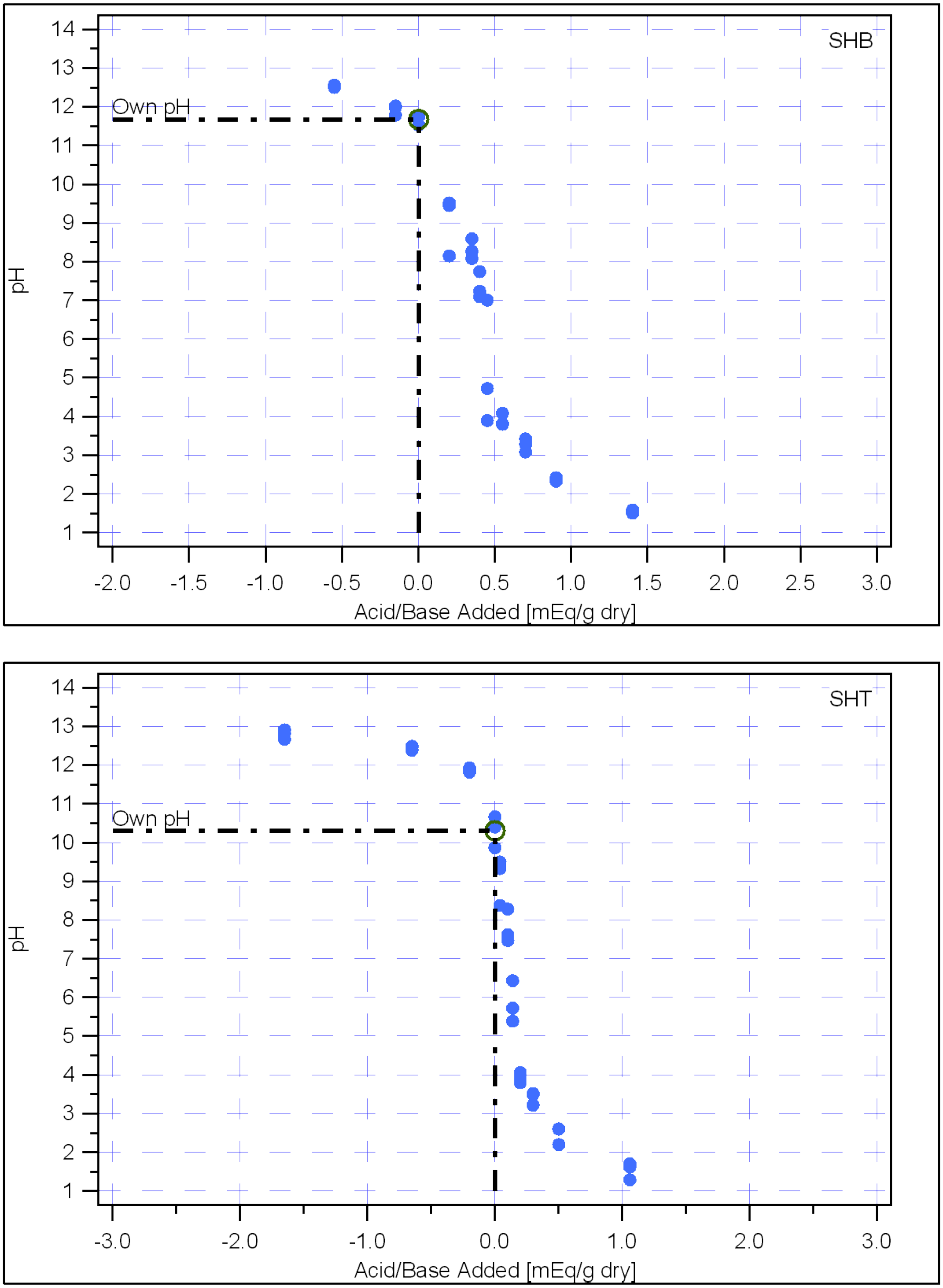


Brayton Point (East-Bit., CS-ESP). **BPB** – fly ash without ACI; **BPT** – fly ash with ACI.

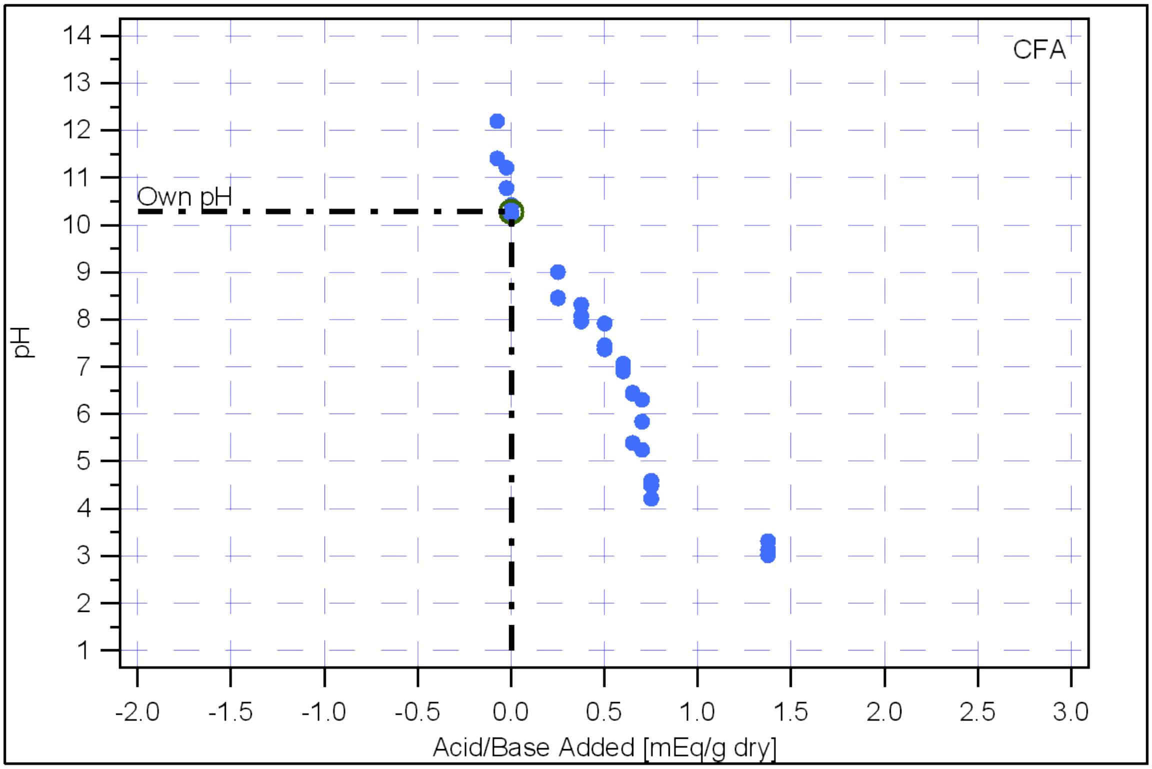


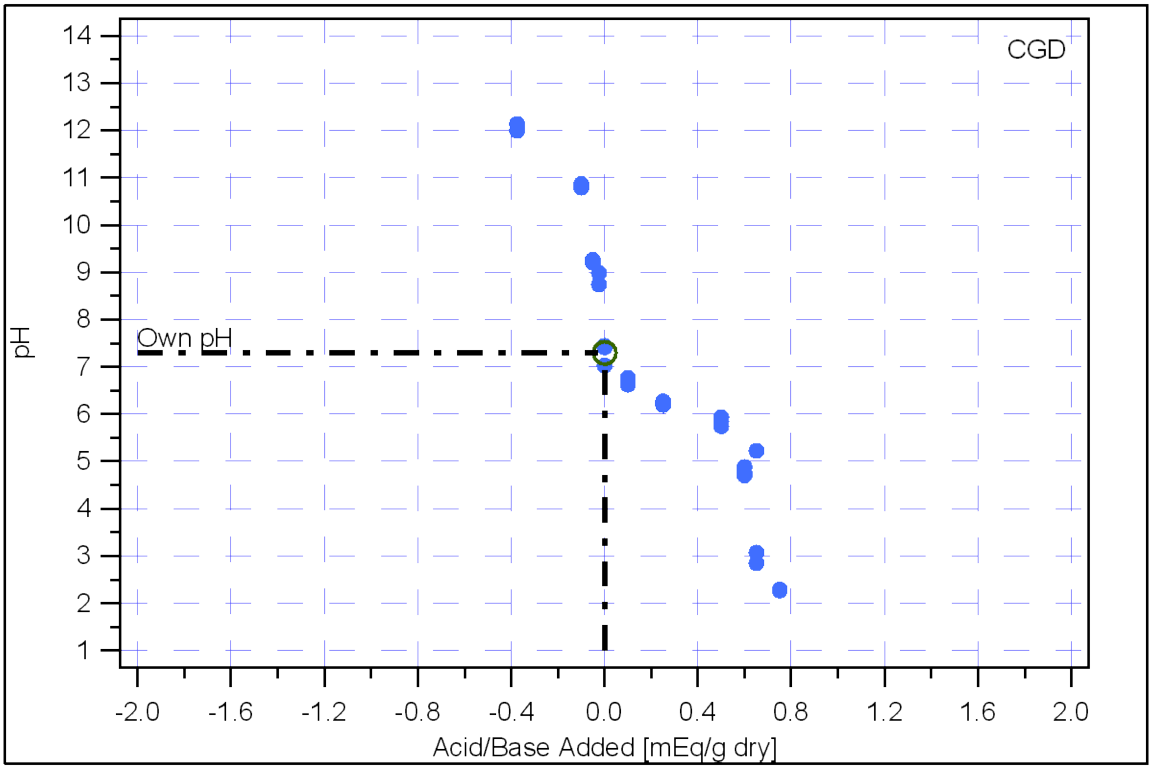


Pleasant Prairie (PRB, CS-ESP). **PPB** – fly ash without ACI; **PPT** – fly ash with ACI.

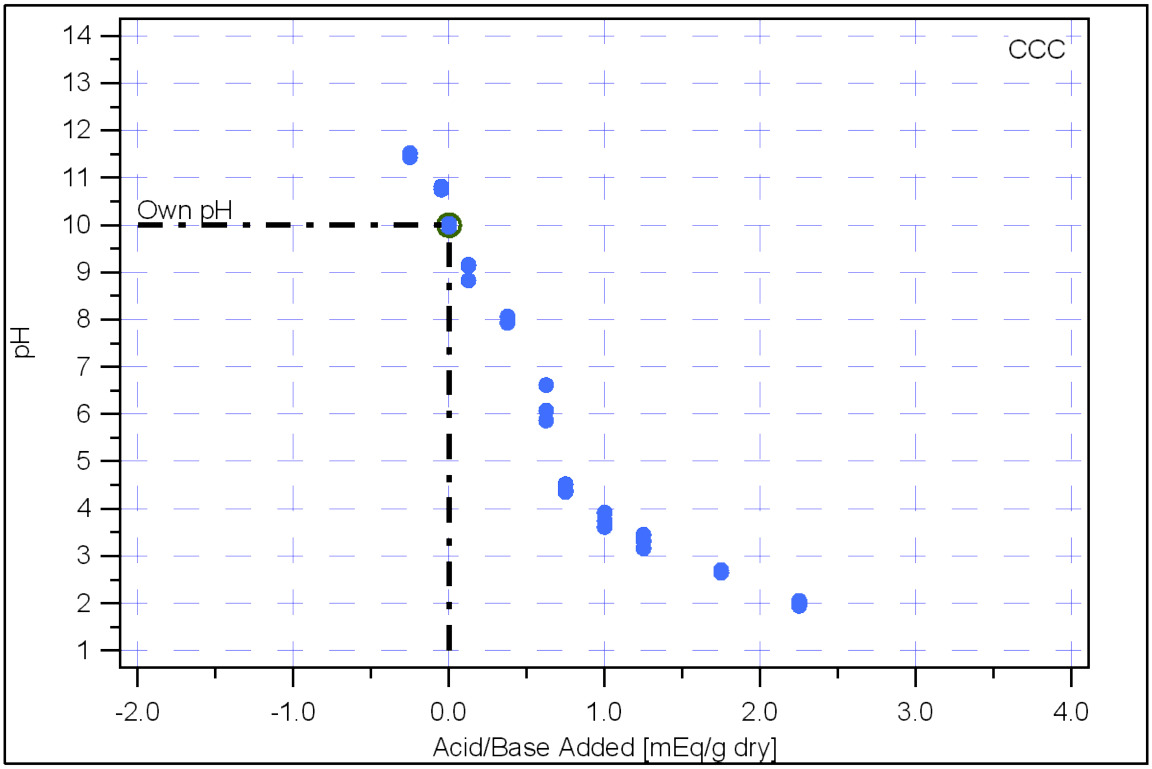


Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** – fly ash without ACI; **SHT** – fly ash with ACI.

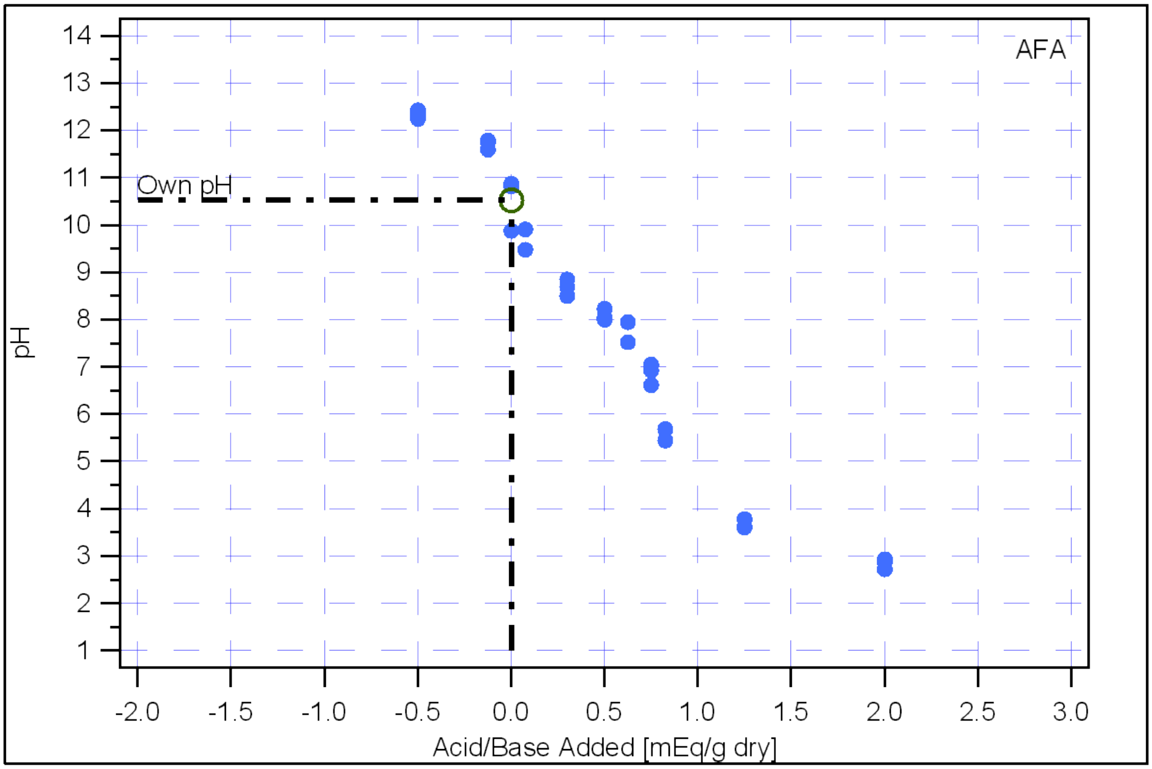


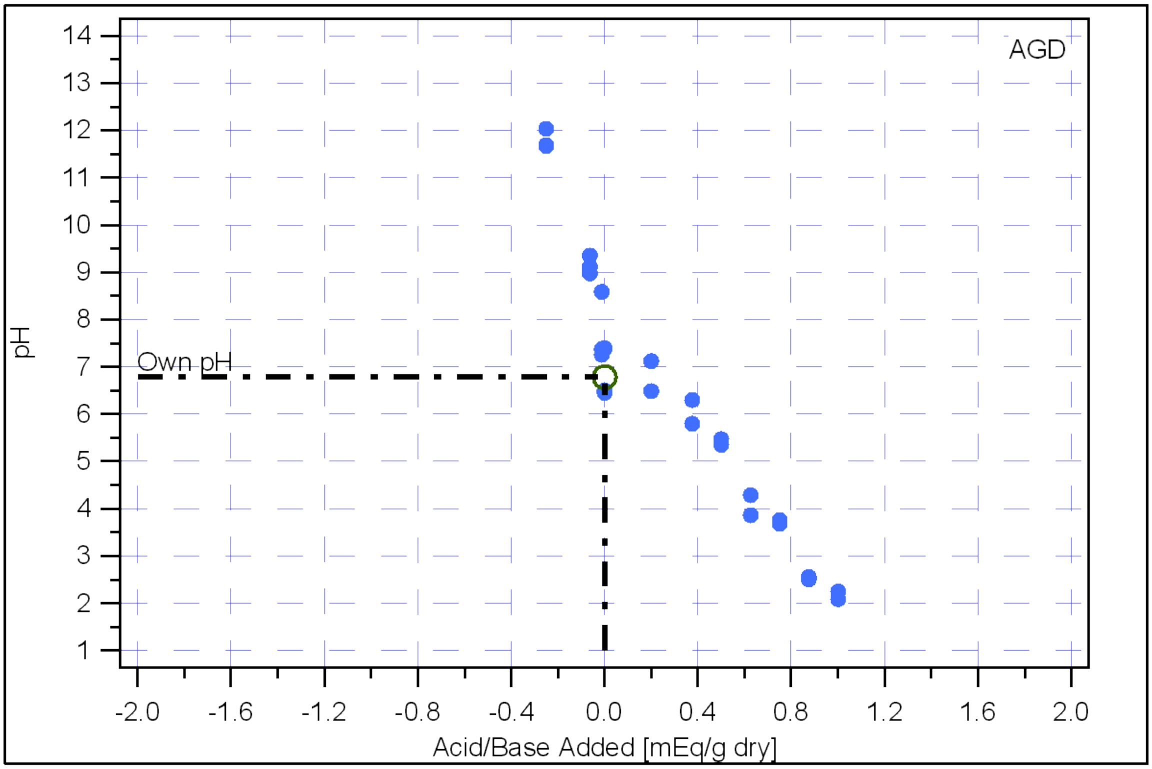


Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA – fly ash; **CGD** – scrubber sludge.

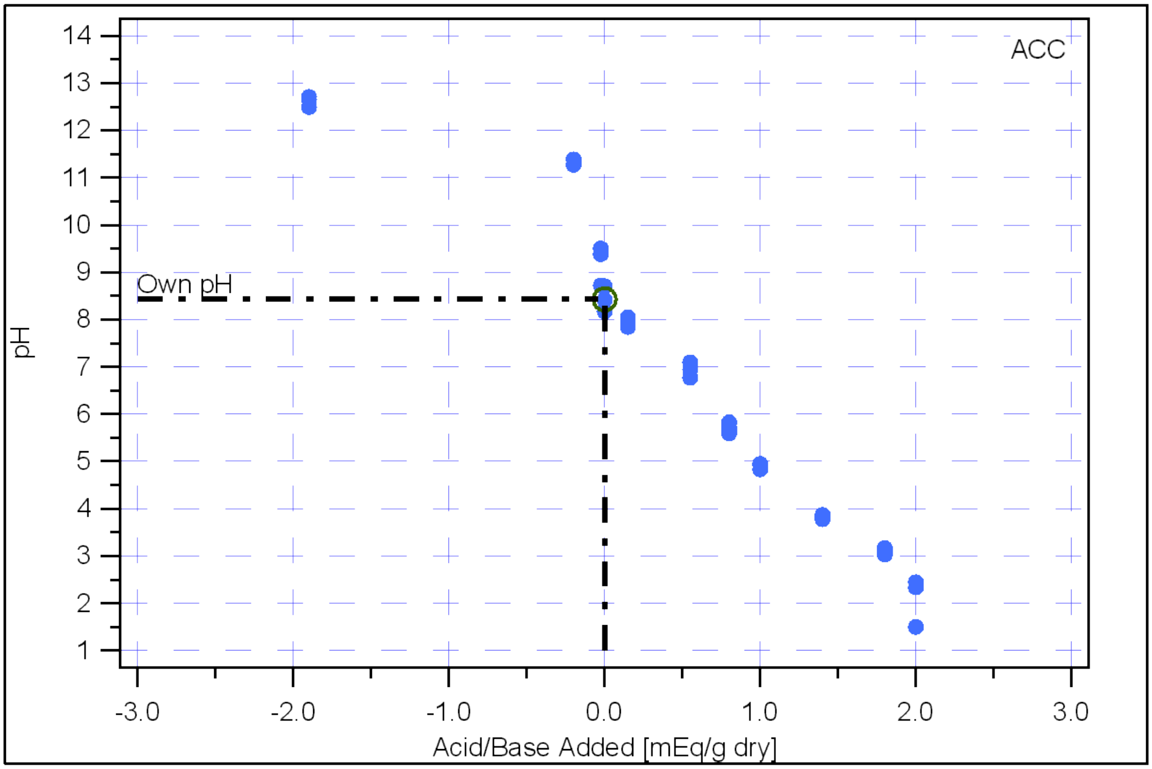


Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CCC – mixed fly ash and scrubber sludge (as managed).

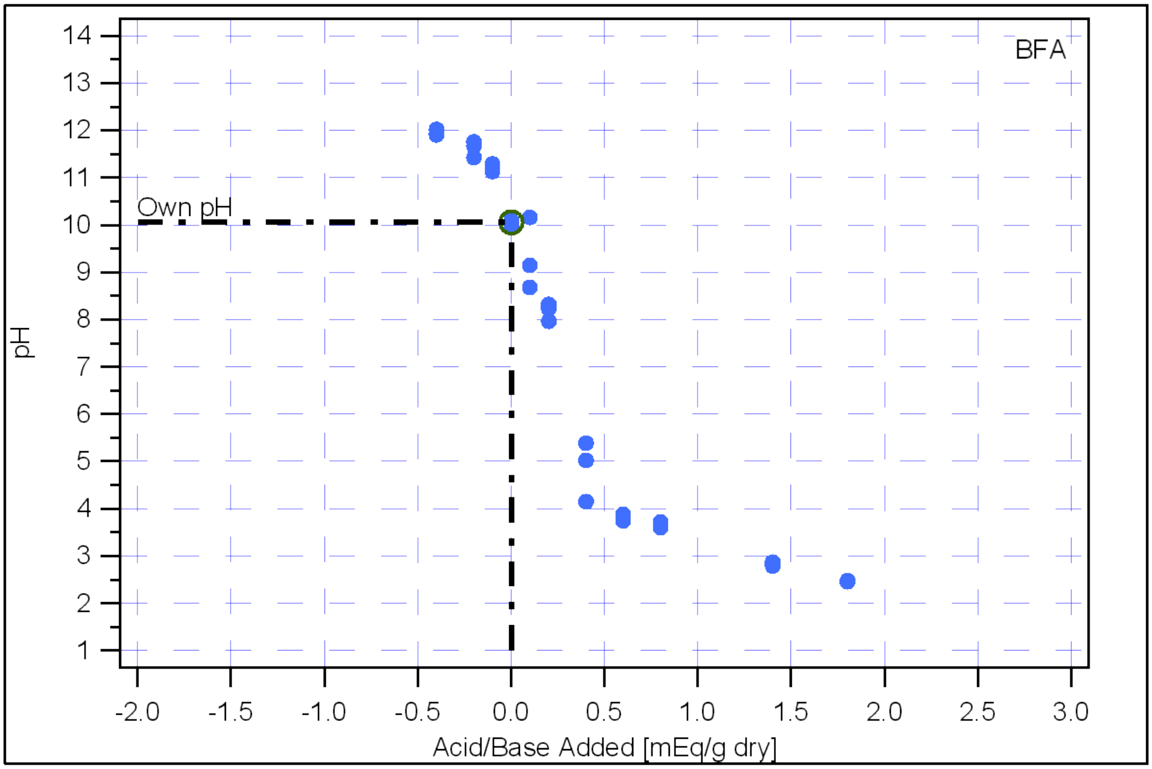


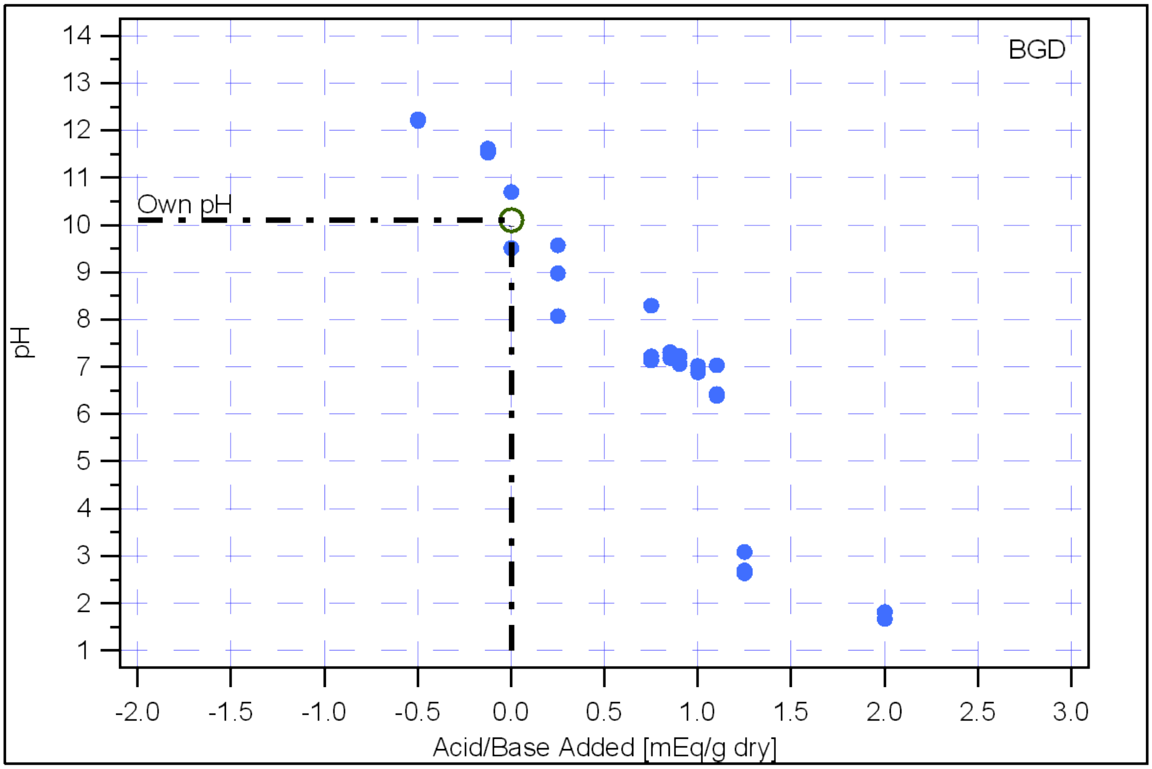


Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA – fly ash; **AGD** – scrubber sludge.

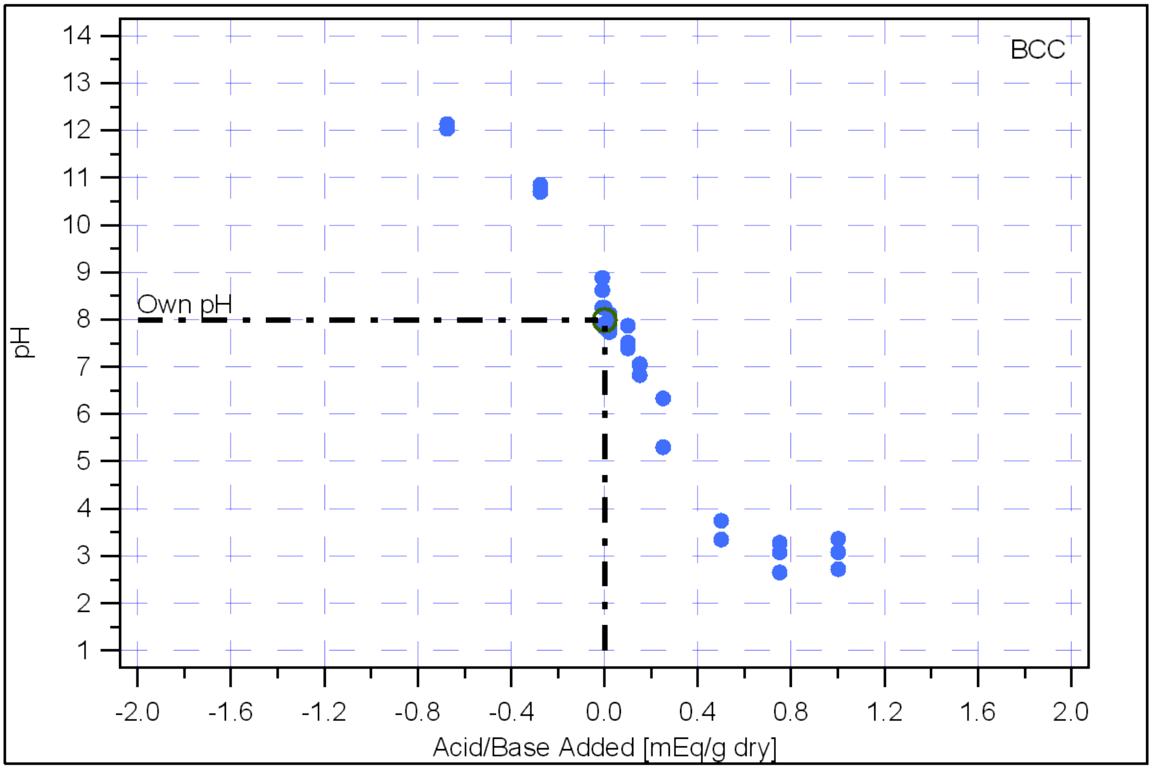


Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
ACC – mixed fly ash and scrubber sludge (as managed).

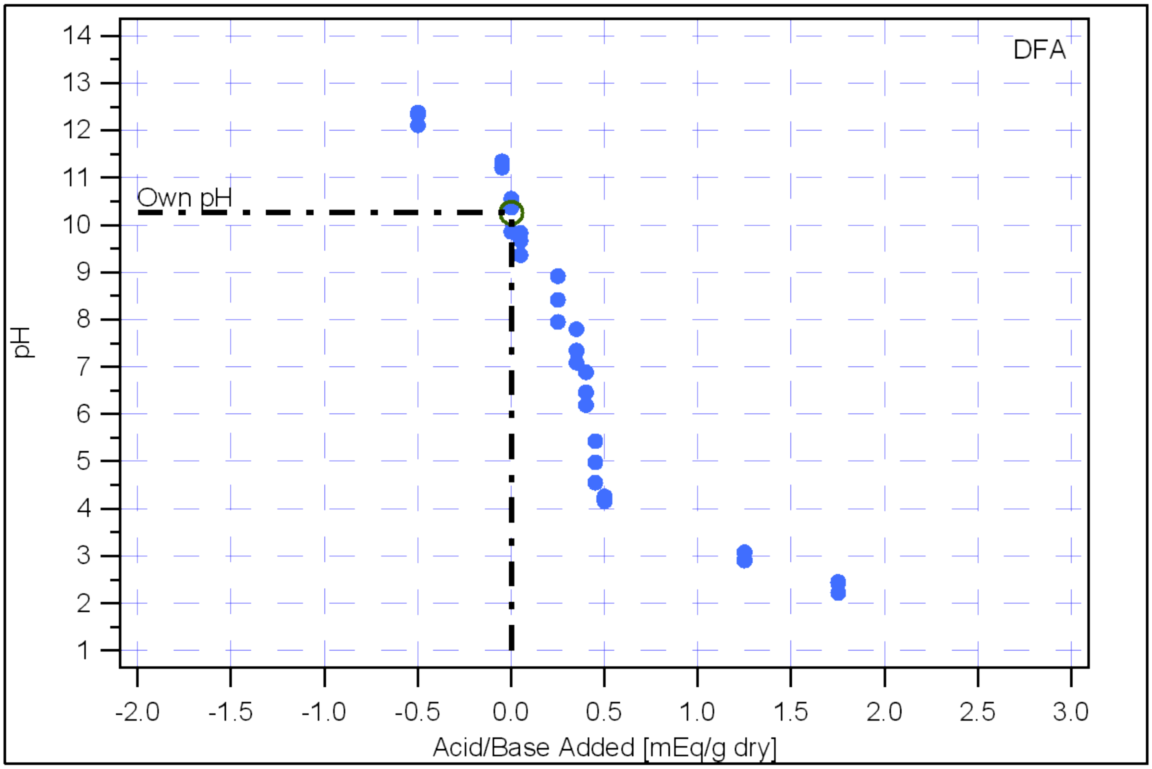


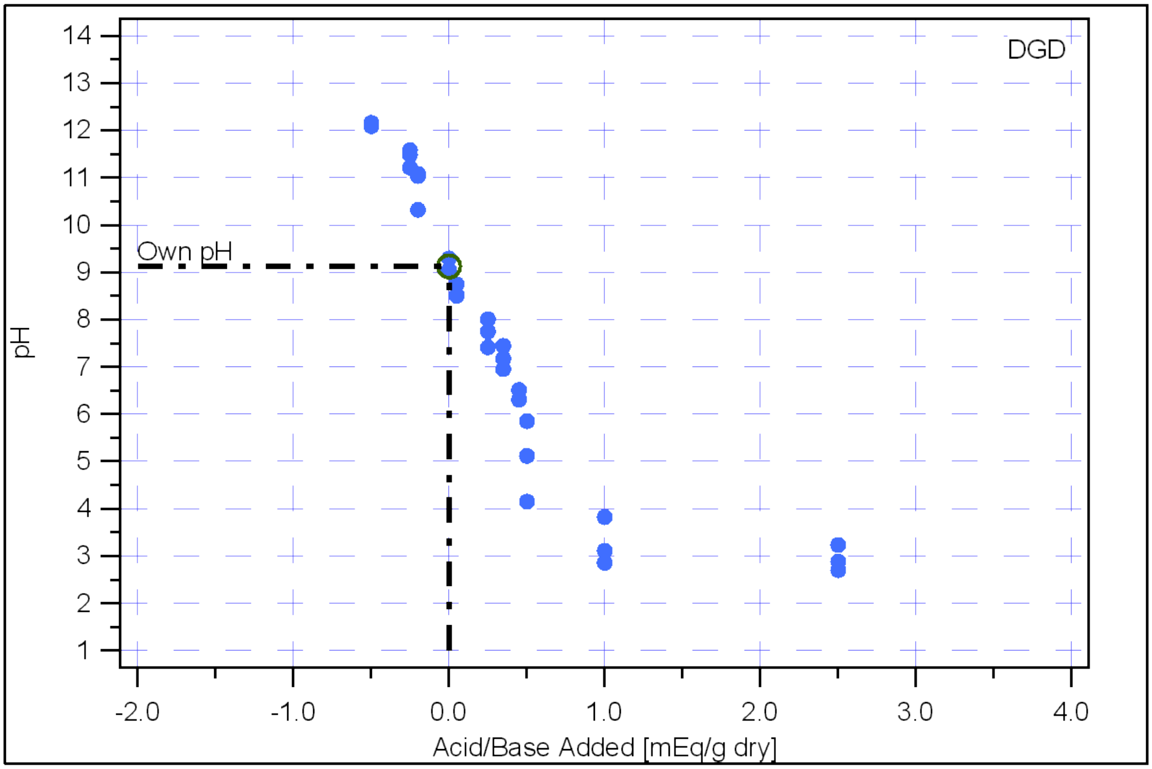


Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA – fly ash; **BGD** – scrubber sludge.

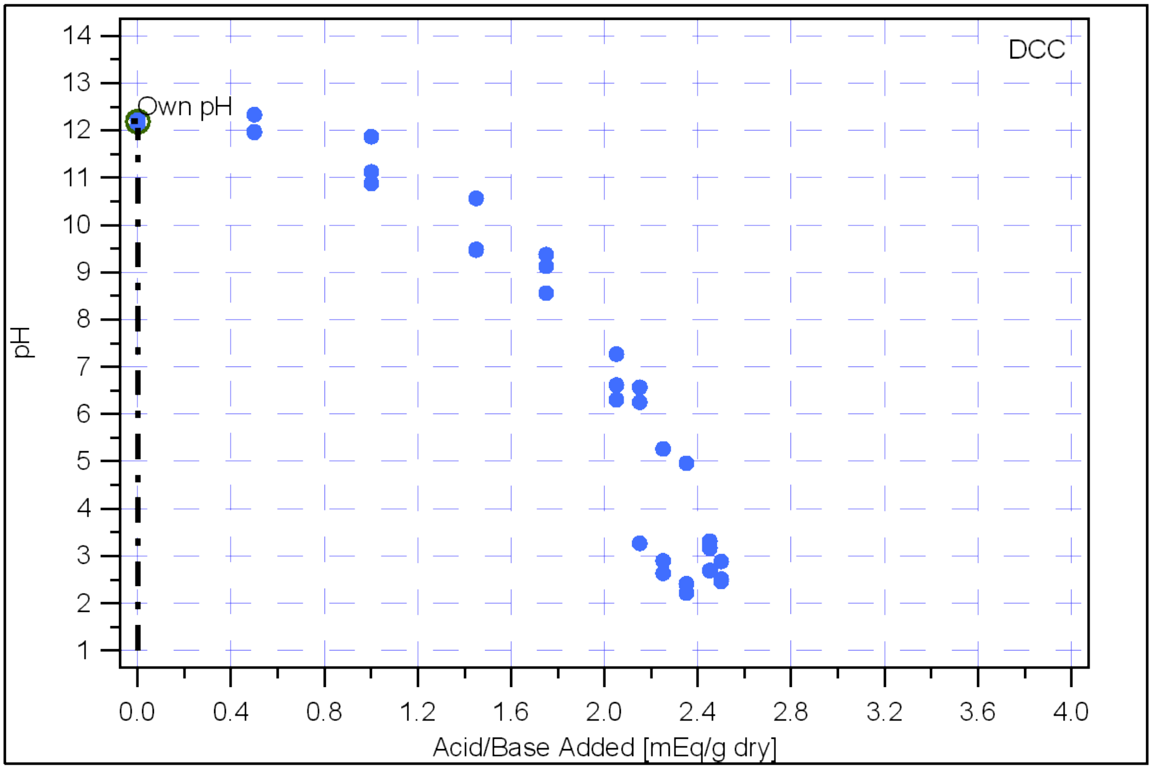


Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BCC – mixed fly ash and scrubber sludge (as managed).

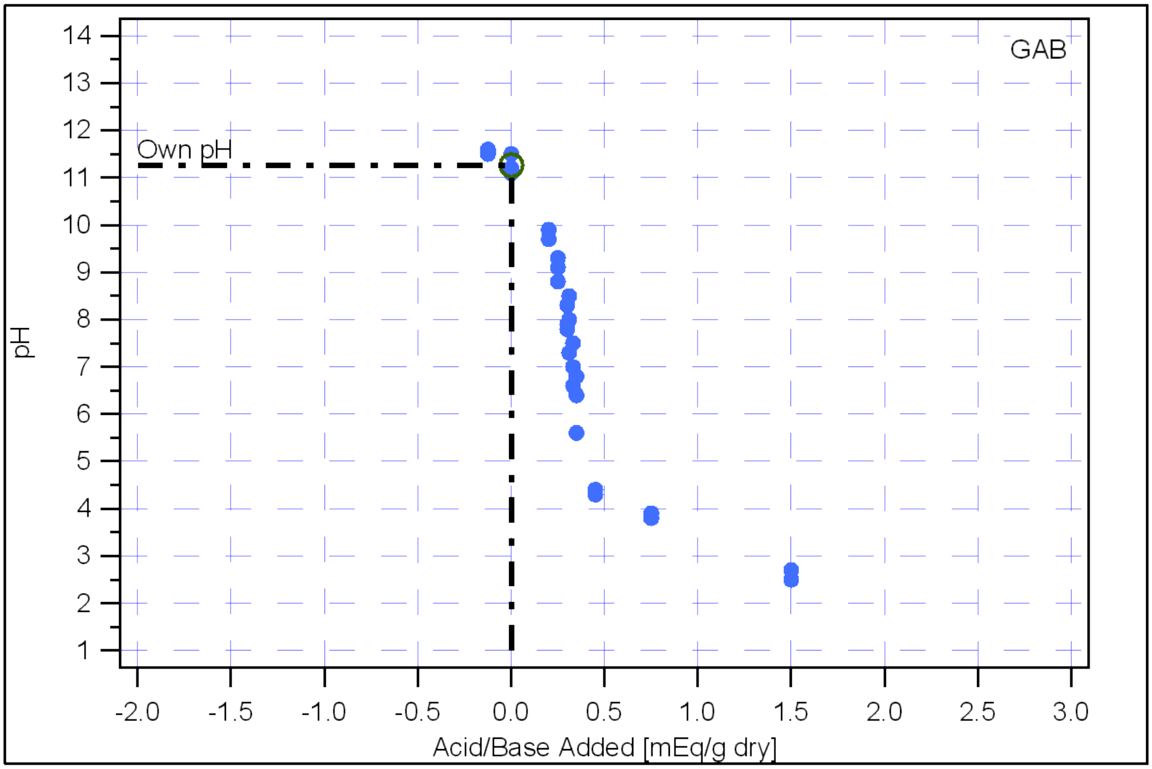


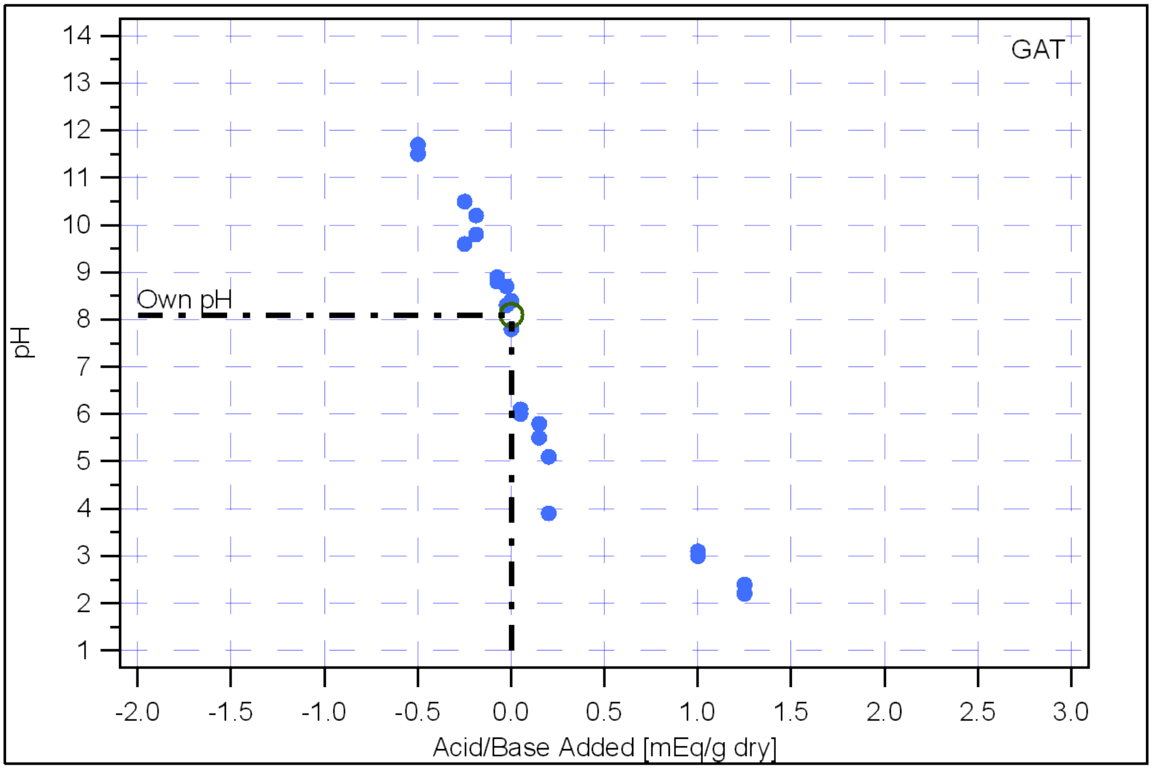


Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA – fly ash; **DGD** – scrubber sludge.

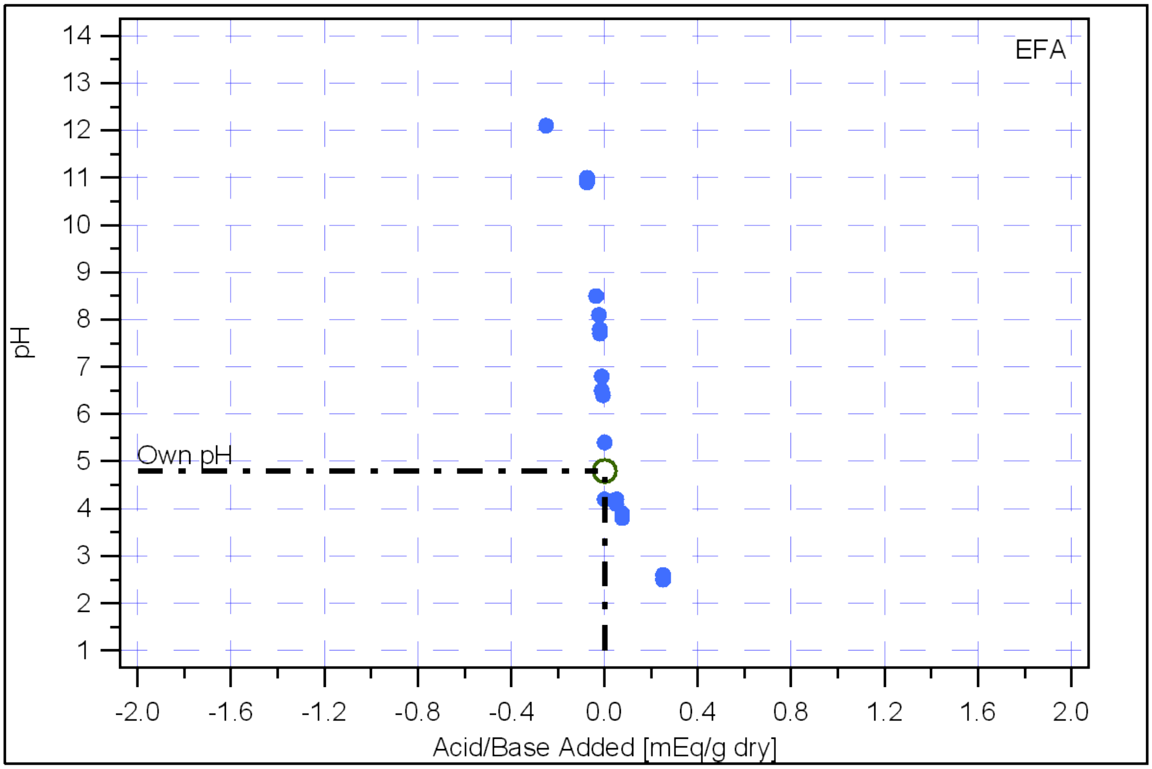


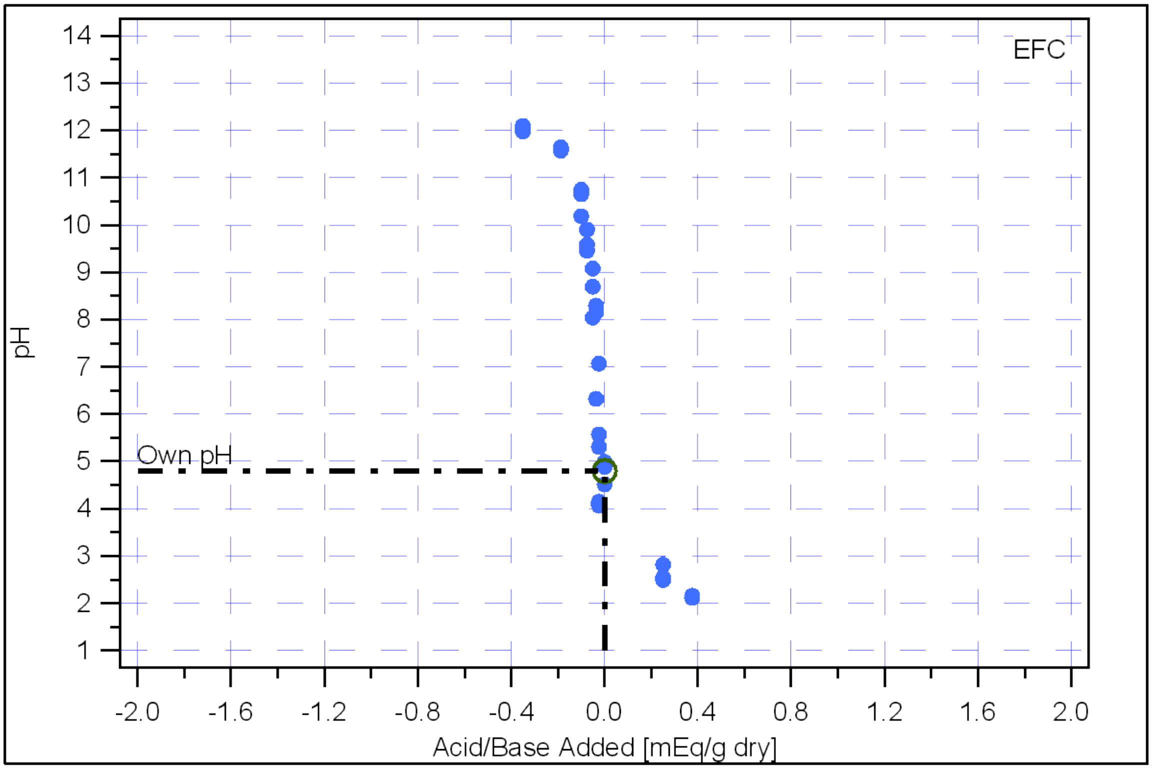
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DCC – mixed fly ash and scrubber sludge (as managed).



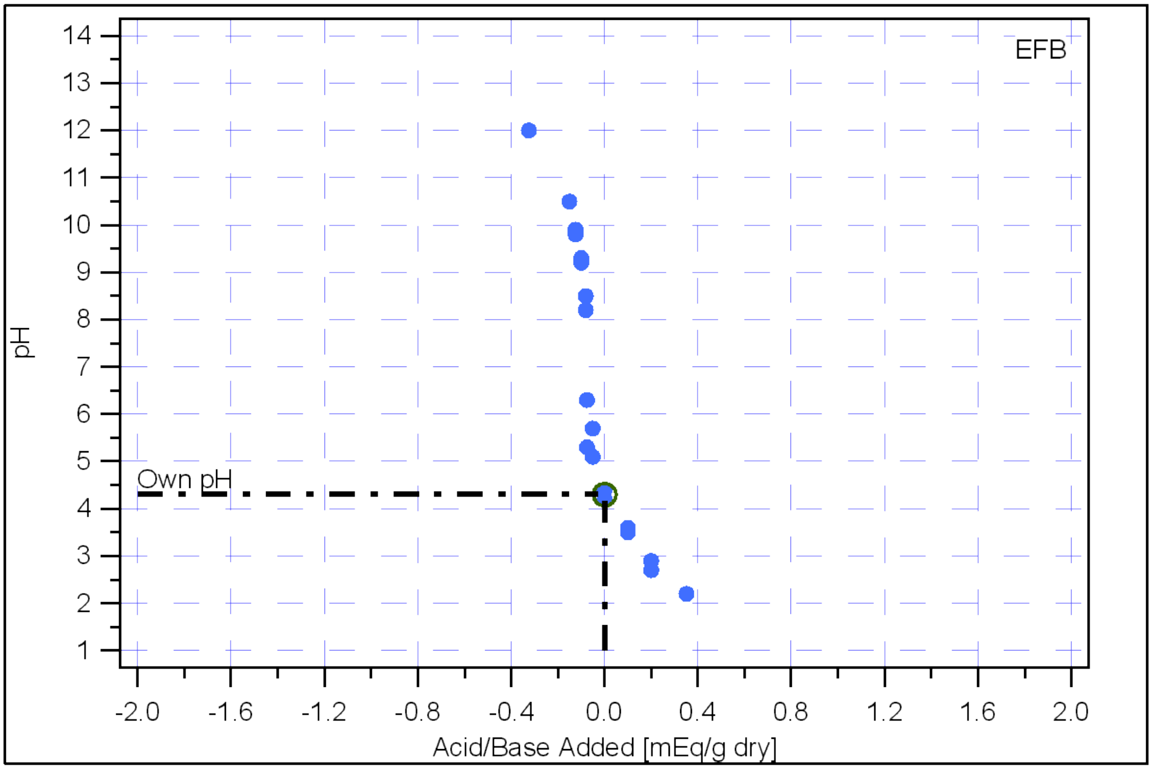


Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** – fly ash without ACI; **GAT** fly ash with ACI.

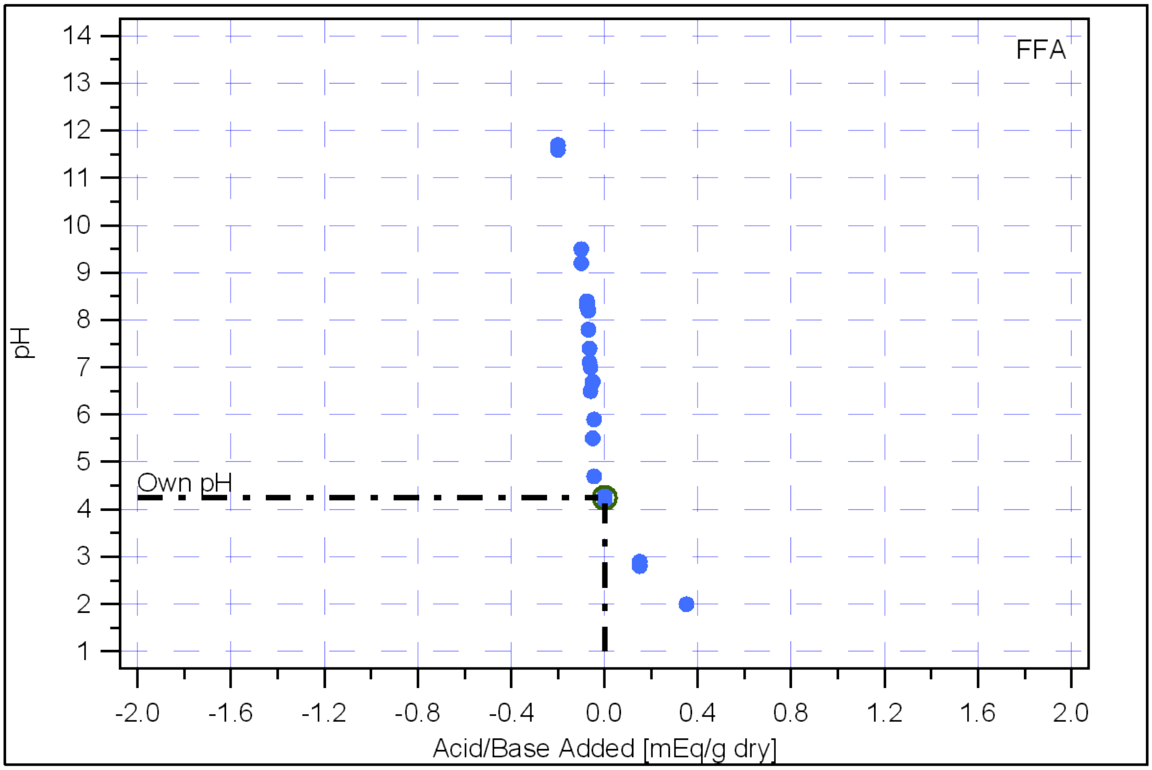




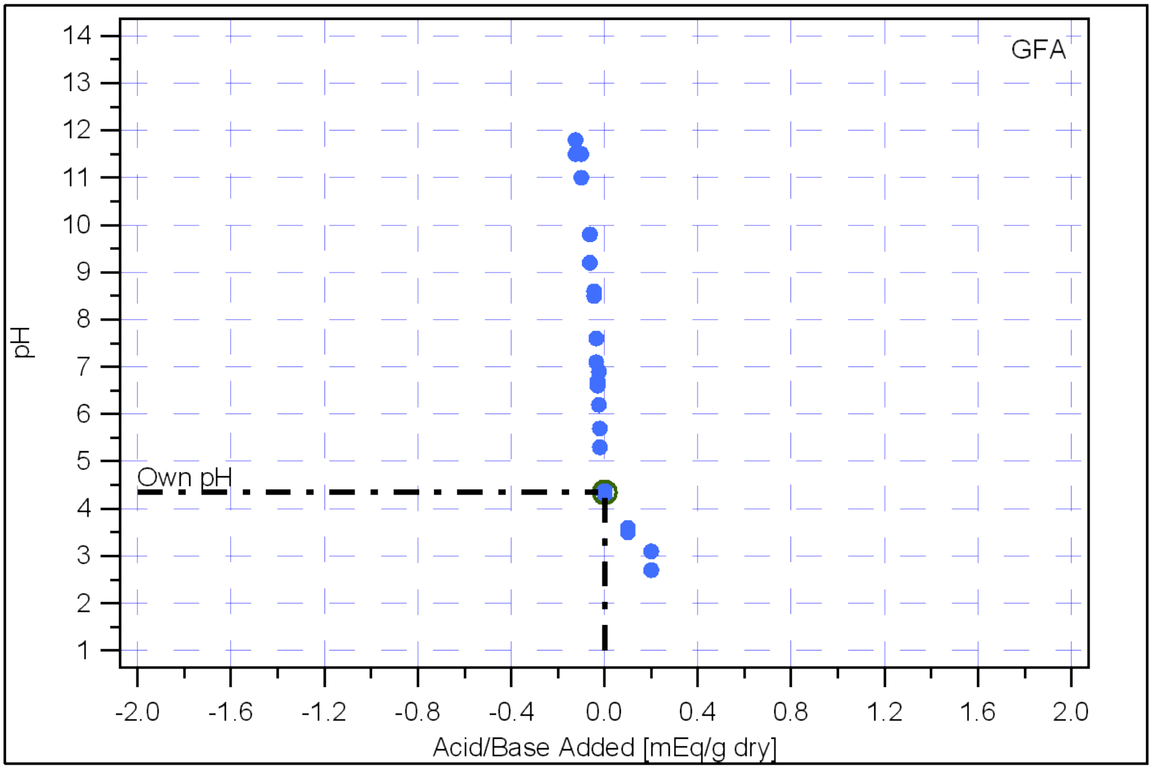
Facility E (Med. S East-Bit.). **EFA, EFC** – fly ash SCR on.



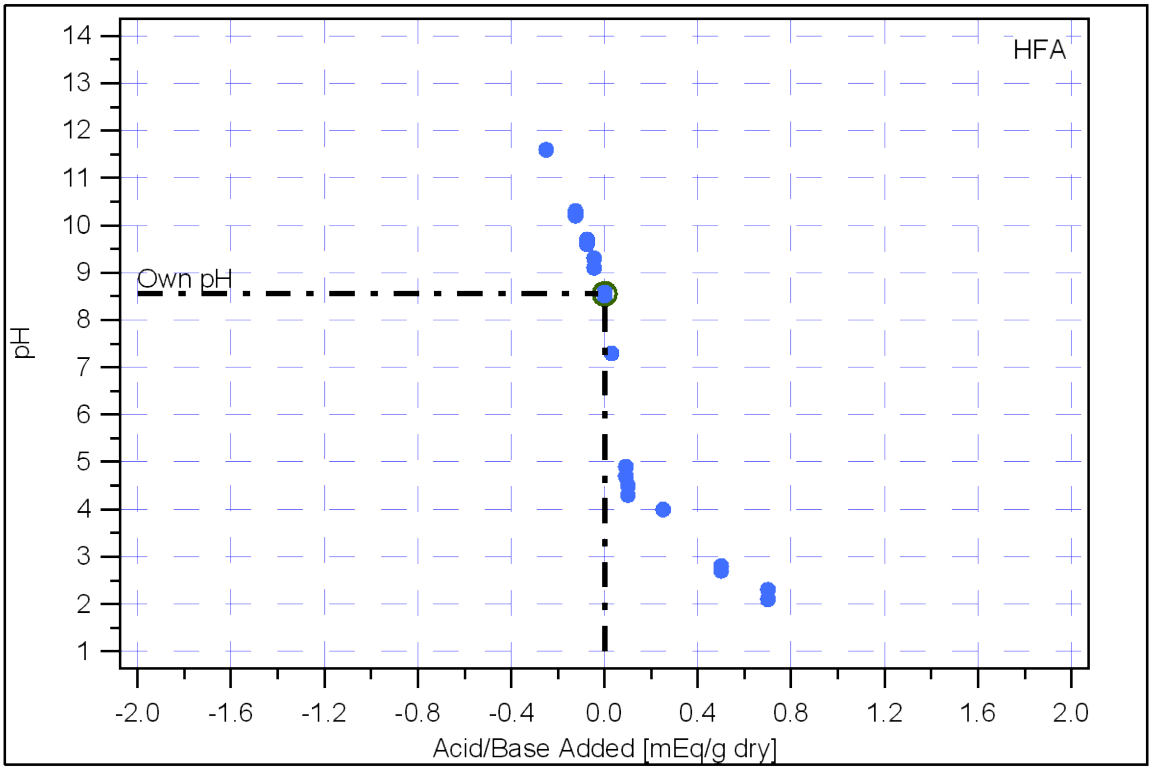
Facility E (Med. S East-Bit.). **EFB** – fly ash SCR-BP.



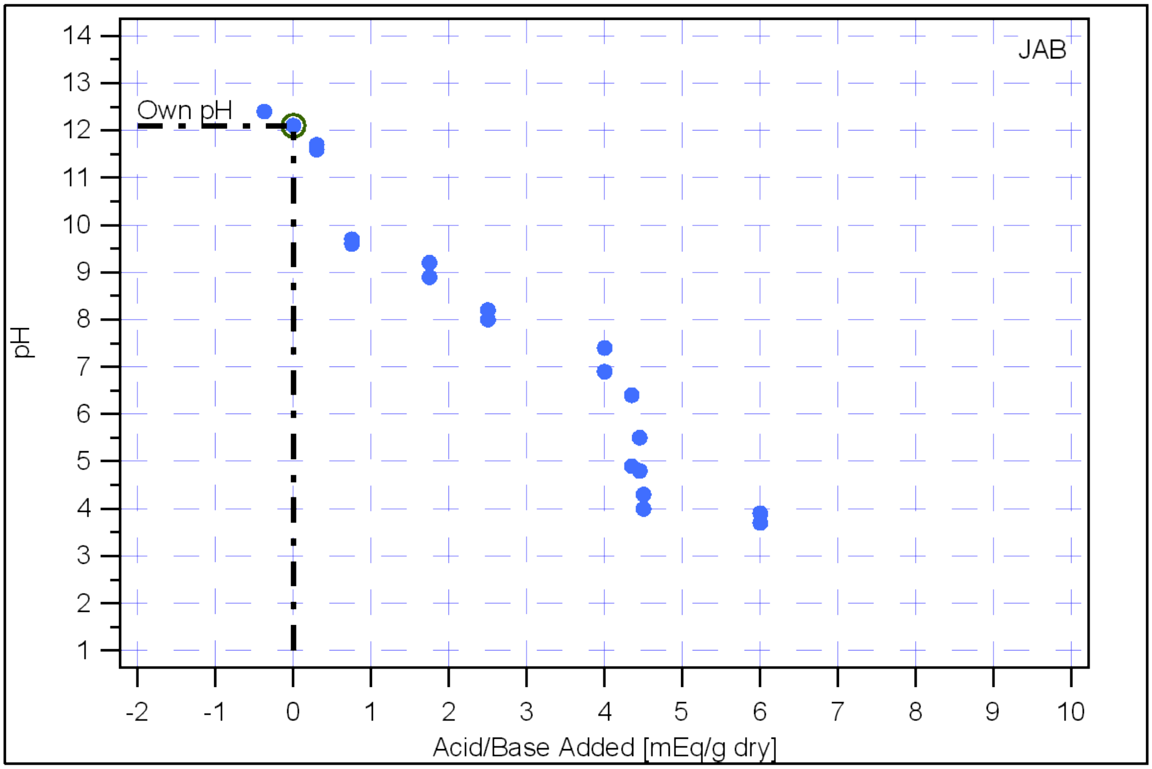
Facility F (Low S East-Bit., CS-ESP). **FFA** – fly ash.

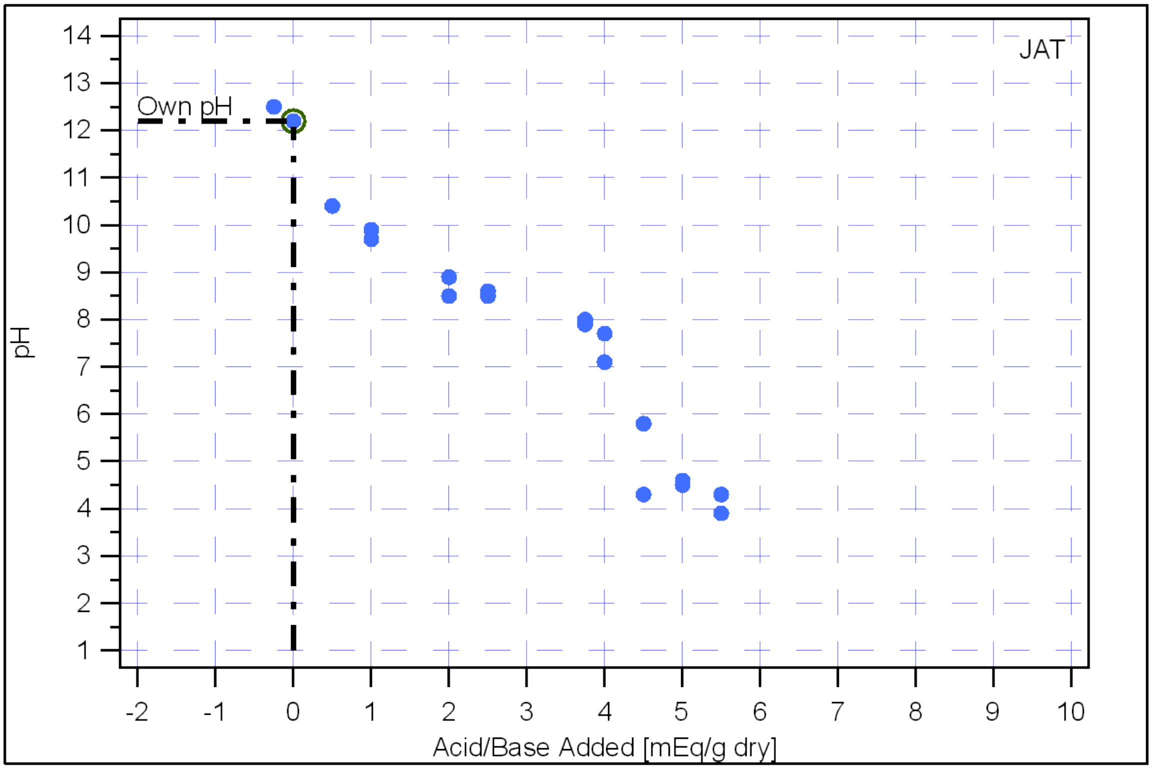


Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** – fly ash.

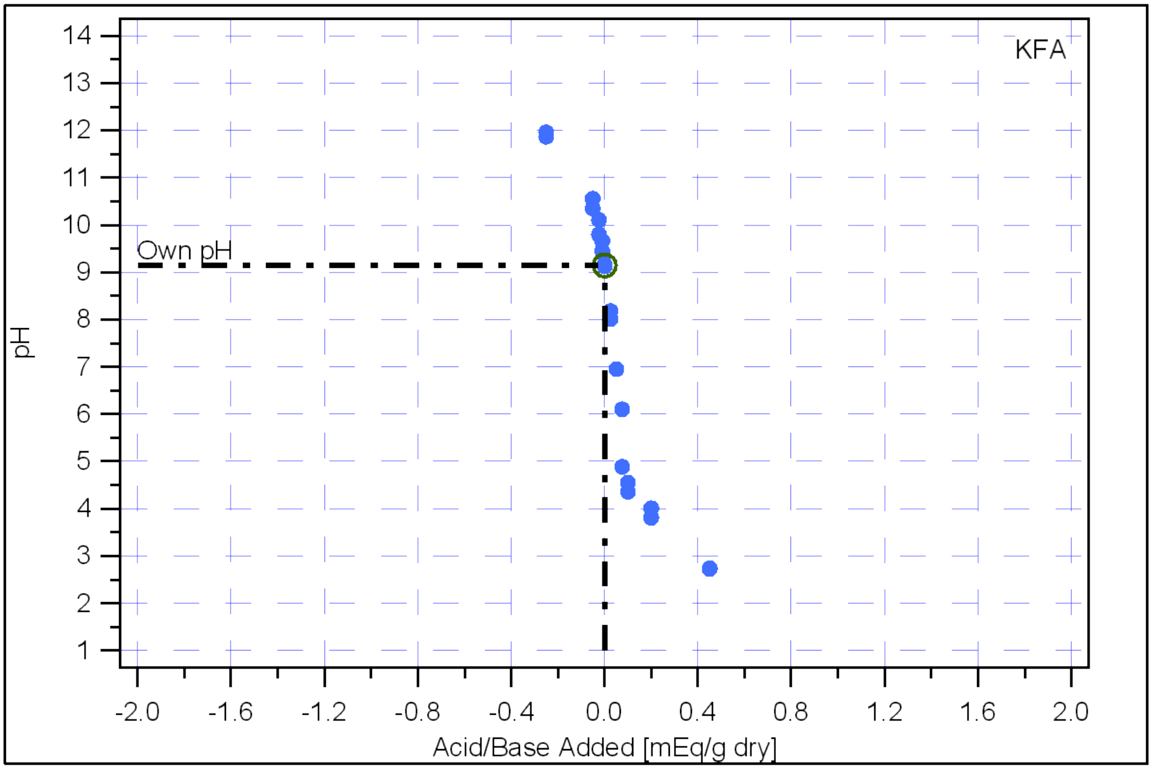


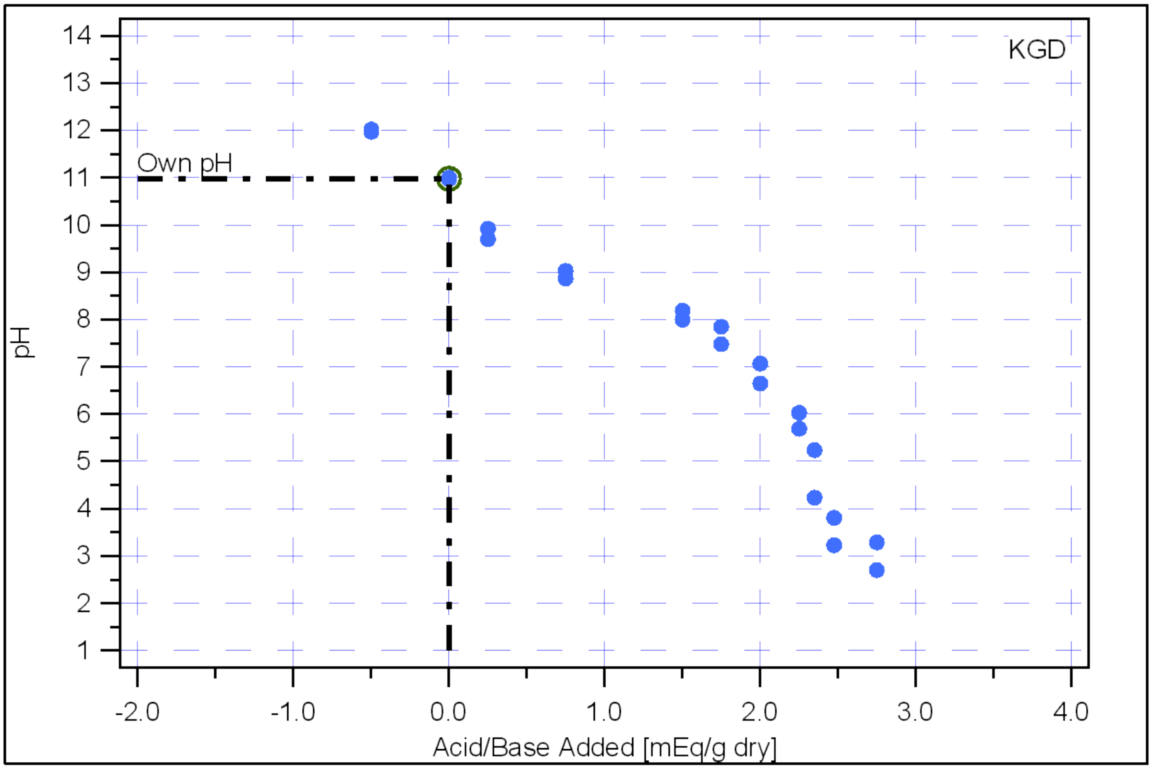
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** – fly ash.



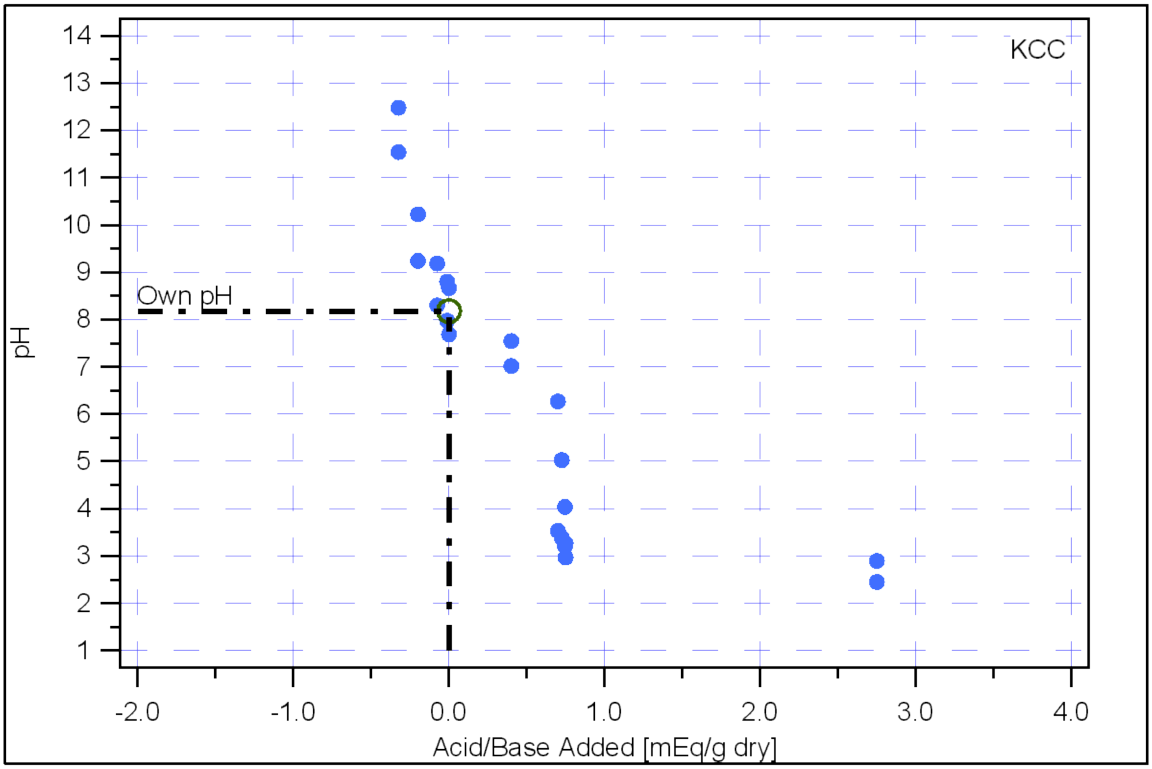


Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** – fly ash without Br-ACI; **JAT** – fly ash with Br-ACI.

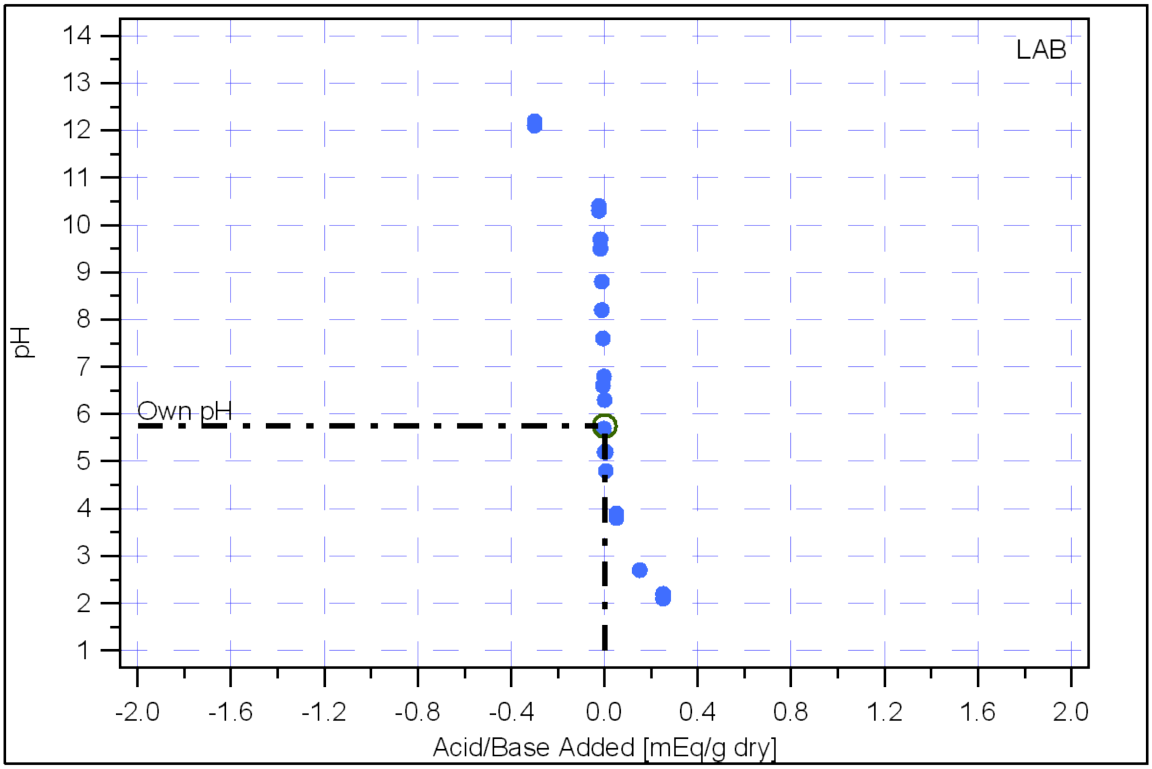


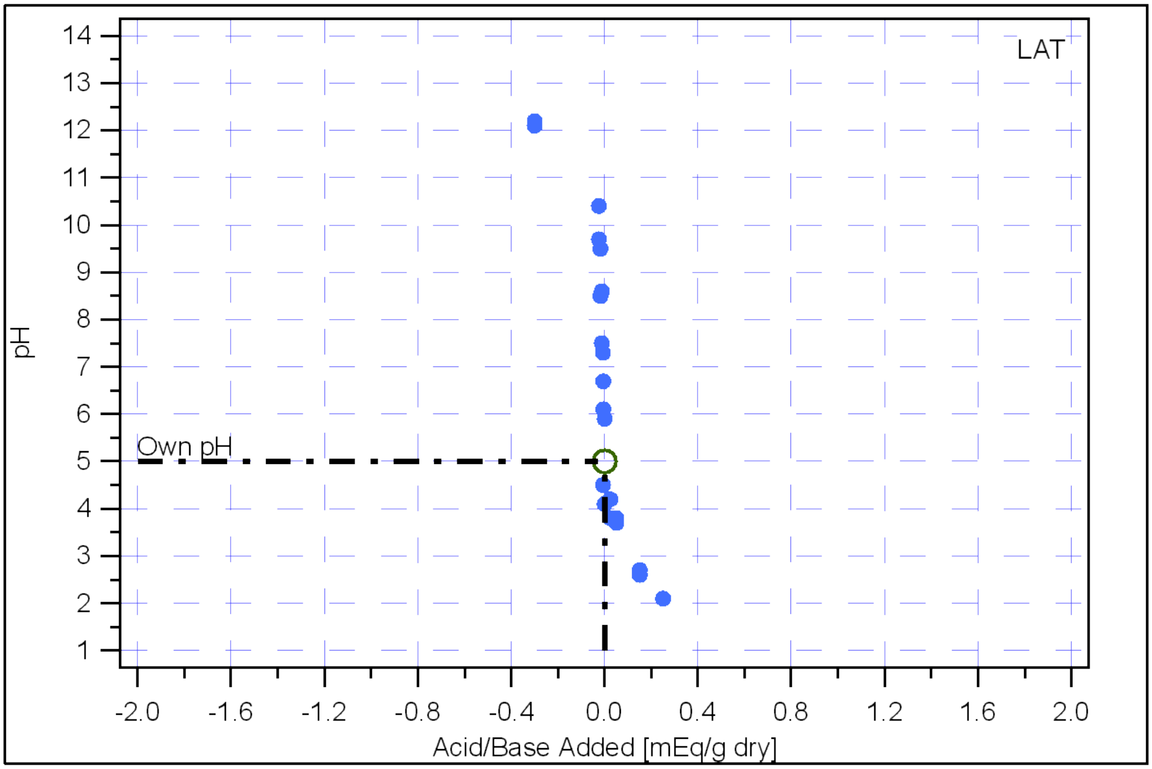


Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA – fly ash; **KGD** – scrubber sludge.

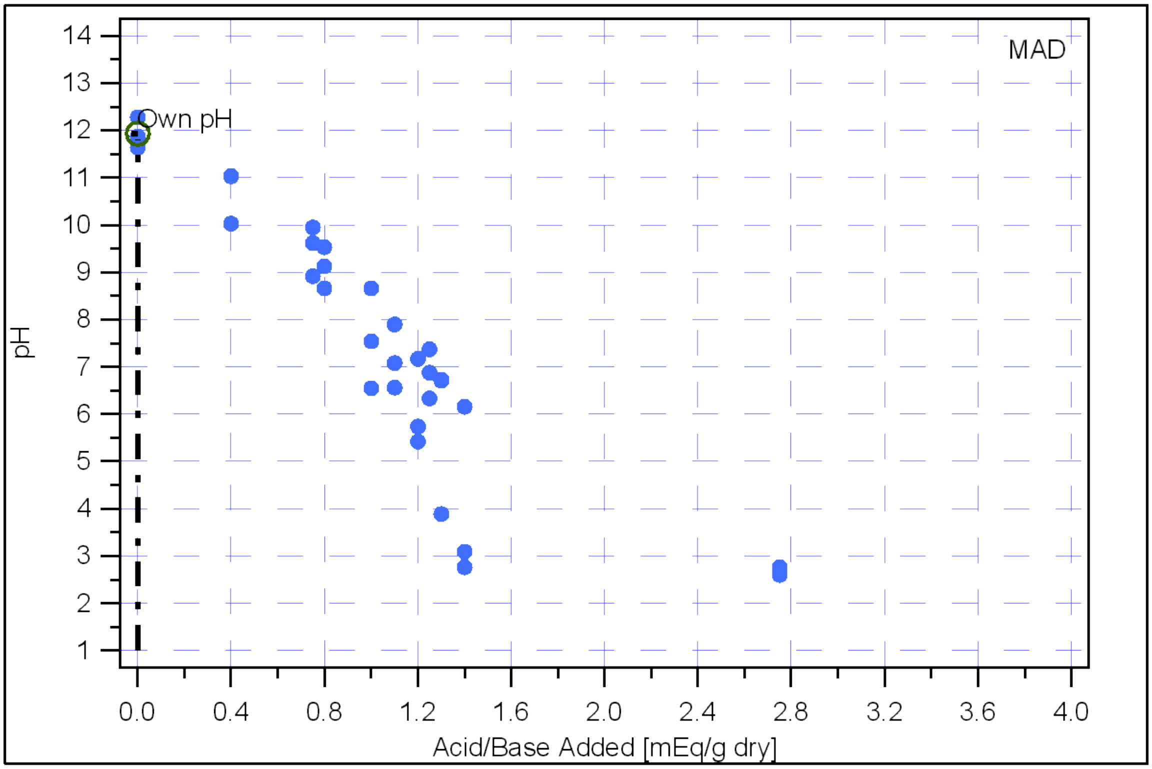


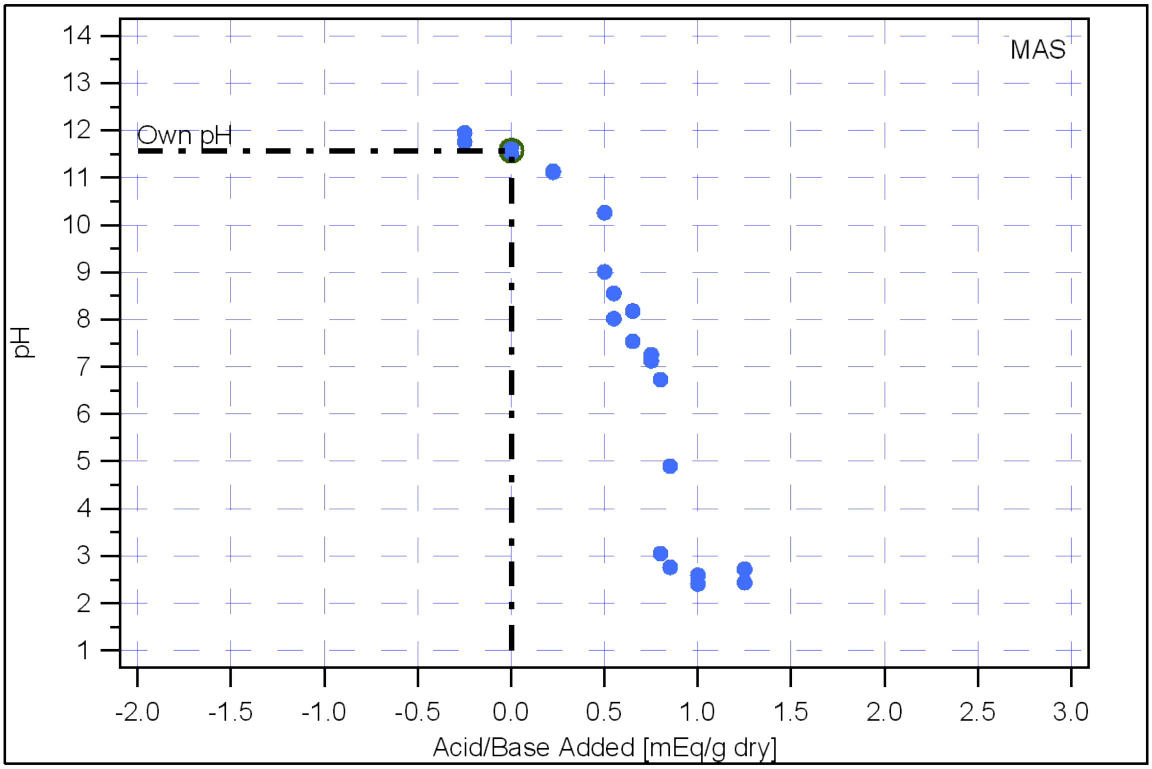
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KCC – mixed fly ash and scrubber sludge (as managed).



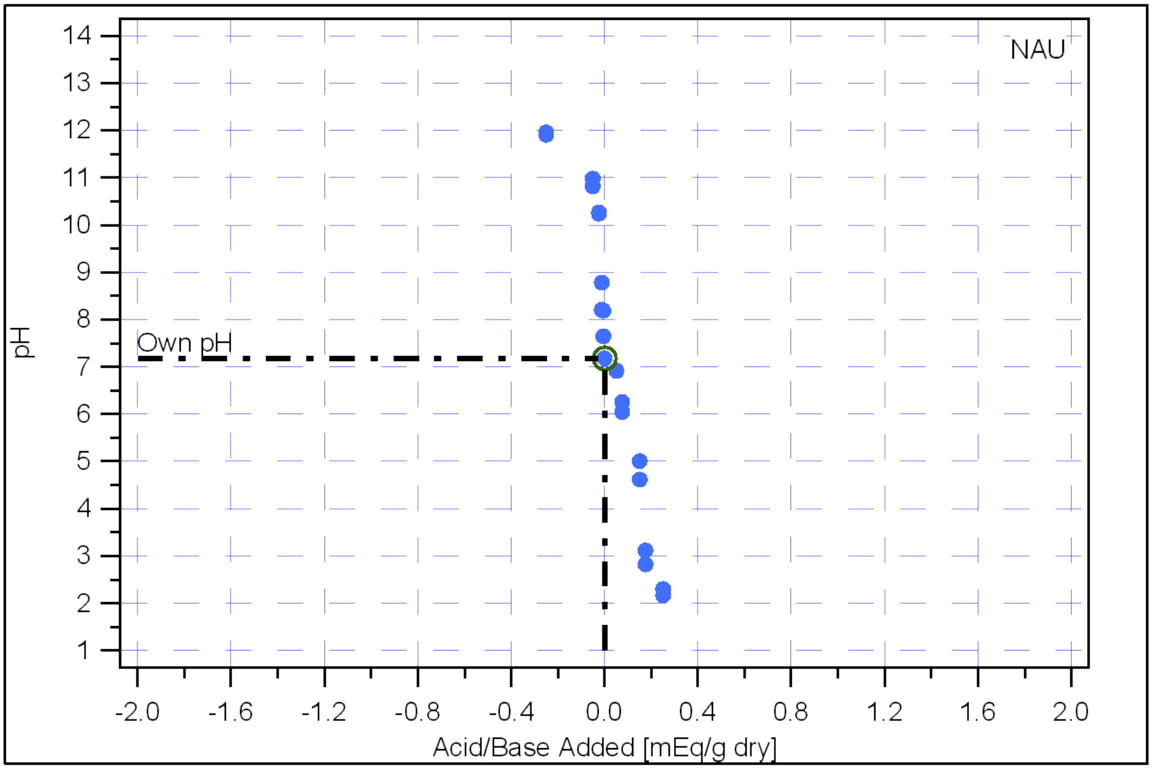


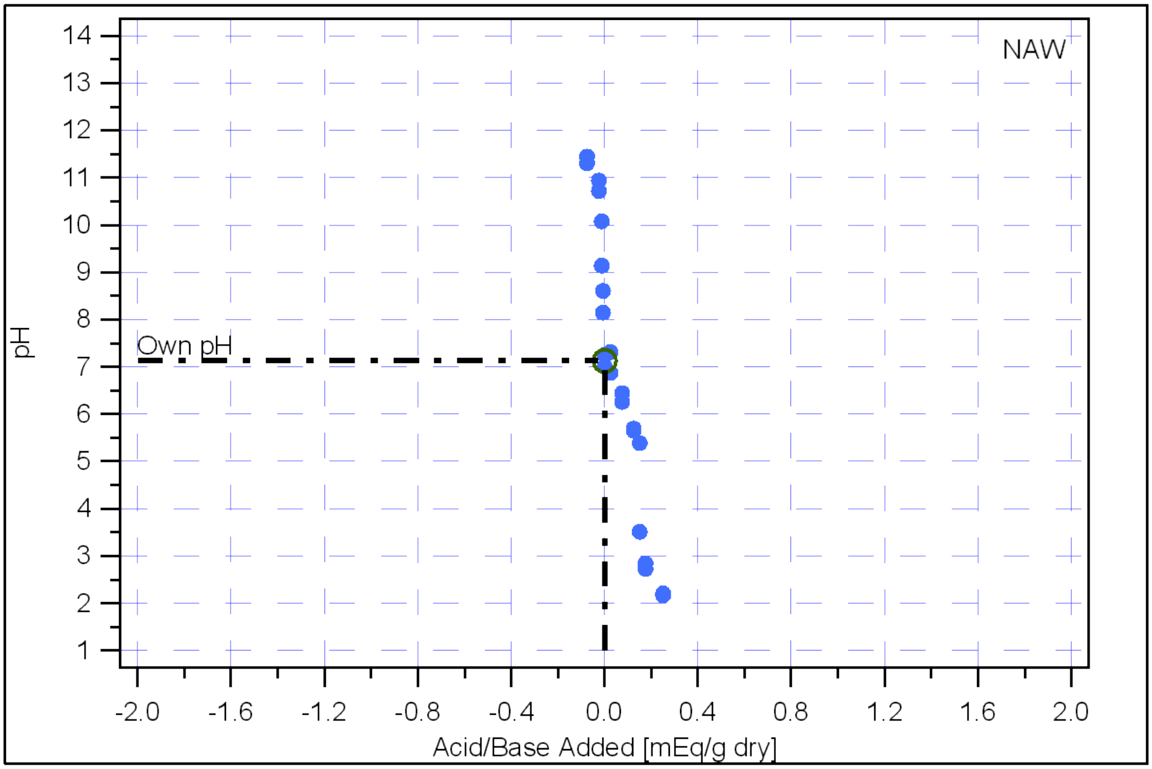
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB – fly ash without Br-ACI; **LAT** – fly ash with Br-ACI.



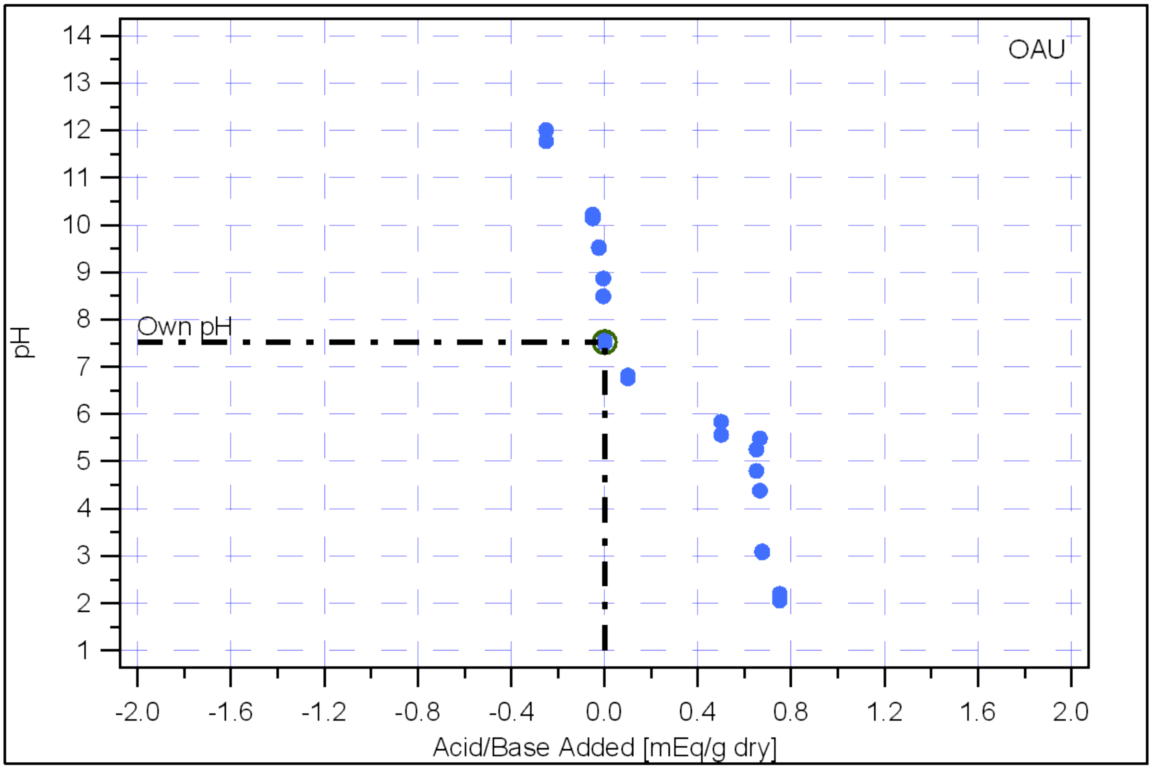


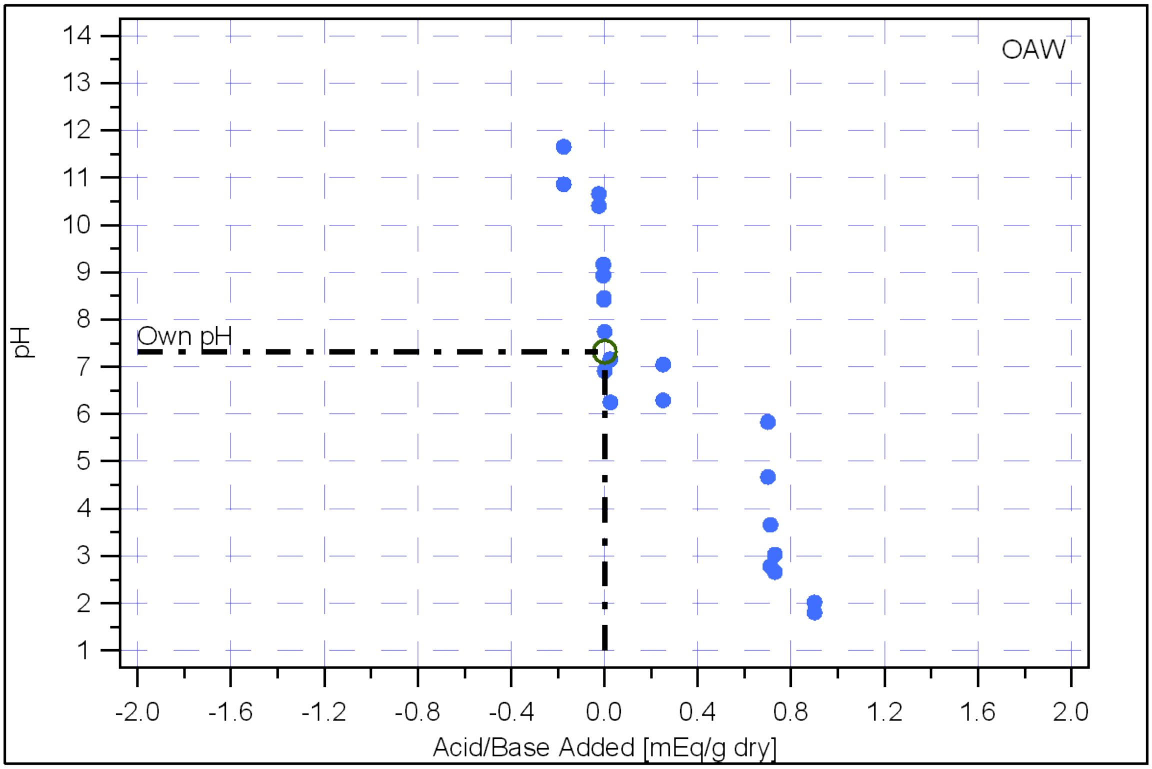
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD – SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS – SCR on; mixed fly ash and scrubber sludge (as managed).



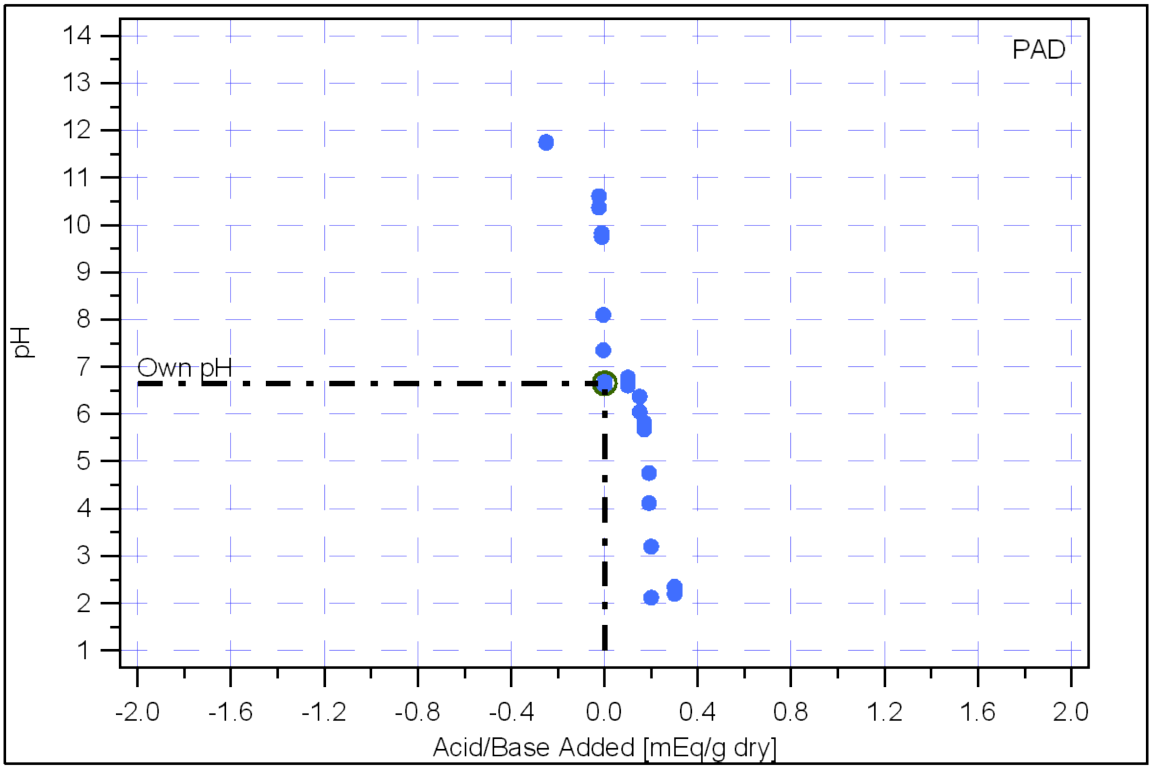


Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU – unwashed gypsum; **NAW** – washed gypsum.

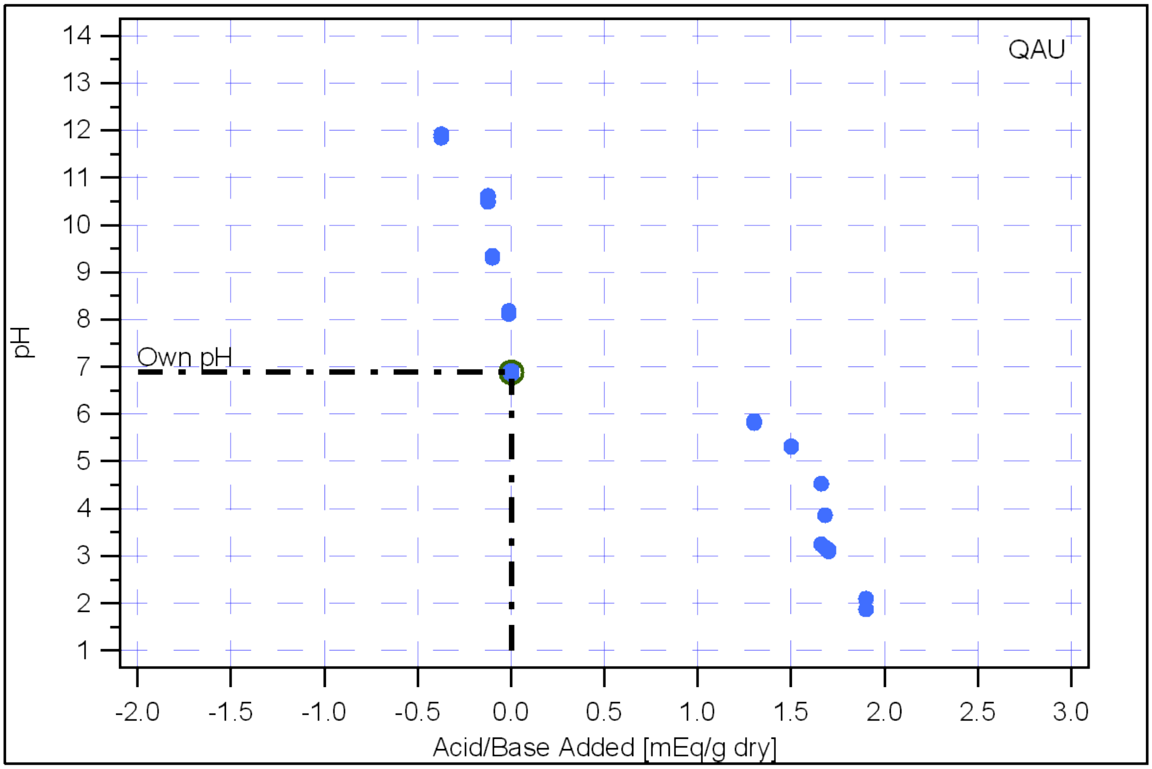




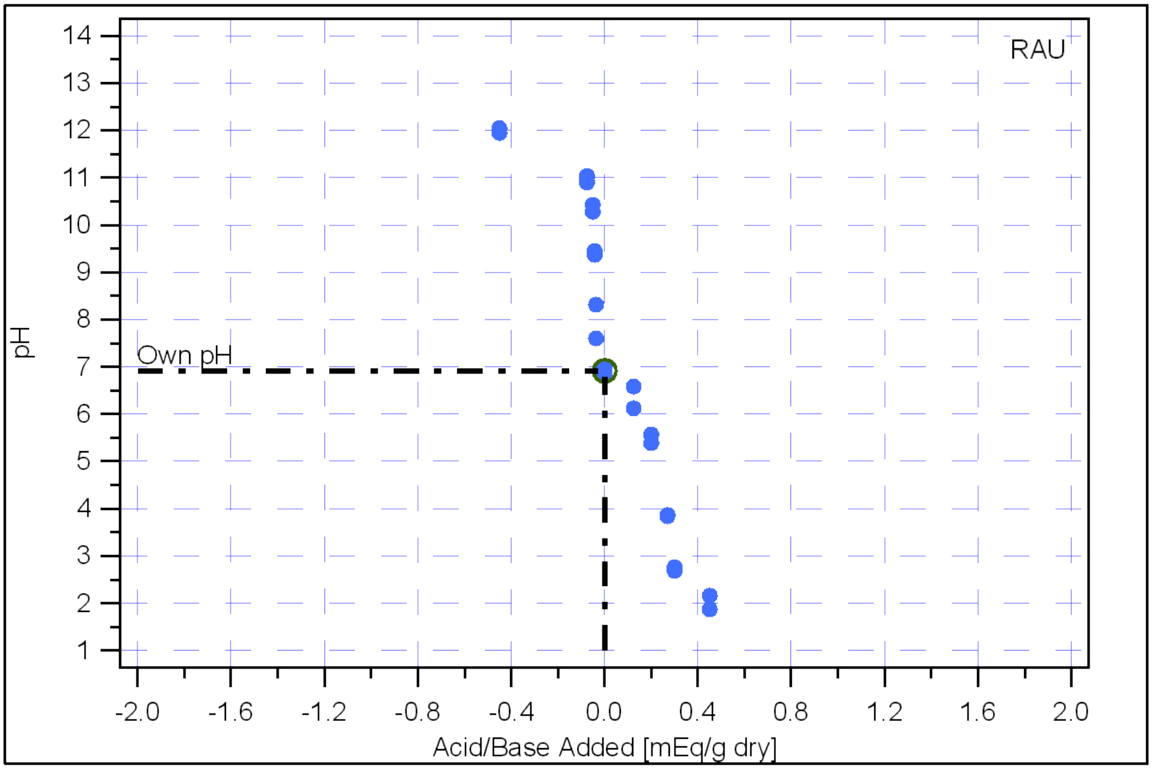
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU – unwashed gypsum; **OAW** – washed gypsum.



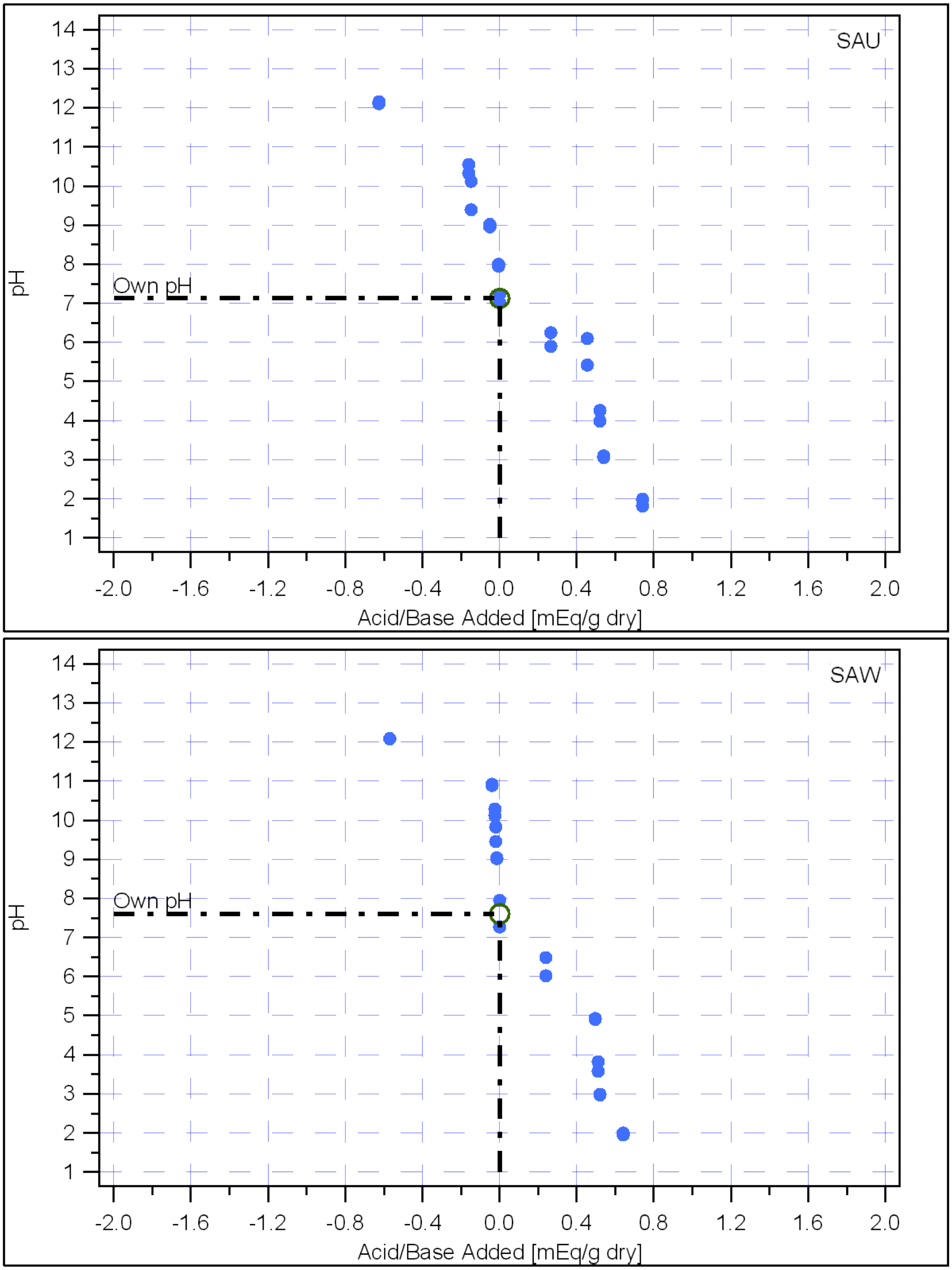
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** – unwashed gyp.



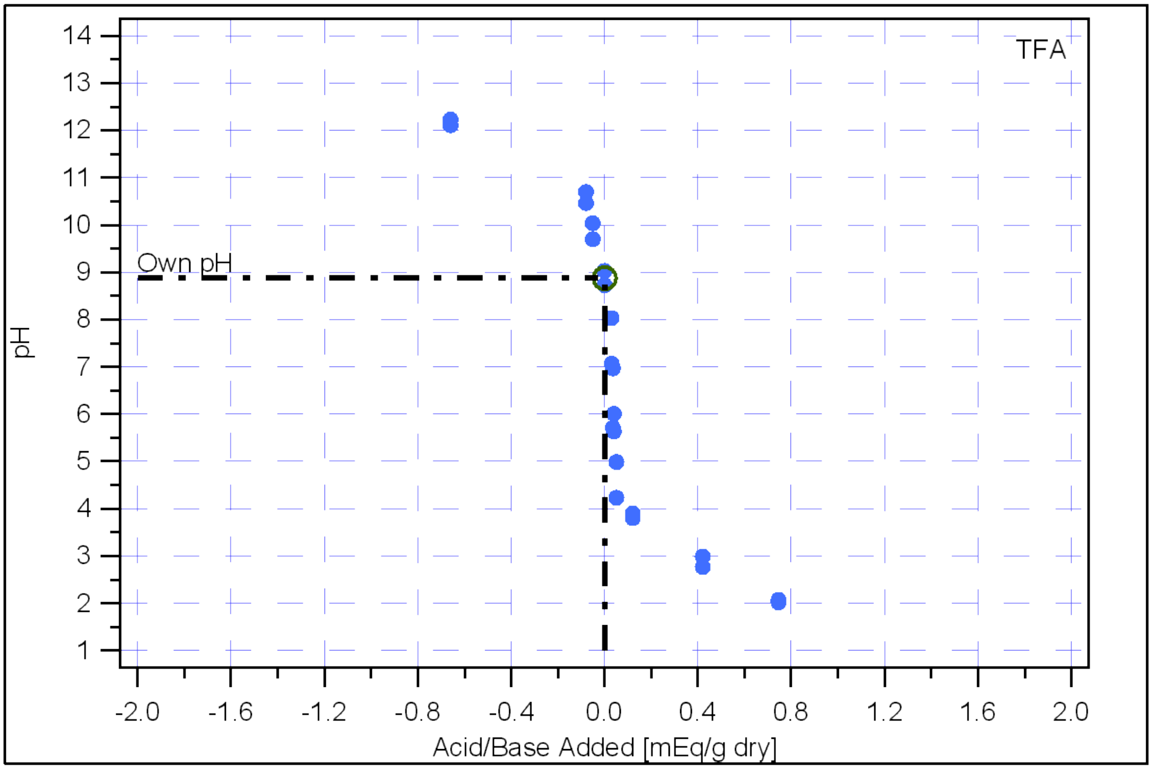
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** – unwashed gypsum.



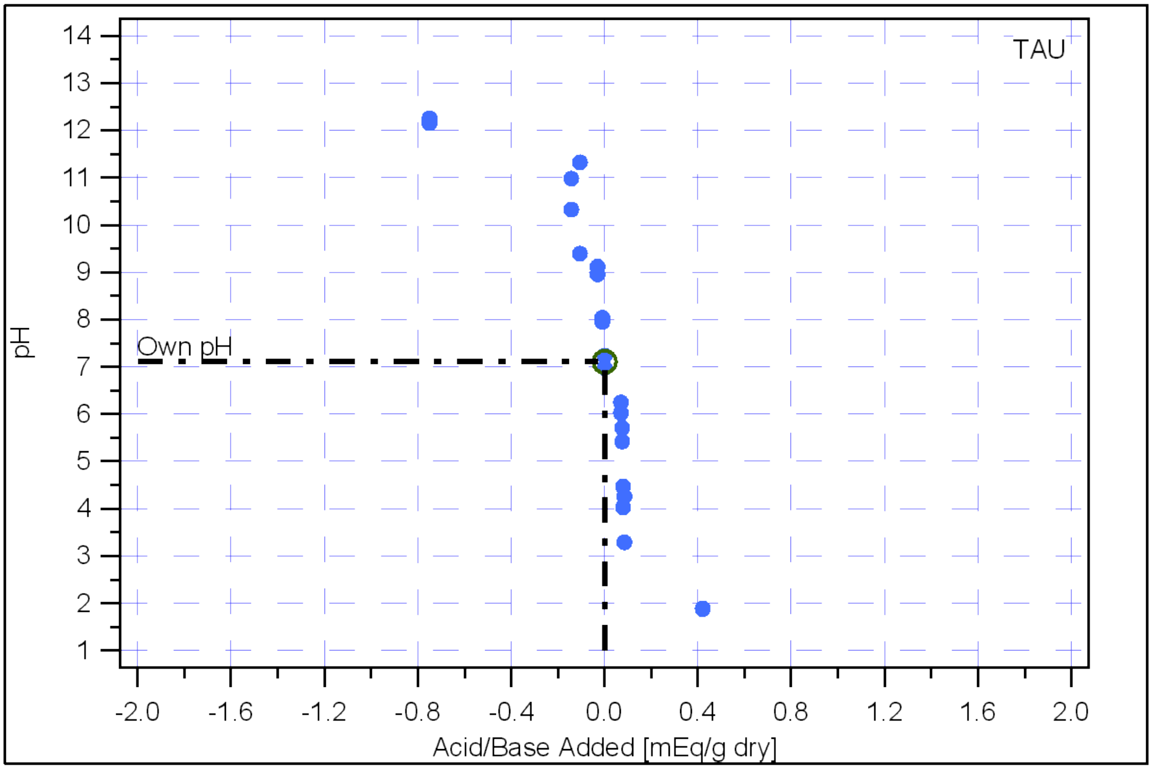
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** – unwashed gypsum.

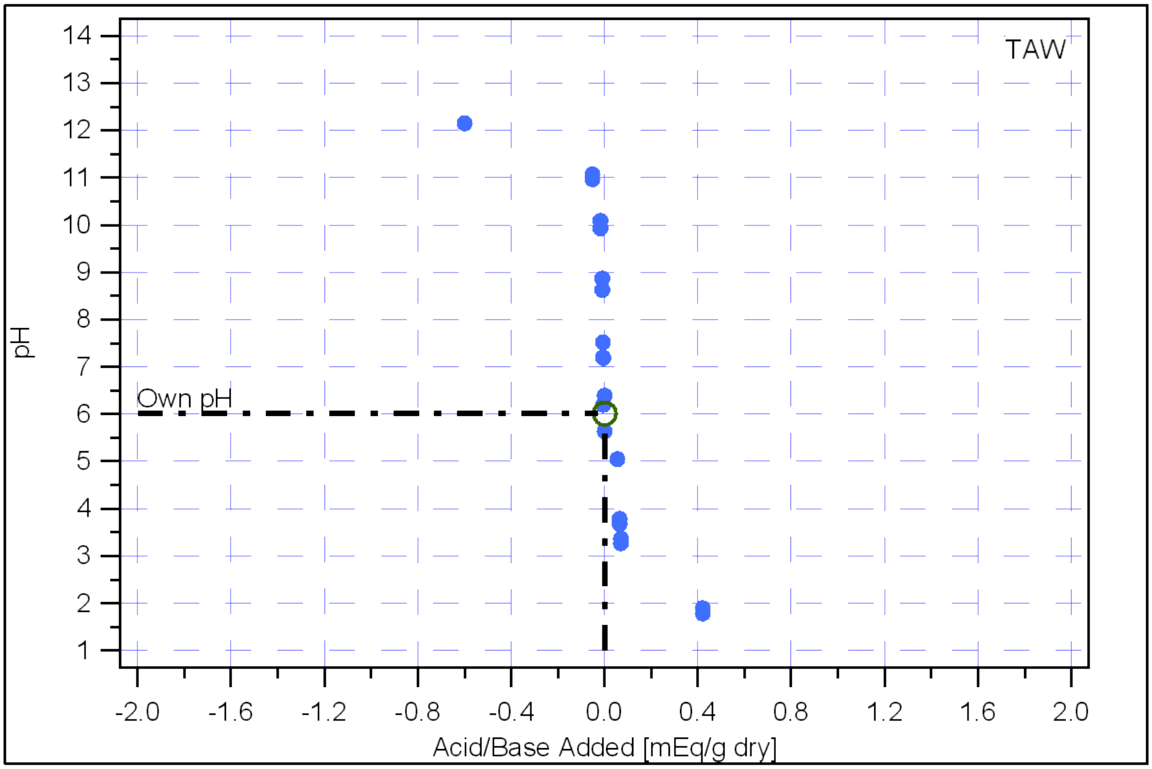


Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU – unwashed gypsum; **SAW** – washed gypsum.

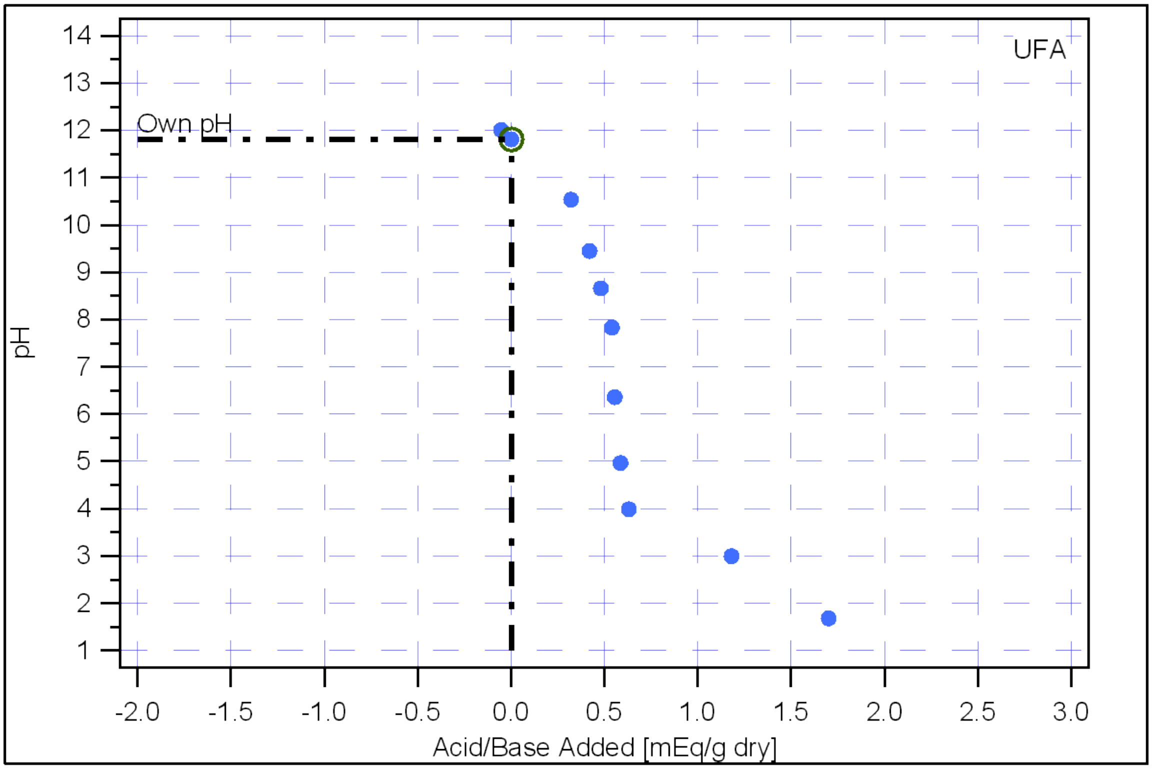


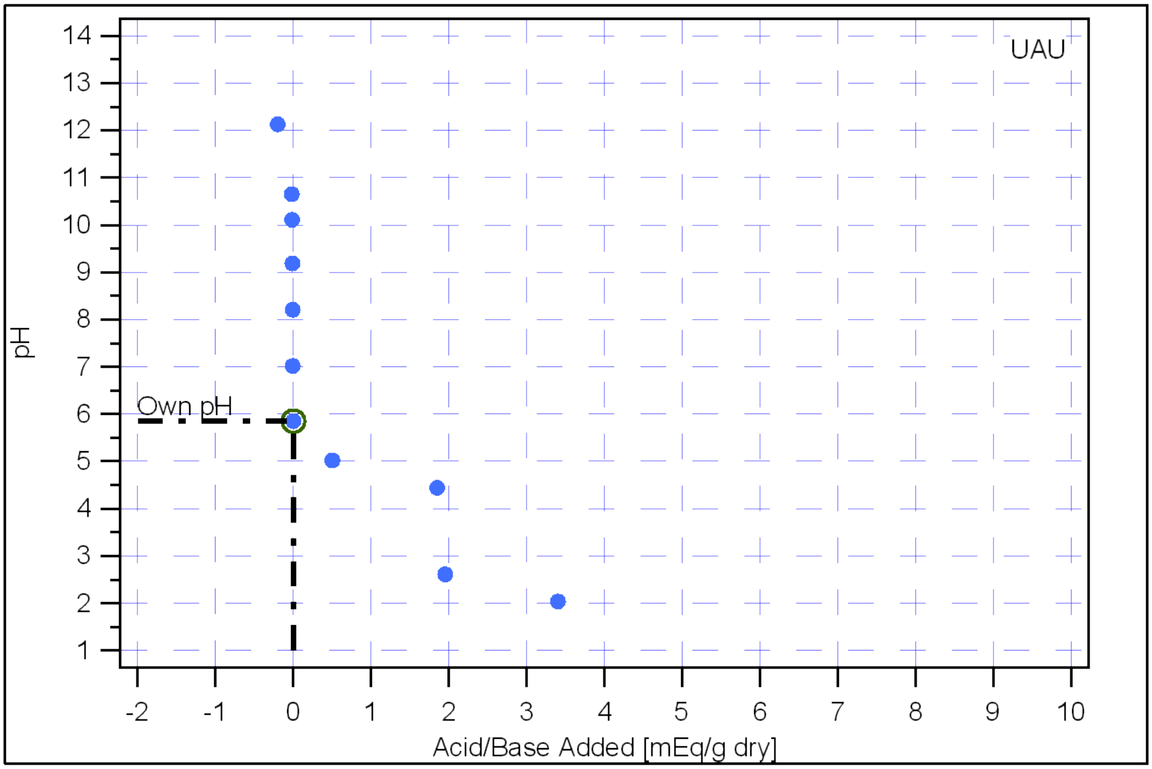
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA – fly ash.



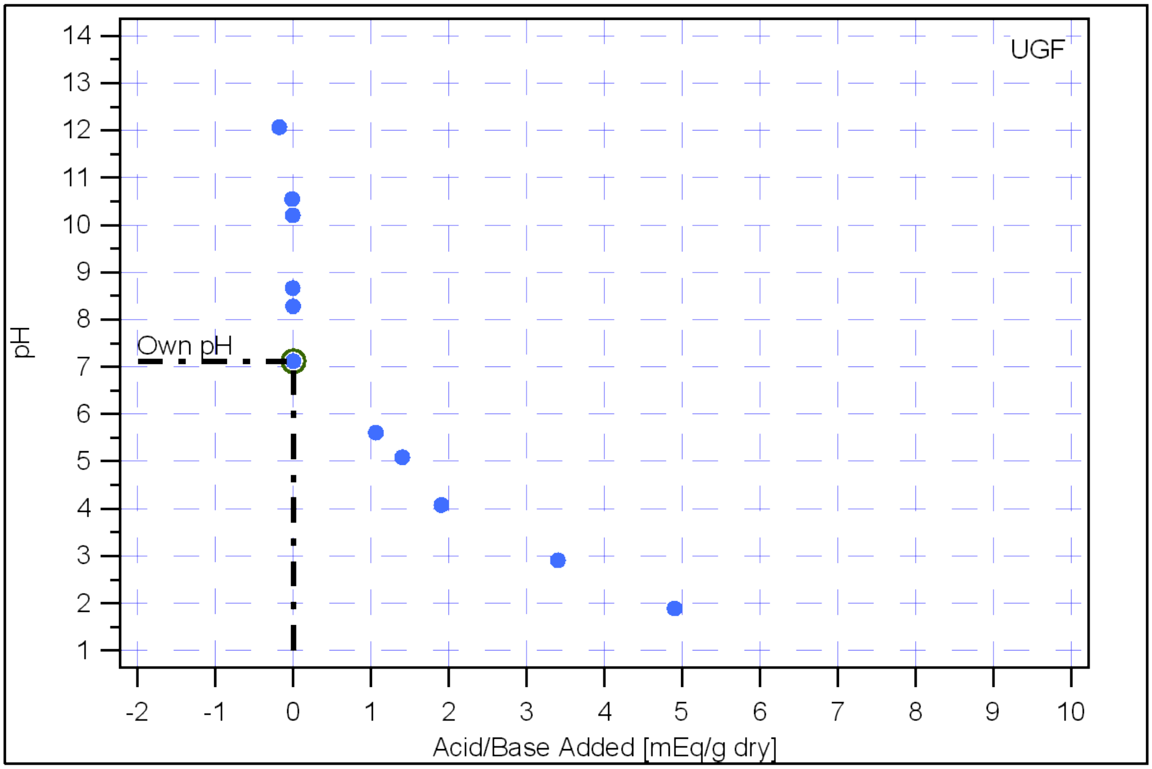


Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TAU – unwashed gypsum; **TAW** – washed gypsum.

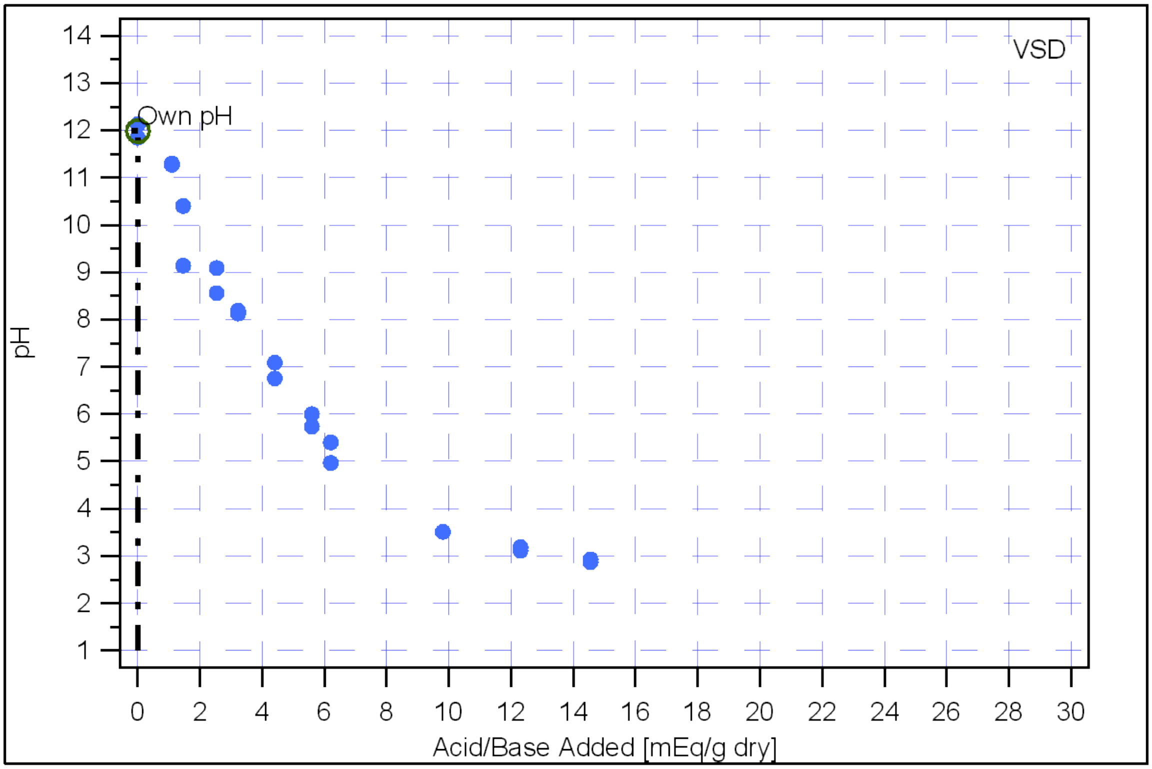




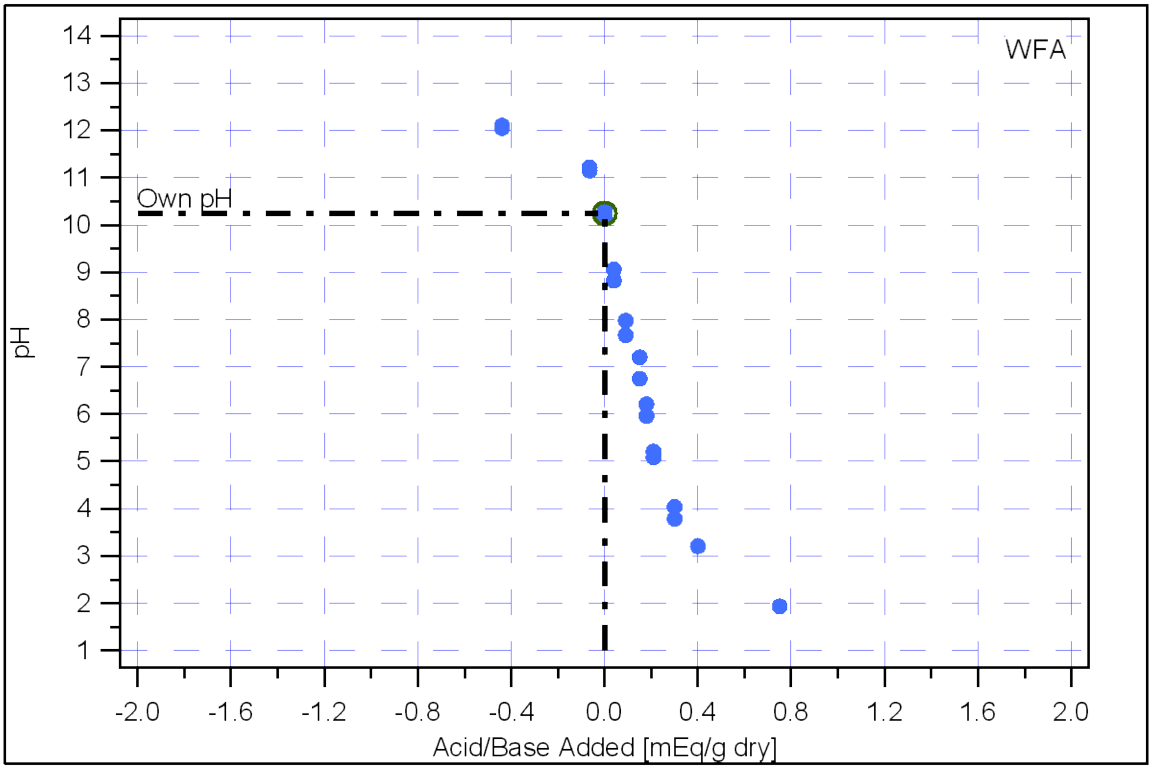
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **UFA** – fly ash; **UAU** – unwashed gypsum.



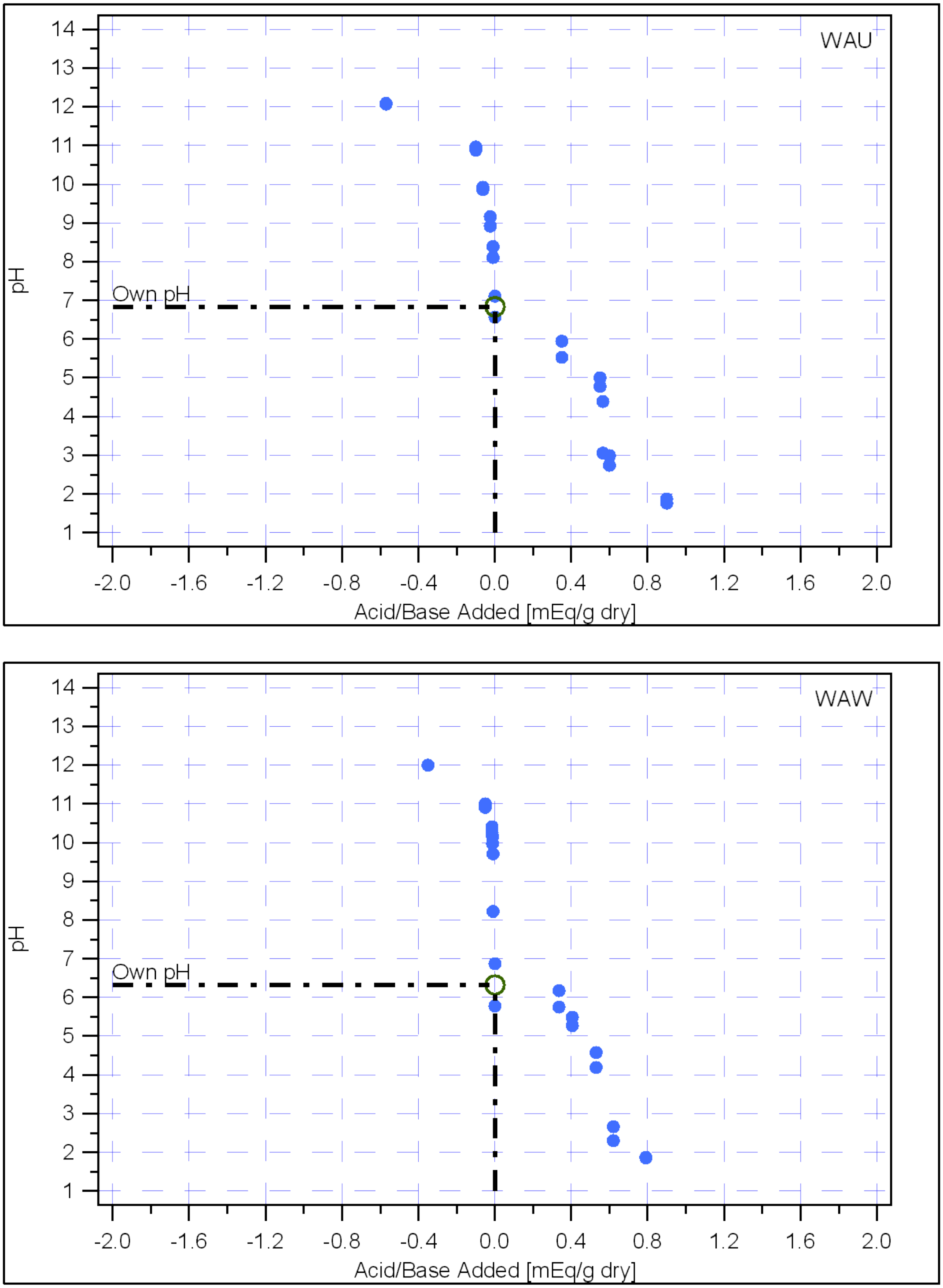
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **UGF** – gypsum/flyash.



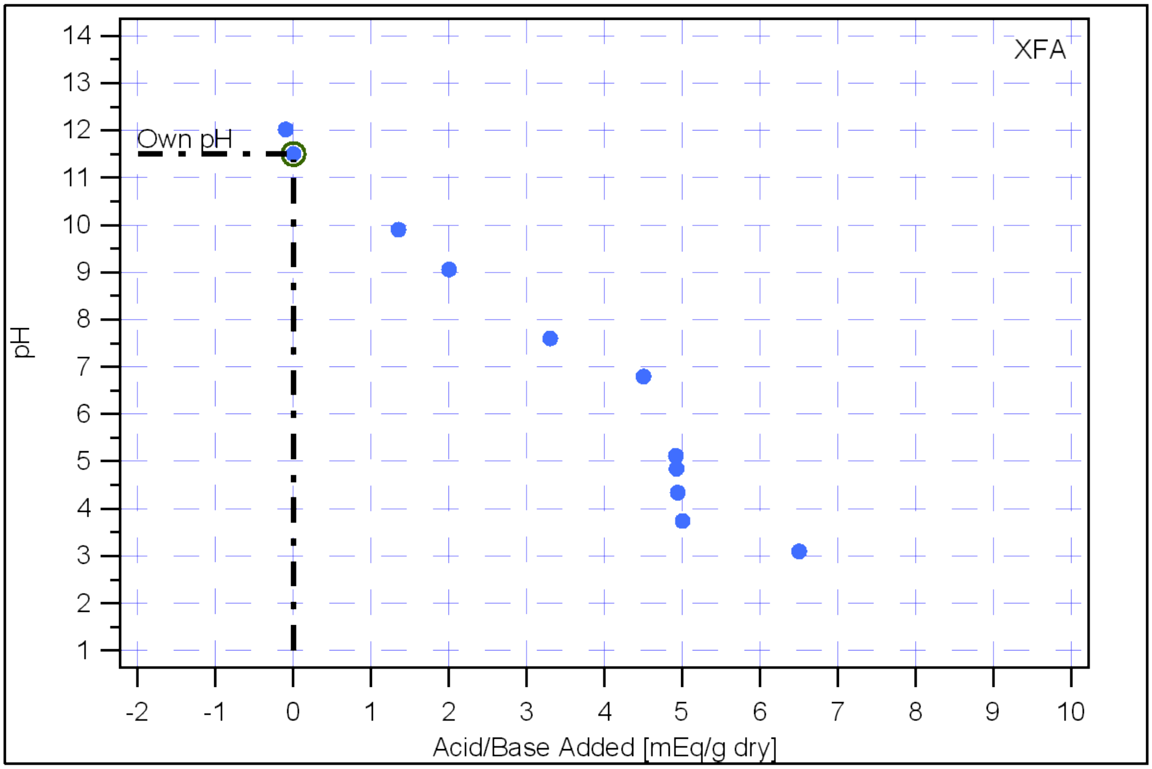
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** – spray dryer ash.



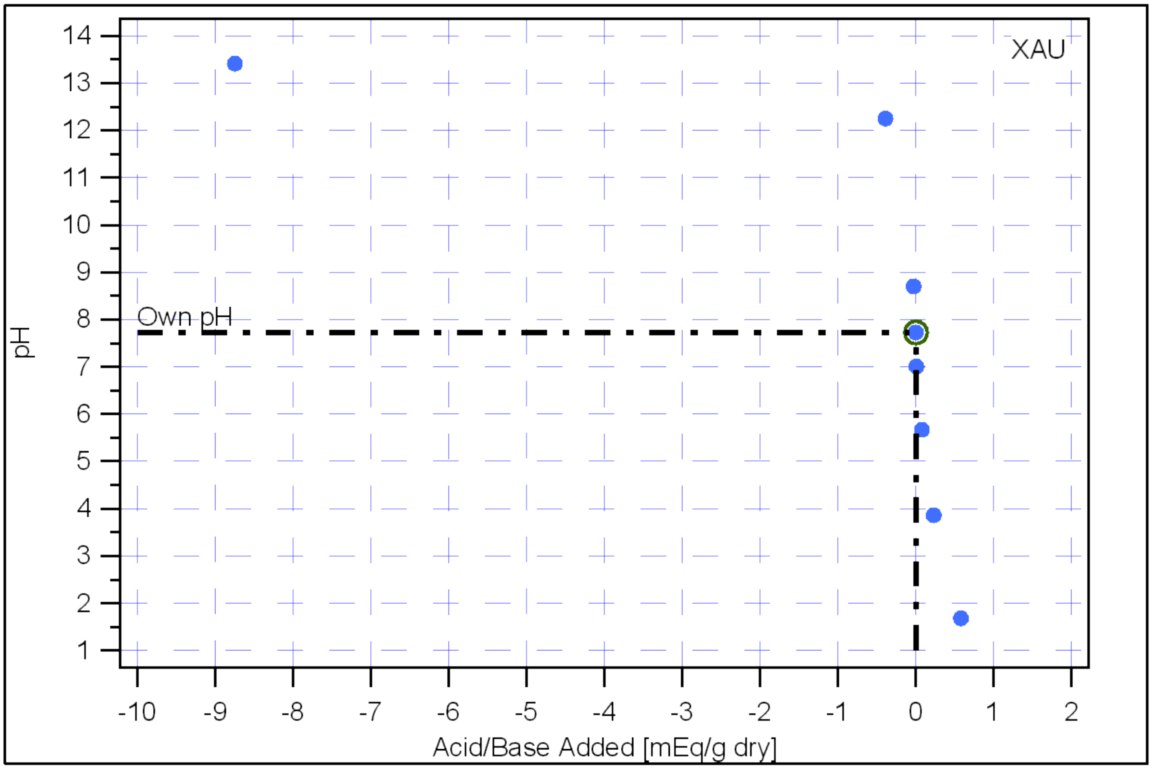
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** – fly ash.

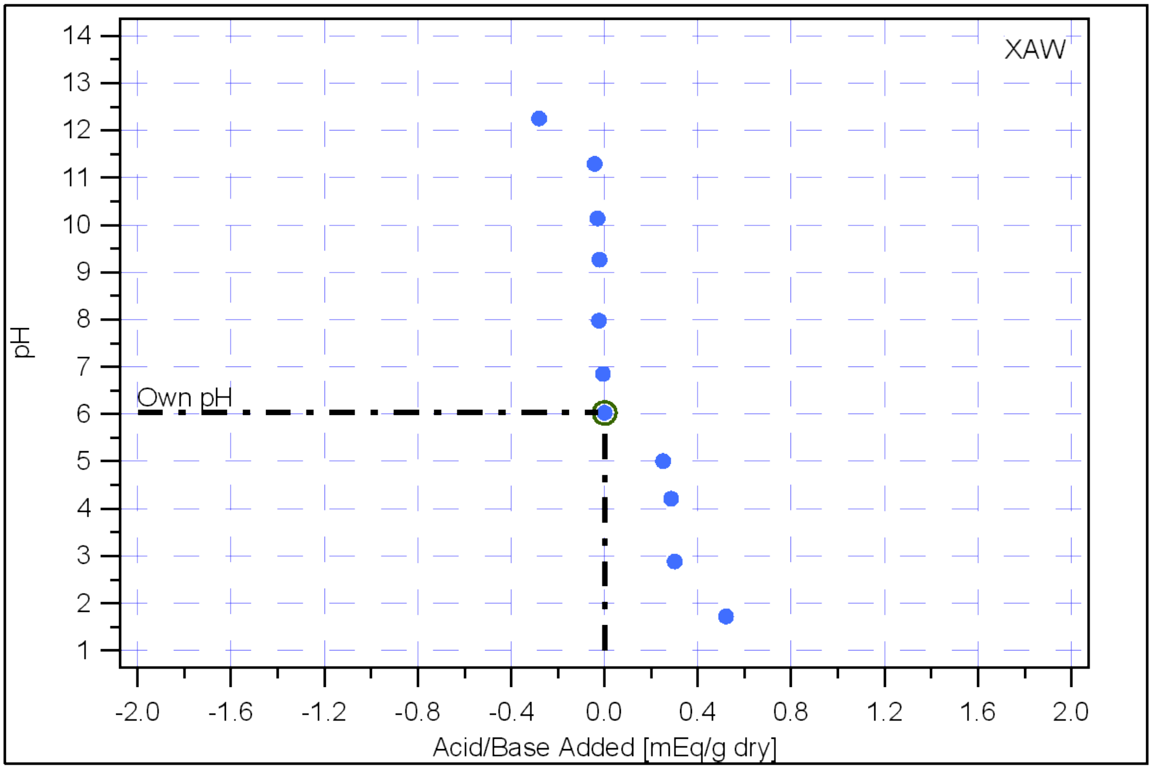


Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WAU** – unwashed gypsum; **WAW** – washed gypsum.

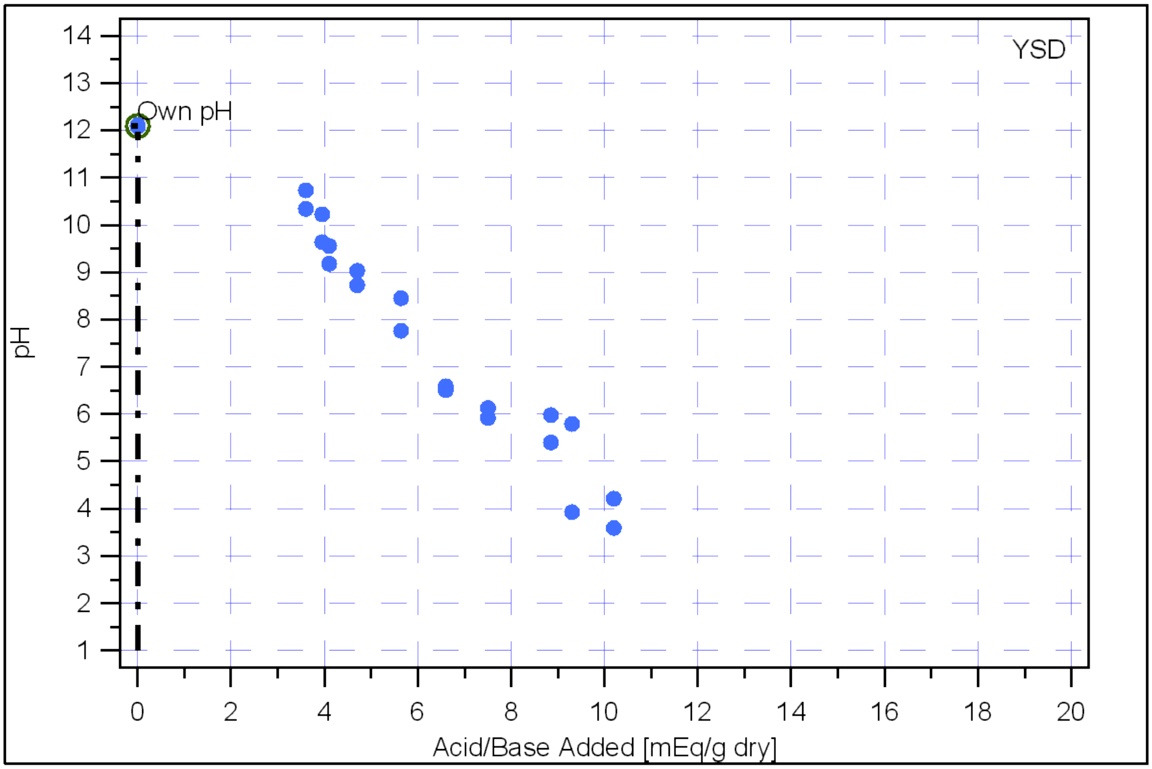


Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA – fly ash.

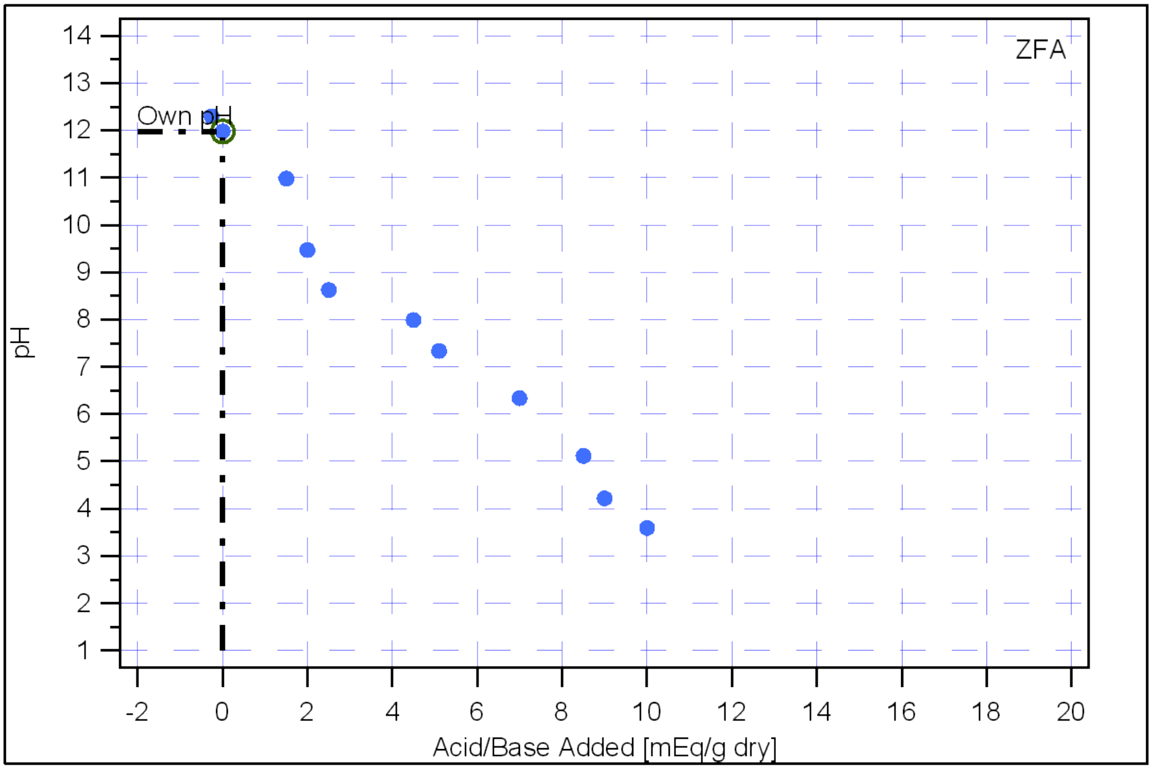




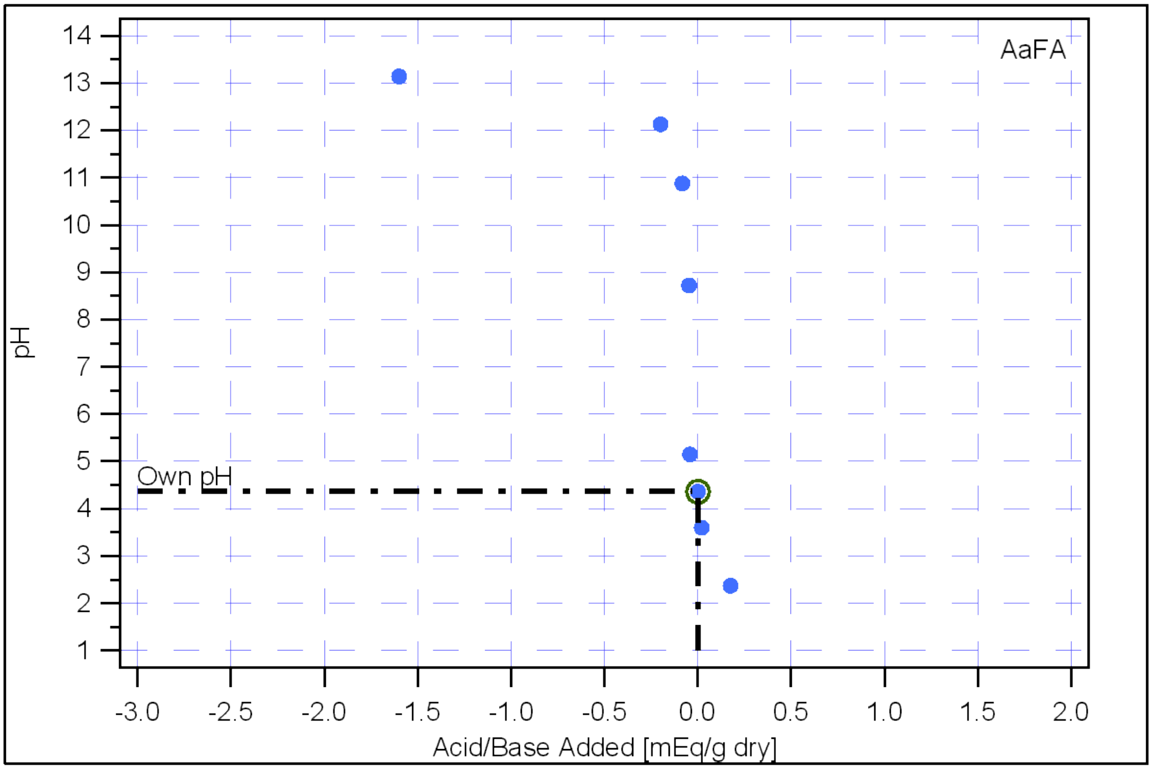
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XAU – unwashed gypsum; **XAW** – washed gypsum.

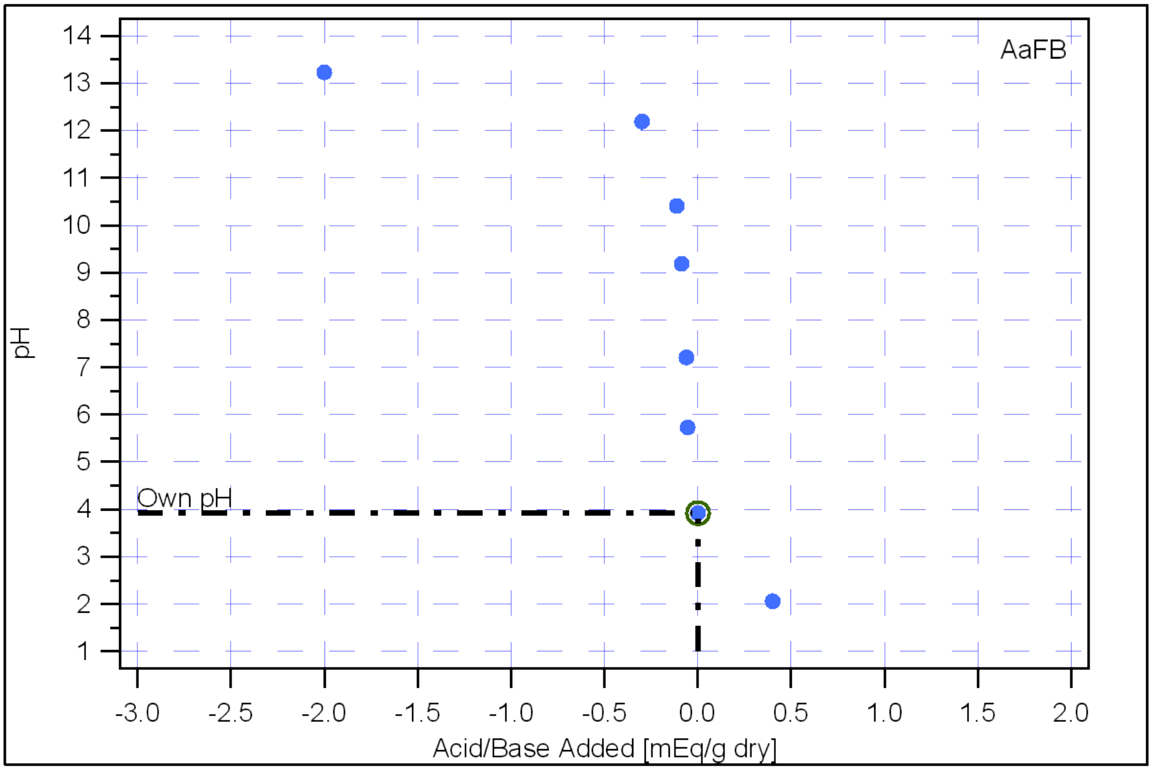


Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** – spray dryer ash.

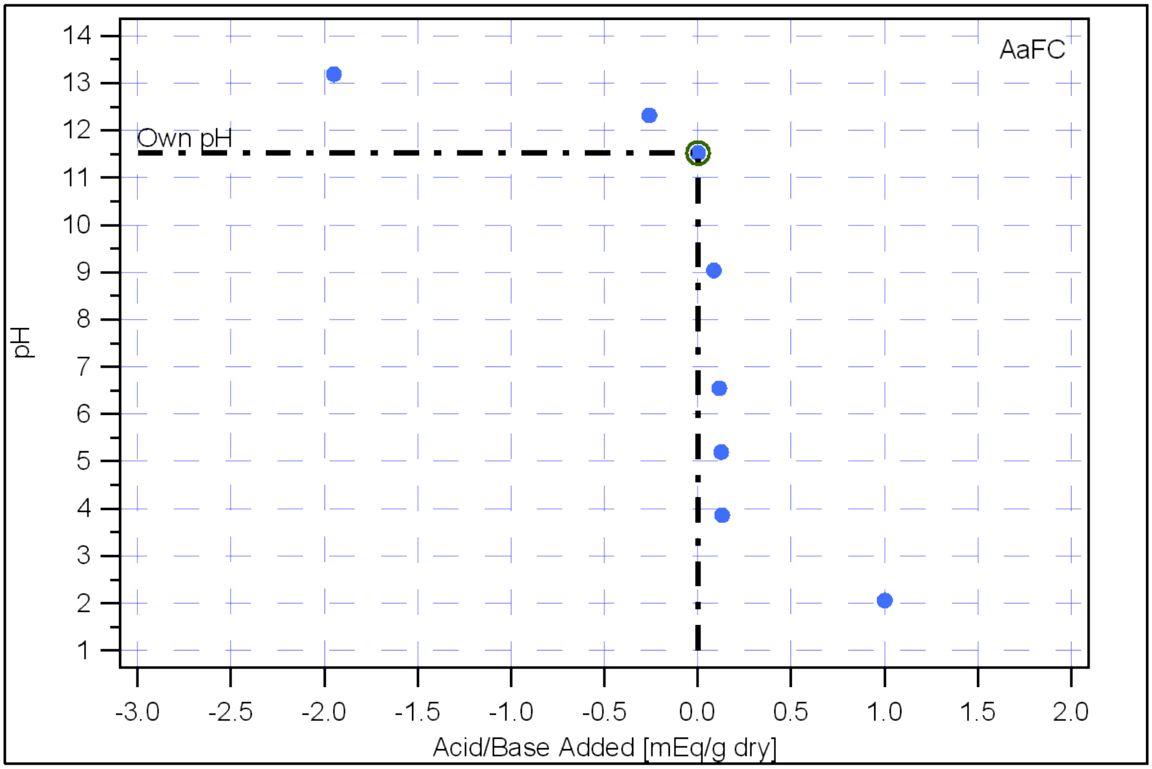


Facility Z (PRB, CS-ESP). **ZFA** – fly ash.

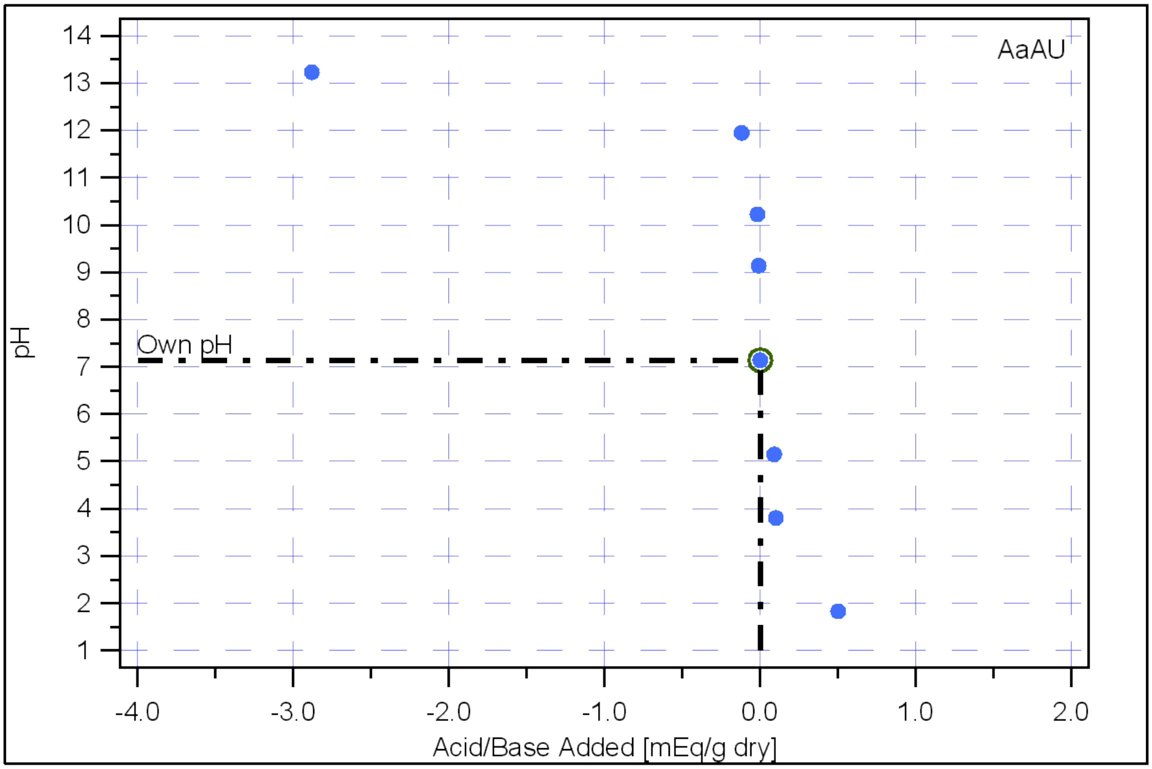


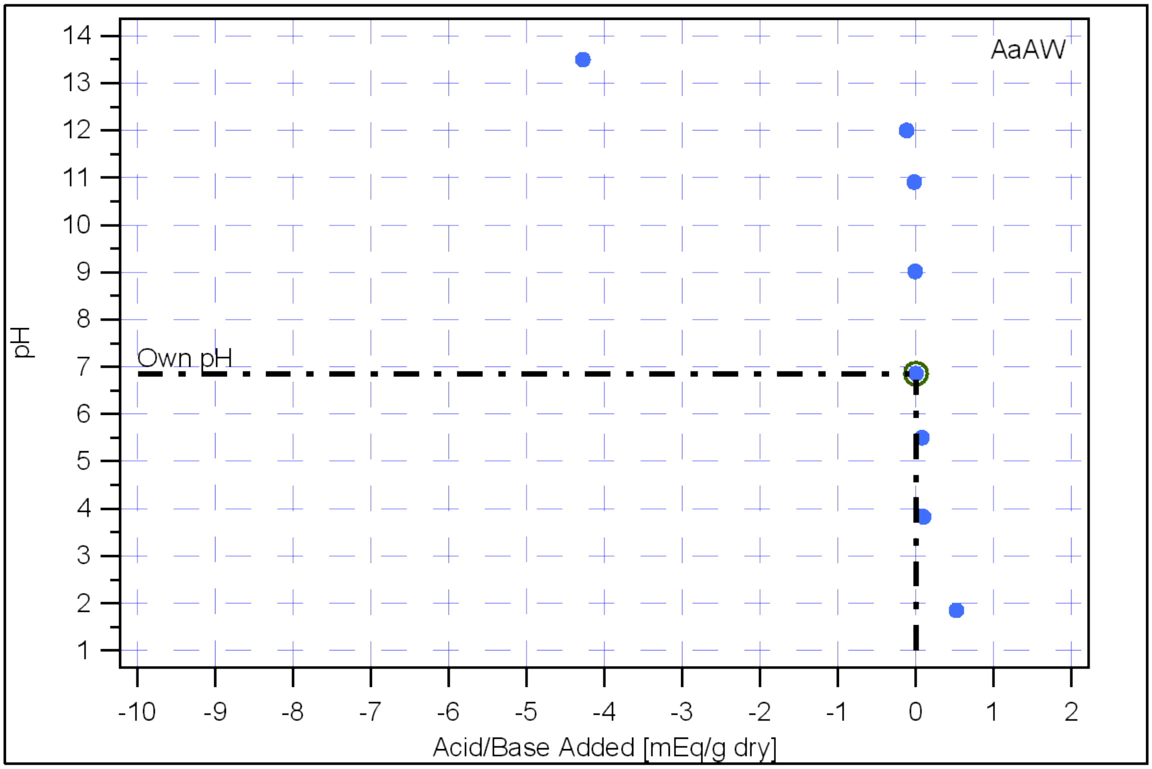


Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB – fly ash (CS-ESP).

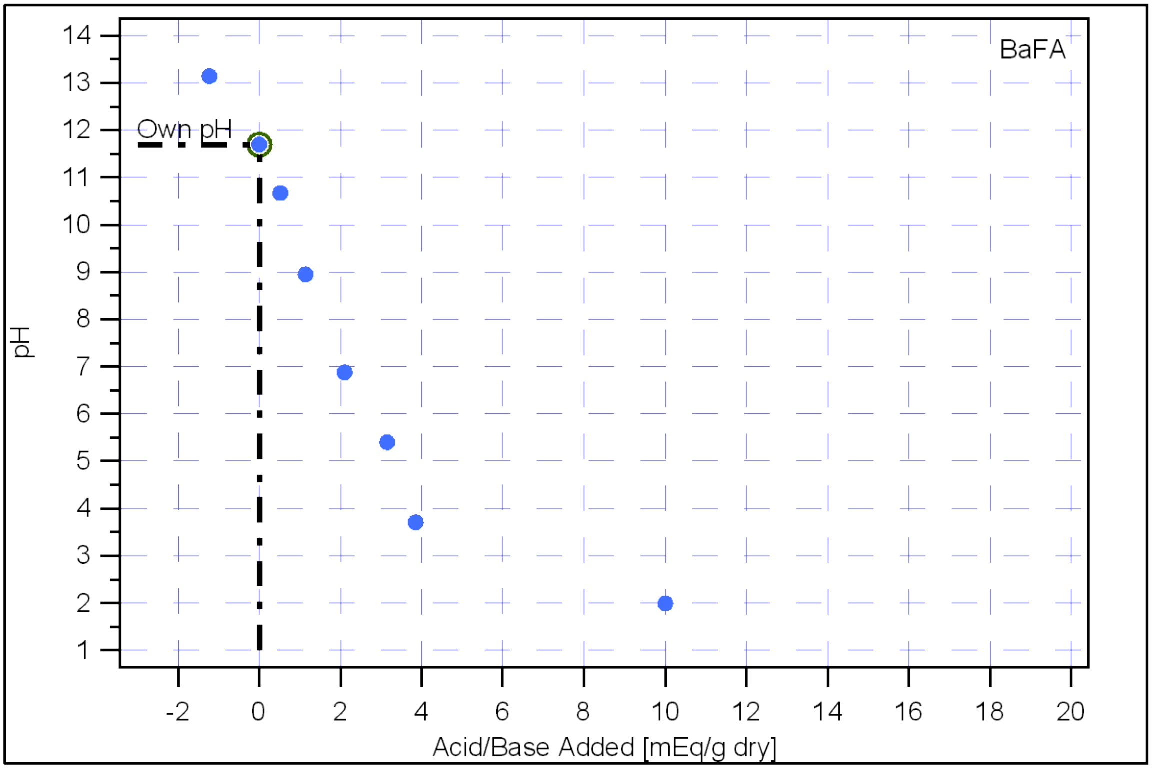


Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFC – fly ash (HS-ESP).

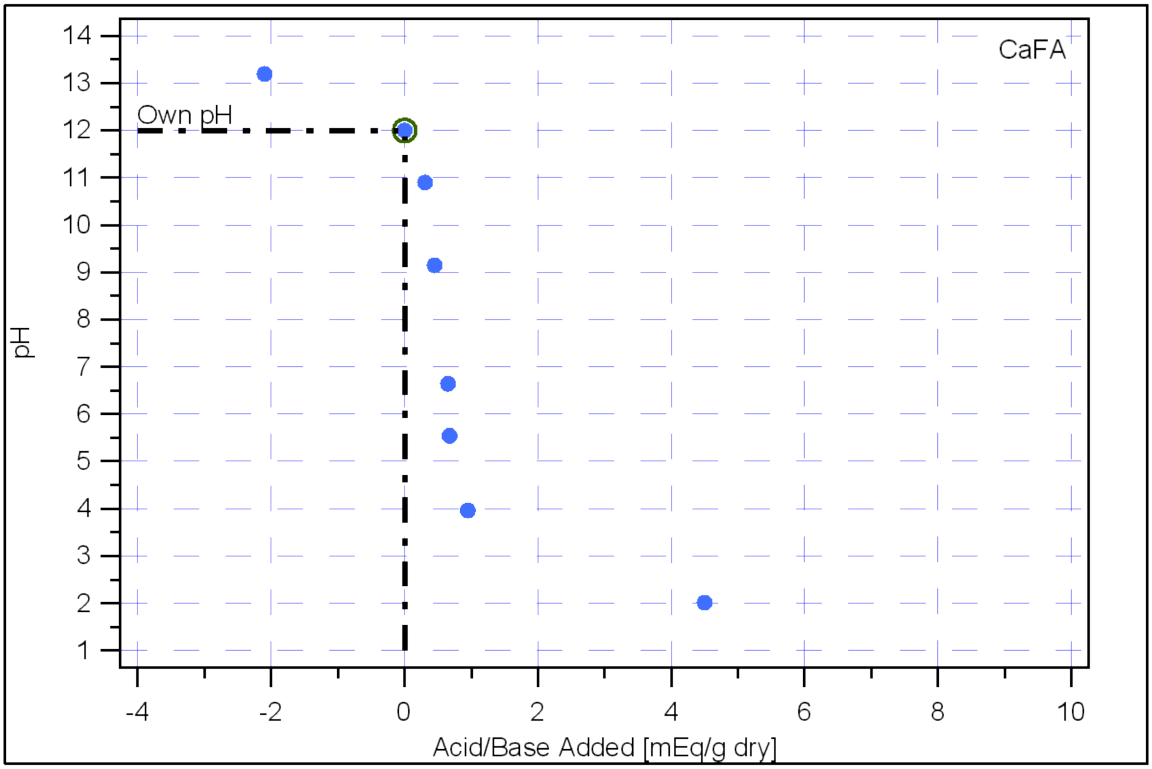


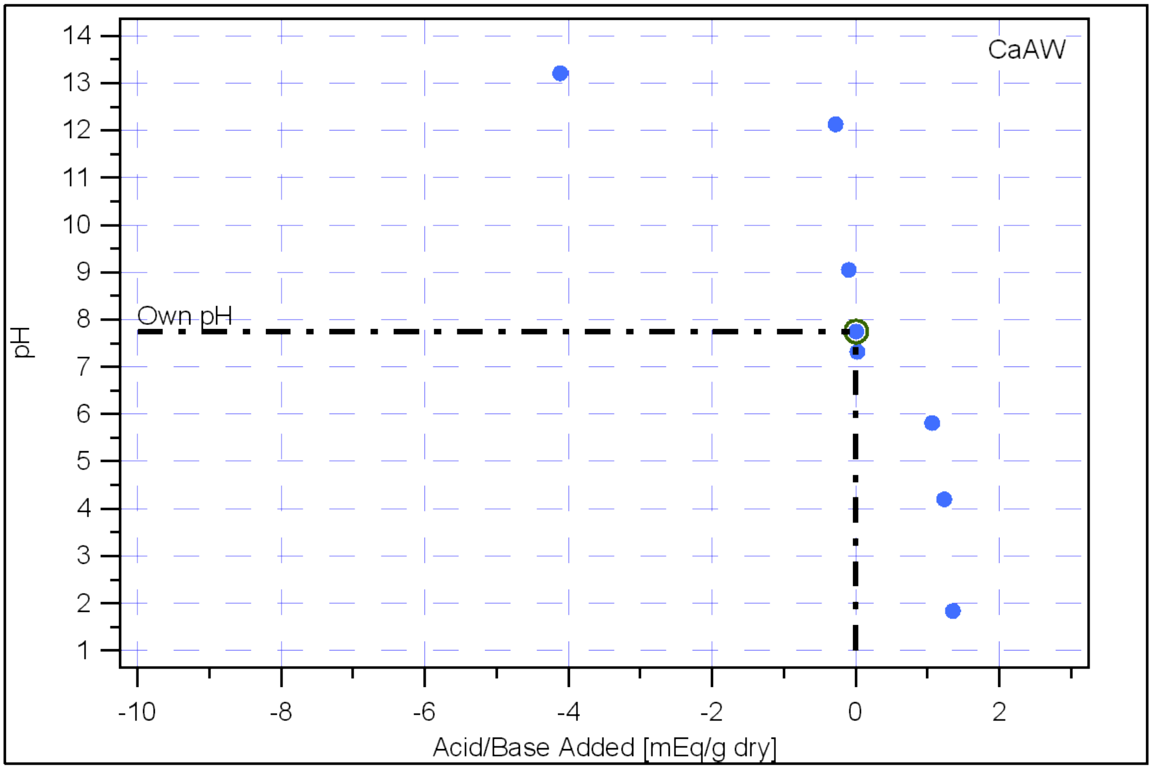


Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaAU – unwashed gypsum; **AaAW** – washed gypsum.

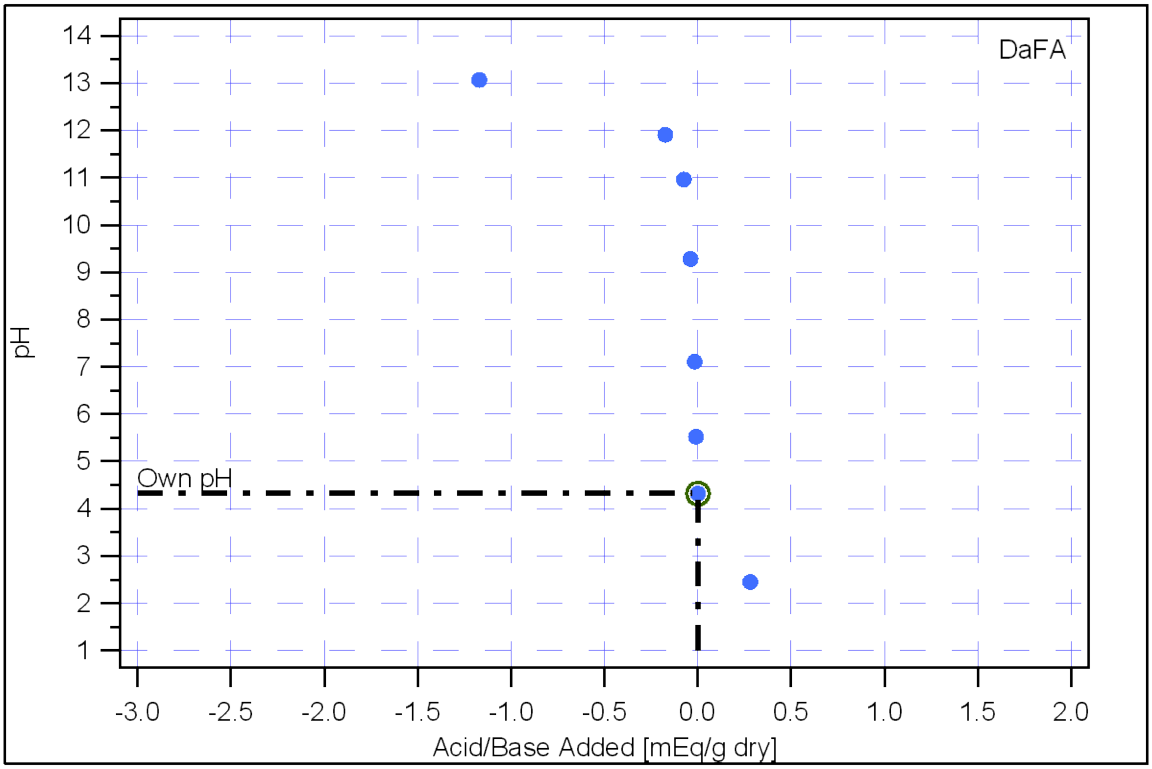


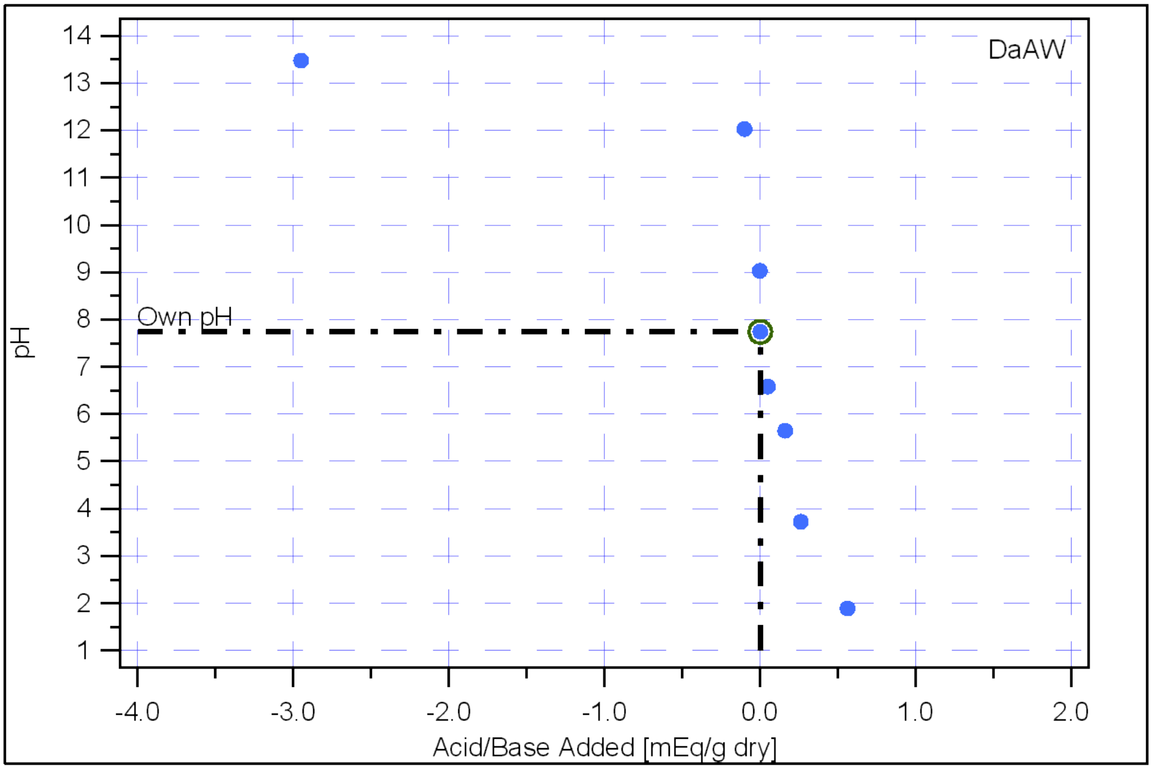
Facility Ba (PRB-Lignite Blend., CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** – fly ash.





Facility Ca (Gulf Coast Lignite., CS-ESP, Limestone, Forced Oxidation).
CaFA – fly ash; **CaAW** – washed gypsum.





Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA – fly ash; **DaAW** – washed gypsum.

Appendix H

Hexavalent Chromium and Total Chromium Analyses by Arcadis and ERG

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
						%		mg/L	mg/L	%		mg/L	mg/L	%

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	2.3	7.67	575	565	98	9.09	363	355	98
							7.67	349	381	109	9.14	397	399	101
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	5.4	7.11	605	614	101	8.22	377	328	87
							7.47	521	522	100	8.46	377	362	96
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	1.7	7.13	83.2	72.9	88	8.37	60.5	48.1	79
							7.26	80.6	79.5	99	8.42	60 3	52.6	87
Facility U	UFA	CS ESP	SCR	None	None	7.6	NA	NA	NA	NA	NA	NA	NA	NA
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	2.3	7.29	621	606	98	8.44	529	579	109
							7.42	542	535	99	8.80	512	499	97

Bituminous, Med S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
Facility T	TFA	CS ESP	None	None	None	8.4	NA	NA	NA	NA	NA	NA	NA	NA
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	4.2	NA	NA	NA	NA	NA	NA	NA	NA
Facility K	KFA	CS ESP	None	None	None	3.0	7.59	2.33	2.89	124	9.20	30 2	19.6	65
							7.67	2.34	3.11	133	9.27	34 9	23.1	66
Facility Aa	AaFA	CS ESP	SCR	None	None	1.2	NA	NA	NA	NA	NA	NA	NA	NA
Facility Aa	AaFB	CS ESP	SCR	None	None	1.8	NA	NA	NA	NA	NA	NA	NA	NA
Facility Da	DaFA	CS ESP	SCR	None	None	1.8	NA	NA	NA	NA	NA	NA	NA	NA
Facility Aa	AaFC	HS ESP	SCR	None	None	2.2	NA	NA	NA	NA	NA	NA	NA	NA

Fly Ash without Hg Sorbent Injection

Sub-Bituminous & Sub-bit/bituminous mix

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
St. Clair	JAB	CS ESP	None	None	None	19.7	7.03	1041	1140	109	9.93	1031	1100	107
							7.17	918	945	103	10.16	978	1100	112

Lignite

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	16.5	NA	NA	NA	NA	NA	NA	NA	NA

NA - not analyzed

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO$_3$ Control	pH	Eluate Total Cr	Eluate Cr (VI) Conc.	Eluate Cr (VI)
							mg/L	mg/L	%

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

Facility B	*DFA*	*CS ESP*	*SCR-BP*	*None*	*None*	10.06	304	305	100
						10.06	359	361	101
Facility A	*CFA*	*Fabric F.*	*SNCR-BP*	*None*	*None*	10.59	356	367	103
						10.74	266	269	101
Facility B	*BFA*	*CS ESP*	*SCR*	*None*	*None*	10.32	61.2	53.2	87
						10.39	60.5	54.0	89
Facility U	UFA	CS ESP	SCR	None	None	NA	NA	NA	NA
Facility A	*AFA*	*Fabric F.*	*SNCR*	*None*	*None*	10.42	460	463	101
						10.54	496	490	99

Bituminous, Med S

Facility T	TFA	CS ESP	None	None	None	NA	NA	NA	NA
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	NA	NA	NA	NA
Facility K	KFA	CS ESP	None	None	None	10.02	27.3	30.1	110
						10.64	35.2	40.6	115
Facility Aa	AaFA	CS ESP	SCR	None	None	NA	NA	NA	NA
Facility Aa	AaFB	CS ESP	SCR	None	None	NA	NA	NA	NA
Facility Da	DaFA	CS ESP	SCR	None	None	NA	NA	NA	NA
Facility Aa	AaFC	HS ESP	SCR	None	None	NA	NA	NA	NA

Fly Ash without Hg Sorbent Injection

Sub-Bituminous & Sub-bit/bituminous mix

St. Clair	JAB	CS ESP	None	None	None	12.10	1072	1080	101
						12.35	1062	1130	106

Lignite

Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	NA	NA	NA	NA

NA - not analyzed

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Solid Phase Cr (VI)	pH	Total Cr	Cr (VI) Conc.	Cr (VI)	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
						%		mg/L	mg/L	%		mg/L	mg/L	%
Fly Ash without and with Hg Sorbent Injection Pairs														
Sub-bituminous (Class C)														
St. Clair	JAB	CS ESP	None	None	None	19.7	7.03	1041	1140	109	9.93	1031	1100	107
							7.17	918	945	103	10.16	978	1100	112
Lignite (Class C)														
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	27.0	NA	NA	NA	NA	NA	NA	NA	NA
Spray dryer with Fabric Filter (fly ash and FGD collected together)														
Sub-bituminous														
Facility V	VSD	Fabric F.	SCR	None	None	17.4	NA	NA	NA	NA	NA	NA	NA	NA
Filter Cake														
Bituminous, Med S														
Facility T	TFC	CS ESP	None	None	None	0.7	NA	NA	NA	NA	NA	NA	NA	NA

NA - not analyzed

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
							mg/L	mg/L	%

Fly Ash without and with Hg Sorbent Injection Pairs

Sub-bituminous (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
St. Clair	JAB	CS ESP	None	None	None	12.10	1072	1080	101
						12.35	1062	1130	106

Lignite (Class C)

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	NA	NA	NA	NA

Spray dryer with Fabric Filter (fly ash and FGD collected toge

Sub-bituminous

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
Facility V	VSD	Fabric F.	SCR	None	None	NA	NA	NA	NA

Filter Cake

Bituminous, Med S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	pH	Total Cr	Cr (VI) Conc.	Cr (VI)
Facility T	TFC	CS ESP	None	None	None	NA	NA	NA	NA

NA - not analyzed

Appendix I

Summary of Statistics (Min/Max/Own pH Values)

Facility	Al						As					
	Al_max_Val	Al_min_Val	Al_ownpHVal	Al_pH_at_Max	Al_pH_at_Min	Al_ownph	As_max_Val	As_min_Val	As_ownpHVal	As_pH_at_Max	As_pH_at_Min	As_ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	6400 00	3810.00	4110.00	12.18	12.14	12.24	35 30	5.40	6.67	9.19	12.14	12.24
Facility F (FFA)	29484 90	25.00	29673.35	9 20	6.70	4.25	2007.10	22.97	53.70	11 60	6.70	4.25
Facility B (DFA)	3583 35	157.97	825.69	12 33	6.46	10.26	261 55	33.79	46.83	7 95	11.35	10.26
Facility A (CFA)	7794 04	35.71	1804.46	12 20	7.07	10.28	111 38	9.31	14.06	9 00	11.21	10.28
Facility B (BFA)	1970 00	826.00	1245.00	9.45	12.02	10.06	99.40	23.20	28.95	8 24	11.76	10.06
Facility U (UFA)	7751.76	10.00	21.45	10 54	12.32	11.81	773 63	21.04	40.97	6 36	12.19	11.81
Salem Harbor (SHB)	2104 92	331.03	1996.89	11.76	8.59	11.68	105 00	18.00	19.30	8 59	11.76	11.68
Facility G (GFA)	25156.10	33.47	10673.80	11 50	6.20	4.35	1862 05	20.77	34.41	11 50	6.20	4.35
Facility A (AFA)	24600 00	1310.00	13426.67	12 35	8.00	10.52	173 00	7.20	39.83	5 69	8.09	10.52
Facility L (LAB)	20919 24	30.15	1087.32	12.10	6.40	5.75	1686 99	23.49	25.95	12.10	6.30	5.75
Facility C (GAB)	34209 60	58.09	13419.61	11 20	6.60	11.27	1113.43	123.96	237.37	8 30	11.60	11.27
Facility T (TFA)	25605.70	113.17	7085.60	10.46	5.71	8.88	1720 59	288.05	500.57	12.11	6.71	8.88
Facility E (EFB)	91369 20	32.02	29776.20	12 00	5.70	4.30	1283 89	12.04	56.28	12 00	6.30	4.30
Facility W (WFA)	49019.40	186.79	10015.98	10 33	7.67	10.25	18197 07	117.01	3236.78	10 33	6.21	10.25
Facility E (EFA)	27515.10	42.45	572.40	12.10	6.40	4.80	761 57	5.48	16.28	12.10	6.50	4.80
Facility K (KFA)	31246 00	44.42	17159.46	11 87	6.10	9.15	130.14	22.02	68.42	6 95	9.27	9.15
Facility Aa (AaFA)	23751.70	6517.90	12337.40	12.13	8.72	4.36	1152 51	373.74	167.75	12.13	8.72	4.36
Facility Aa (AaFB)	29740 20	12.51	29843.30	12.19	5.73	3.92	1187 89	97.21	757.91	12.19	5.73	3.92
Facility Da (DaFA)	20581 30	45.92	4795.10	11 91	7.11	4.32	1909 37	228.88	331.13	10 96	5.52	4.32
Facility Aa (AaFC)	15348 00	53.52	15348.00	11 52	6.55	11.52	425 23	29.95	254.56	12 32	11.47	11.52
Facility E (EFC)	76844.40	7.03	769.59	11 99	6.33	4.80	747.46	1.14	9.52	12 07	6.33	4.80
Facility H (HFA)	54623 00	164.46	2339.03	11 60	7.30	8.55	76 58	32.22	36.47	11 60	9.30	8.55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	97500 00	98.46	26700.00	12.10	5.71	11.22	12 80	3.26	4.00	12 02	10.51	11.22
Facility J (JAB)	514917 86	702.07	102345.42	12 20	6.40	12.10	58 06	0.32	0.92	12 20	9.60	12.10
Facility Z (ZFA)	41067.40	189.46	10105.60	10 98	6.34	11.98	0 32	0.32	0.32	7 34	7.34	11.98
Facility X (XFA)	28448.10	1847.26	28448.10	11 50	6.80	11.50	1.10	0.32	0.32	9 90	12.02	11.50
Facility Ca (CaFA)	3012 93	10.00	3012.93	12 00	12.06	12.00	101.48	15.79	33.68	9.15	12.06	12.00

Facility	B						Ba					
	B max Val	B min Val	B ownpHVal	B pH at Max	B pH at Min	B ownph	Ba max Val	Ba min Val	Ba ownpHVal	Ba pH at Max	Ba pH at Min	Ba ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	30871.40	2430.60	2267.98	12.39	12.18	12 88	1830.00	301.00	1810.00	12.14	8.02	12 24
Facility F (FFA)	2705 59	2206.58	2910.91	9.20	8.40	4 25	322.77	97.47	115.67	9.20	5.50	4 25
Facility B (DFA)	25805 59	757.79	3551.28	6.89	12.33	10 26	276.80	129.78	192.38	10.88	8.42	10 26
Facility A (CFA)	11814 88	412.26	1480.31	7.07	7.72	10 28	2950.67	194.14	625.42	7.88	10.22	10 28
Facility B (BFA)	57359 05	2486.02	7216.20	9.29	11.91	10 06	205.00	87.20	143.00	11.91	9.57	10 06
Facility U (UFA)	39415.70	1466.22	10835.70	6.36	12.32	11 81	1176.38	331.45	881.70	10.54	12.32	11 81
Salem Harbor (SHB)	20534.10	1484.62	4886.93	9.45	11.67	11 64	1000.00	138.00	778.00	11.99	7.74	11 68
Facility G (GFA)	2178.18	1539.05	1987.25	11.00	8.60	4 35	297.36	75.36	95.36	9.80	6.20	4 35
Facility A (AFA)	11267.41	209.68	320.43	5.69	12.24	10 52	3720.00	218.00	349.00	7.69	7.52	10 52
Facility L (LAB)	2586.70	480.50	590.78	6.50	7.60	5.75	219.28	63.59	125.13	8.20	6.50	5.75
Facility C (GAB)	12929.40	1148.41	5449.60	7.30	11.60	11 27	1007.89	59.60	569.83	11.70	7.80	11 27
Facility T (TFA)	47149 20	7469.63	8229.03	9.00	9.70	8 88	818.44	189.20	373.88	10.46	5.71	8 88
Facility E (EFB)	3397 55	1998.64	2565.79	12.00	6.30	4 30	177.43	84.71	92.91	10.50	6.30	4 30
Facility W (WFA)	34753 90	2777.40	3139.63	10.33	12.10	10 25	231.52	59.82	69.00	7.67	10.31	10 25
Facility E (EFA)	2894 30	2157.44	2644.94	12.10	8.50	4 80	377.10	79.26	80.61	12.10	6.40	4 80
Facility K (KFA)	272943.76	28095.68	32484.17	9.27	11.96	9.15	442.29	81.14	170.90	9.27	6.95	9.15
Facility Aa (AaFA)	2134 05	2099.99	2336.11	12.13	10.88	4 36	610.93	388.83	220.54	12.13	8.72	4 36
Facility Aa (AaFB)	2374 35	2214.50	2729.65	5.73	9.19	3 92	652.94	177.28	220.66	9.19	5.73	3 92
Facility Da (DaFA)	1554.14	1416.36	1529.28	5.52	10.96	4 32	1229.51	314.48	349.89	11.91	5.52	4 32
Facility Aa (AaFC)	12137 80	5341.71	7386.50	11.31	12.32	11 52	2121.59	314.20	1700.87	11.39	6.55	11 52
Facility E (EFC)	5995 09	2994.29	4298.65	11.99	9.90	4 80	518.96	50.64	77.63	11.99	9.59	4 80
Facility H (HFA)	173444 00	14348.10	20722.25	8.90	11.60	8 55	223.03	49.84	80.71	11.60	7.30	8 55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	29226 20	3846.36	9495.67	8.36	12.10	11 32	101000.00	1030.00	22933.33	12.09	5.56	11 22
Facility J (JAB)	17608 90	235.65	295.95	9.20	12.10	12.10	4801.77	246.26	853.55	11.70	9.60	12.10
Facility Z (ZFA)	8602 85	524.54	3360.89	9.47	10.98	11 98	671282.99	6961.94	219461.96	12.37	6.34	11 98
Facility X (XFA)	11142.70	761.61	761.61	9.06	11.50	11 50	160764.25	6498.60	32923.08	12.02	6.80	11 50
Facility Ca (CaFA)	65990 90	17626.20	17626.20	12.06	12.00	12 00	4946.58	690.49	2732.22	12.06	9.15	12 00

Facility	Cd						Co					
	Cd max Val	Cd min Val	Cd ownpHVal	Cd pH at Max	Cd pH at Min	Cd ownph	Co max Val	Co min Val	Co ownpHVal	Co pH at Max	Co pH at Min	Co ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	70 60	22.70	24.07	12.37	12.14	12.24	223 00	0.50	0.86	9.19	12.06	12.24
Facility F (FFA)	4 68	1.01	10.19	5.90	9.20	4.25	61 68	0.21	96.86	5.90	8.20	4.25
Facility B (DFA)	15 06	0.66	0.79	5.43	11.34	10.26	32 35	0.21	0.21	5.43	9.84	10.26
Facility A (CFA)	11 05	0.09	0.29	5.84	8.45	10.28	145 07	0.21	0.21	5.84	10.17	10.28
Facility B (BFA)	22 20	0.96	1.03	9.45	11.43	10.06	17.10	0.94	5.51	9.37	11.30	10.06
Facility U (UFA)	149 32	18.30	23.48	12.32	9.45	11.81	19 93	0.21	2.89	6.36	12.19	11.81
Salem Harbor (SHB)	36 50	2.37	3.85	12.03	11.53	11.68	42 20	0.21	0.21	7.01	8.15	11.68
Facility G (GFA)	3.49	1.26	5.34	5.70	7.60	4.35	52 03	0.21	65.43	5.70	11.80	4.35
Facility A (AFA)	23.10	0.09	0.73	5.69	11.76	10.52	157 00	1.38	7.72	5.69	12.24	10.52
Facility L (LAB)	1 86	0.33	0.46	6.50	7.60	5.75	30 80	0.21	6.25	6.50	7.60	5.75
Facility C (GAB)	34 89	0.09	0.09	11.20	6.60	11.27	78.16	0.21	0.21	5.60	9.30	11.27
Facility T (TFA)	37.71	4.67	4.97	9.00	10.04	8.88	11 09	0.21	0.98	5.71	10.46	8.88
Facility E (EFB)	2 39	0.38	10.42	5.70	6.30	4.30	37 23	0.21	108.20	5.70	10.50	4.30
Facility W (WFA)	22 25	1.83	2.24	6.21	9.06	10.25	83 30	0.21	0.21	6.21	10.33	10.25
Facility E (EFA)	0 84	0.40	4.54	6.40	8.50	4.80	106 06	0.21	186.30	6.50	12.10	5.40
Facility K (KFA)	27.77	0.09	0.09	9.27	11.96	9.15	2 34	0.21	0.21	9.21	9.80	9.15
Facility Aa (AaFA)	3 96	3.81	30.04	12.13	8.72	4.36	0 21	0.21	189.39	12.13	12.13	4.36
Facility Aa (AaFB)	9 56	5.92	49.14	5.73	10.41	3.92	75 99	0.21	248.74	5.73	12.19	3.92
Facility Da (DaFA)	27 81	3.72	38.55	5.52	9.28	4.32	100.17	0.21	109.99	5.52	11.91	4.32
Facility Aa (AaFC)	44 04	4.08	4.69	11.47	9.04	11.52	58 32	0.21	0.21	6.55	12.32	11.52
Facility E (EFC)	0 84	0.09	10.03	11.99	5.57	4.70	40 25	0.21	77.47	6.33	11.62	4.80
Facility H (HFA)	78.19	6.22	6.36	8.60	8.60	8.55	3.11	0.21	0.52	7.30	8.90	8.55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	17 00	0.09	0.15	5.56	12.02	11.22	503 00	0.21	0.66	5.56	12.02	11.22
Facility J (JAB)	3 59	0.46	0.58	12.20	11.60	12.10	74.78	0.21	0.21	5.50	11.80	12.10
Facility Z (ZFA)	0.70	0.09	0.09	6.34	8.63	11.98	375 29	0.21	0.21	6.34	12.37	11.98
Facility X (XFA)	2 67	0.09	0.09	9.90	12.02	11.50	23 56	0.21	0.21	6.80	12.02	11.50
Facility Ca (CaFA)	106 00	3.39	3.43	5.54	9.15	12.00	221.77	0.96	0.96	5.54	12.00	12.00

Facility	Cr						Hg					
	Cr_max_Val	Cr_min_Val	Cr_ownpHVal	Cr_pH_at_Max	Cr_pH_at_Min	Cr_ownph	Hg_max_Val	Hg_min_Val	Hg_ownpHVal	Hg_pH_at_Max	Hg_pH_at_Min	Hg_ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	42.70	2.56	27.38	9.19	12.39	12.24	0.12	0.00	0.04	11.71	12 06	12.24
Facility F (FFA)	96.45	4.32	27.59	11 60	5.90	4.25	0.19	0.02	0.08	9.50	8.40	4.25
Facility B (DFA)	1718 02	13.79	131.54	10.43	7.80	10.26	0.42	0.01	0.02	10.43	7 95	10.26
Facility A (CFA)	1358 51	119.56	186.77	8.17	11.21	10.28	0 07	0.01	0.04	10.78	7.72	10.28
Facility B (BFA)	3680 00	757.00	850.50	9.45	8.24	10.06	0 07	0.01	0.03	11.18	8 68	10.06
Facility U (UFA)	7369 95	117.36	1883.17	12 32	6.36	11.81	0 03	0.00	0.00	12.32	7 83	11.81
Salem Harbor (SHB)	527 00	0.25	451.67	11 91	7.01	11.68	0 08	0.01	0.04	8.27	8.15	11.68
Facility G (GFA)	96 32	3.31	8.77	11 80	6.20	4.35	0 06	0.01	0.02	11.00	8 50	4.35
Facility A (AFA)	1870 00	835.00	1104.67	10.73	5.44	10.52	0.49	0.03	0.12	8.04	12 35	10.52
Facility L (LAB)	18 96	0.25	1.29	12.10	5.70	5.75	0.12	0.00	0.01	6.70	10 30	5.75
Facility C (GAB)	86 57	0.25	0.25	11 20	7.30	11.27	0 05	0.00	0.02	9.90	8 80	11.27
Facility T (TFA)	258.75	22.22	62.10	9 00	5.71	8.88	0 00	0.00	0.00	6.71	6.71	8.88
Facility E (EFB)	55 21	6.58	18.82	12 00	5.70	4.30	0 04	0.00	0.01	9.90	10 50	4.30
Facility W (WFA)	2552.40	8.77	290.01	10 33	6.21	10.25	0 00	0.00	0.00	10.33	10 33	10.25
Facility E (EFA)	46.77	0.91	0.85	12.10	8.50	4.80	0 06	0.00	0.02	12.10	7.70	4.80
Facility K (KFA)	137.43	0.99	21.47	9 27	6.10	9.15	0.14	0.02	0.02	9.27	9 27	9.15
Facility Aa (AaFA)	108.77	44.07	33.91	12.13	8.72	4.36	0 01	0.00	0.01	12.13	10 88	4.36
Facility Aa (AaFB)	561.43	12.48	225.20	12.19	5.73	3.92	0 00	0.00	0.00	10.41	10.41	3.92
Facility Da (DaFA)	107.40	0.25	32.32	11 91	5.52	4.32	0 00	0.00	0.00	5.52	5 52	4.32
Facility Aa (AaFC)	1850.47	7.05	233.26	11.47	6.55	11.52	0 01	0.00	0.00	11.47	11 39	11.52
Facility E (EFC)	141 21	10.07	13.39	11 99	5.57	4.80	0 03	0.01	0.02	10.66	9 90	4.80
Facility H (HFA)	95 64	7.50	20.47	11 60	7.30	8.55	0 04	0.00	0.02	11.60	8 00	8.55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	1400 00	1.27	2.93	5.40	11.60	11.22	0 21	0.00	0.01	11.40	12 09	11.22
Facility J (JAB)	5457 59	269.56	612.45	12 20	11.60	12.10	0 05	0.00	0.03	12.10	11 90	12.10
Facility Z (ZFA)	1920 35	0.25	6.30	9.47	12.37	11.98	0 00	0.00	0.00	12.37	12 37	11.98
Facility X (XFA)	3442 95	0.25	187.15	9 06	11.99	11.50	0 04	0.02	0.04	9.06	12 02	11.50
Facility Ca (CaFA)	2323.45	5.63	625.64	12 06	5.54	12.00	0 01	0.00	0.00	12.06	11 84	12.00

Facility	**Mo**						**Pb**					
	Mo_max_Val	**Mo_min_Val**	**Mo_ownpHVal**	**Mo_pH_at_Max**	**Mo_pH_at_Min**	**Mo_ownph**	**Pb_max_Val**	**Pb_min_Val**	**Pb_ownpHVal**	**Pb_pH_at_Max**	**Pb_pH_at_Min**	**Pb_ownph**
Fly Ash - Bituminous												
Brayton Point (BPB)	2419 09	859.01	772.19	12.39	12.18	12.88	8.65	0.29	5.20	12.18	12.39	12.24
Facility F (FFA)	1956 24	464.94	38.00	9.50	5 90	4.25	0.87	0.12	1.44	8 30	8.40	4.25
Facility B (DFA)	7401 59	131.58	1955.66	10.32	5.43	10.26	0.57	0.12	0.16	7 80	6.46	10.26
Facility A (CFA)	2161.70	428.15	521.47	6.91	10 06	10.28	1.28	0.12	0.12	10.78	8.09	10.28
Facility B (BFA)	11436 06	1282.45	1822.15	9.45	9 88	10.06	0.73	0.12	0.12	9 37	11.13	10.06
Facility U (UFA)	125858 80	10096.31	14391.59	12.32	6 36	11.81	3.20	0.12	0.71	12 32	9.45	11.81
Salem Harbor (SHB)	13129 20	1119.47	1826.51	12.10	7.10	11.64	3.48	0.24	0.46	11.75	9.45	11.68
Facility G (GFA)	1259.13	369.35	57.78	11.80	5.70	4.35	0.28	0.12	0.46	7 60	11.80	4.35
Facility A (AFA)	9075 50	230.67	586.85	7.52	5 69	10.52	1.83	0.31	0.34	12 24	8.50	10.52
Facility L (LAB)	788 02	221.80	243.18	6.50	6 50	5.75	0.71	0.12	0.32	6 50	6.40	5.75
Facility C (GAB)	14658 90	1317.36	3009.33	11.60	6.40	11.27	0.12	0.12	0.12	11 20	11.20	11.27
Facility T (TFA)	8488 54	853.99	1024.63	8.81	5 64	8.88	4.14	0.12	0.12	12 23	5.64	8.88
Facility E (EFB)	2587 56	382.59	9.36	12.00	5.70	4.30	0.94	0.12	0.12	9 80	10.50	4.30
Facility W (WFA)	17928.47	1255.17	1970.54	10.29	6 21	10.25	7.01	0.33	0.83	10 29	7.67	10.25
Facility E (EFA)	1864.79	853.87	47.18	12.10	6.40	4.80	0.59	0.12	0.12	6 50	12.10	4.80
Facility K (KFA)	36054 07	1262.83	2297.47	9.27	6.10	9.15	0.45	0.12	0.12	9.16	9.27	9.15
Facility Aa (AaFA)	2838 53	2731.47	135.71	12.13	8.72	4.36	2.17	0.12	3.27	8.72	12.13	4.36
Facility Aa (AaFB)	3211 31	2300.23	68.81	12.19	5.73	3.92	0.87	0.12	11.46	12.19	10.41	3.92
Facility Da (DaFA)	3538.43	1736.08	356.49	11.91	5 52	4.32	0.88	0.12	4.60	11 91	5.52	4.32
Facility Aa (AaFC)	45509 56	2932.69	3853.29	11.47	6 55	11.52	5.00	0.12	0.12	12 32	11.52	11.52
Facility E (EFC)	2011 85	281.89	163.59	11.99	6 33	4.80	0.26	0.12	0.12	11 99	11.62	4.80
Facility H (HFA)	55235 80	3954.03		8.90	8.10	8.55	2.12	0.12	0.23	7 80	8.90	8.55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	774.44	0.50	0.50	8.36	11 60	11.32	4.82	0.71	3.74	12.17	5.71	11.22
Facility J (JAB)	4009.77	171.91	666.50	12.20	5 50	12.10	2.42	0.12	0.12	12 20	11.80	12.10
Facility Z (ZFA)	705 87	4.32	8.62	7.99	12 37	11.98	4.06	0.12	0.12	12 37	6.34	11.98
Facility X (XFA)	2403 83	7.45	546.12	9.90	11 99	11.50	1.02	0.12	0.12	12 02	9.06	11.50
Facility Ca (CaFA)	10945 90	1098.29	1985.31	12.06	5 54	12.00	35.34	0.37	2.56	12 06	9.15	12.00

Facility	PH						Sb					
	PH_max_Val	PH_min_Val	PH_ownpHVal	PH_pH_at_Max	PH_pH_at_Min	PH_ownph	Sb_max_Val	Sb_min_Val	Sb_ownpHVal	Sb_pH_at_Max	Sb_pH_at_Min	Sb_ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	12 39	6.86	12.24	12.39	6 86	12.24	3328.38	1.94	6.94	7.01	12.18	12.88
Facility F (FFA)	11.70	5.50	4.25	11.70	5 50	4.25	194.86	102.04	50.13	11.70	5 90	4.25
Facility B (DFA)	12 38	5.43	10.26	12.38	5.43	10.26	58.44	0.04	6.43	7.09	12 38	10.26
Facility A (CFA)	12 20	5.84	10.28	12.20	5 84	10.28	223.69	6.57	20.67	6.91	7 88	10.28
Facility B (BFA)	12 02	7.97	10.06	12.02	7 97	10.06	49.20	0.97	5.71	7.97	11.43	10.06
Facility U (UFA)	12 32	6.36	11.81	12.32	6 36	11.81	59.12	0.27	0.63	7.83	11 95	11.81
Salem Harbor (SHB)	12.10	7.01	11.68	12.10	7 01	11.68	162.22	4.00	13.03	8.08	11 93	11.64
Facility G (GFA)	11 80	5.70	4.35	11.80	5.70	4.35	99.48	16.68	29.46	11.80	6 60	4.35
Facility A (AFA)	12 35	5.44	10.52	12.35	5.44	10.52	165.98	5.29	12.96	8.04	11.76	10.52
Facility L (LAB)	12 20	5.70	5.75	12.20	5.70	5.75	148.50	4.00	57.62	12.10	6.40	5.75
Facility C (GAB)	11 80	5.60	11.27	11.80	5 60	11.27	129.52	4.00	30.86	8.30	11 60	11.27
Facility T (TFA)	12 23	5.64	8.88	12.23	5 64	8.88	168.50	42.62	70.97	8.81	12.11	8.88
Facility E (EFB)	12 00	5.70	4.30	12.00	5.70	4.30	108.52	48.57	29.24	12.00	5.70	4.30
Facility W (WFA)	12.10	5.96	10.25	12.10	5 96	10.25	1166.10	119.68	131.76	10.33	6 21	10.25
Facility E (EFA)	12.10	6.40	4.80	12.10	6.40	4.80	82.25	43.18	21.09	12.10	6.40	4.80
Facility K (KFA)	11 96	6.10	9.15	11.96	6.10	9.15	54.20	12.06	30.07	9.16	11 96	9.15
Facility Aa (AaFA)	12.13	8.72	4.36	12.13	8.72	4.36	145.09	134.26	51.56	8.72	10 88	4.36
Facility Aa (AaFB)	12.19	5.73	3.92	12.19	5.73	3.92	168.44	157.79	59.92	7.21	9.19	3.92
Facility Da (DaFA)	11 91	5.52	4.32	11.91	5 52	4.32	243.74	173.10	130.12	7.11	5 52	4.32
Facility Aa (AaFC)	12 32	6.55	11.52	12.32	6 55	11.52	144.94	2.86	73.59	9.04	11.47	11.52
Facility E (EFC)	12.10	5.57	4.80	12.10	5 57	4.80	114.32	42.58	46.99	11.62	6 33	4.80
Facility H (HFA)	11 60	7.30	8.55	11.60	7 30	8.55	86.37	15.50	42.70	7.80	9.70	8.55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	12 20	5.40	11.22	12.20	5.40	11.22	399.86	4.00	8.83	8.36	11 60	11.32
Facility J (JAB)	12 20	5.50	12.10	12.20	5 50	12.10	56.64	2.26	7.45	11.80	9 60	12.10
Facility Z (ZFA)	12 37	6.34	11.98	12.37	6 34	11.98	5.23	0.04	0.56	7.99	8 63	11.98
Facility X (XFA)	12 02	6.80	11.50	12.02	6 80	11.50	1.96	0.04	1.96	11.50	6 80	11.50
Facility Ca (CaFA)	12 06	5.54	12.00	12.06	5 54	12.00	75.30	0.20	4.96	10.90	12 06	12.00

Facility	Se						Tl					
	Se_max_Val	Se_min_Val	Se_ownpHVal	Se_pH_at_Max	Se_pH_at_Min	Se_ownph	Tl_max_Val	Tl_min_Val	Tl_ownpHVal	Tl_pH_at_Max	Tl_pH_at_Min	Tl_ownph
Fly Ash - Bituminous												
Brayton Point (BPB)	458 00	43.50	57.03	12.18	12.14	12.24	786.71	12.44	14 50	7.01	12.18	12 88
Facility F (FFA)	1682 38	121.82	50.51	11.60	5.90	4.25	5.70	0.68	8 83	5.90	11.60	4 25
Facility B (DFA)	74.75	6.79	9.27	8.92	11.35	10.26	132.14	0.26	0.73	5.43	9.36	10 26
Facility A (CFA)	323 59	10.01	23.61	7.96	11.21	10.28	55.07	3.21	4 81	6.43	11.41	10 28
Facility B (BFA)	97 50	10.80	15.25	9.45	11.76	10.06	14.74	1.35	1.41	8.32	10.02	10 06
Facility U (UFA)	216 98	39.92	51.97	12.32	11.95	11.81	563.84	118.81	118 81	12.32	11.81	11 81
Salem Harbor (SHB)	2070 00	96.20	1716.67	11.99	12.07	11.68	16.95	0.26	0 58	11.67	11.75	11 64
Facility G (GFA)	1303 84	123.88	61.01	11.80	5.70	4.35	20.78	0.26	33.17	5.70	9.20	4 35
Facility A (AFA)	249 00	25.10	25.67	8.00	9.88	10.52	43.00	1.96	2 88	5.67	12.24	10 52
Facility L (LAB)	45.79	8.90	8.29	12.10	6.30	5.75	446.79	1.59	6 30	6.50	8.80	5.75
Facility C (GAB)	3810.78	991.02	3079.77	11.20	11.60	11.27	327.44	2.50	50 89	8.50	11.60	11 27
Facility T (TFA)	1520.72	156.42	539.47	12.11	5.71	8.88	17.10	0.99	5 00	6.71	10.46	8 88
Facility E (EFB)	859.15	23.56	36.28	12.00	5.70	4.30	69.82	2.59	92 23	5.70	12.00	4 30
Facility W (WFA)	28827 86	1224.33	2855.94	10.33	6.21	10.25	38.81	3.63	4.16	5.96	11.15	10 25
Facility E (EFA)	1433 29	77.57	63.49	12.10	6.50	4.80	7.27	1.07	14.74	6.40	12.10	4 80
Facility K (KFA)	417 58	17.45	122.54	9.27	6.10	9.15	256.81	34.65	38 01	9.27	9.17	9.15
Facility Aa (AaFA)	3641 64	2443.87	213.82	10.88	8.72	4.36	3.56	0.85	33.74	8.72	12.13	4 36
Facility Aa (AaFB)	7386.75	1299.44	496.06	10.41	5.73	3.92	14.15	0.95	38 28	5.73	12.19	3 92
Facility Da (DaFA)	2436 67	371.00	250.89	11.91	5.52	4.32	144.46	5.17	193.12	5.52	11.91	4 32
Facility Aa (AaFC)	773 56	42.76	47.79	11.47	9.04	11.52	29.58	0.26	4 98	6.55	12.32	11 52
Facility E (EFC)	2968.48	65.45	51.97	12.07	6.33	4.80	34.04	1.63	26 51	6.33	11.64	4 80
Facility H (HFA)	120.17	9.13	17.91	11.60	7.30	8.55	176.34	11.40	35 61	7.80	9.70	8 55
Fly Ash - Sub-bituminous												
Pleasant Prairie (PPB)	369 00	35.10	110.90	12.09	11.71	11.22	182.32	0.66	5 58	5.71	8.95	11 32
Facility J (JAB)	312 92	42.75	50.80	12.20	11.60	12.10	22.08	2.50	5 82	5.50	11.90	12.10
Facility Z (ZFA)	434.46	16.51	16.51	6.34	11.98	11.98	7.31	0.26	0 26	6.34	11.98	11 98
Facility X (XFA)	197.14	15.31	22.44	7.60	11.99	11.50	1.54	0.26	0 26	11.99	12.02	11 50
Facility Ca (CaFA)	548 01	141.22	338.64	10.90	6.64	12.00	16.10	0.26	0 26	5.54	12.00	12 00

I/A

Facility	**Al**						**As**					
	Al max Val	**Al min Val**	**Al ownpHVal**	**Al pH at Max**	**Al pH at Min**	**Al ownph**	**As max Val**	**As min Val**	**As ownpHVal**	**As pH at Max**	**As pH at Min**	**As ownph**
Fly Ash - With and without ACI												
Brayton Point (BPB)	6400 00	3810.00	4110.00	12.18	12.14	12.24	35 30	5.40	6.67	9.19	12.14	12.24
Brayton Point (BPT)	103000 00	1540.00	5966.67	5 50	8.89	9.49	42 90	2.26	4.84	12 35	9.04	9.49
Salem Harbor (SHB)	2104 92	331.03	1996.89	11.76	8.59	11.68	105 00	18.00	19.30	8 59	11.76	11.68
Salem Harbor (SHT)	932 68	188.44	532.11	5.72	8.38	10.31	188 00	83.30	156.00	9 33	5.72	10.31
Facility L (LAB)	20919 24	30.15	1087.32	12.10	6.40	5.75	1686 99	23.49	25.95	12.10	6.30	5.75
Facility L (LAT)	21402 23	16.62	1373.00	12.10	6.50	5.00	1312.12	24.58	24.96	12.10	6.50	5.00
Facility C (GAB)	34209 60	58.09	13419.61	11 20	6.60	11.27	1113.43	123.96	237.37	8 30	11.60	11.27
Facility C (GAT)	23475 20	1202.04	2045.14	9 80	8.40	8.10	273.72	69.64	119.67	11 50	8.60	8.10
Pleasant Prairie (PPB)	97500 00	98.46	26700.00	12.10	5.71	11.22	12 80	3.26	4.00	12 02	10.51	11.22
Pleasant Prairie (PPT)	125000 00	138.92	118666.67	11 95	6.86	11.86	14 50	2.99	4.15	11 39	8.25	11.86
Facility J (JAB)	514917 86	702.07	102345.42	12 20	6.40	12.10	58 06	0.32	0.92	12 20	9.60	12.10
Facility J (JAT)	189069.46	158.38	92444.21	12.10	5.80	12.20	2 89	0.32	0.54	12.10	10.40	12.20
Facility Ba (BaFA)	15999.70	35.55	15999.70	11.70	6.88	11.70	36 69	0.85	5.82	8 95	11.82	11.70
SDA												
Facility V (VSD)	13131 50	10.00	172.89	9 09	12.18	11.99	32.16	0.87	1.80	5.74	11.63	11.99
Facility Y (YSD)	7179.46	0.50	16.14	9 03	12.11	12.10	27 96	0.32	2.23	5.79	9.18	12.10

Facility	B						Ba					
	B max Val	B min Val	B ownpHVal	B pH at Max	B pH at Min	B ownph	Ba max Val	Ba min Val	Ba ownpHVal	Ba pH at Max	Ba pH at Min	Ba ownph
Fly Ash - With and without ACI												
Brayton Point (BPB)	30871.40	2430.60	2267.98	12.39	12.18	12 88	1830.00	301.00	1810.00	12.14	8.02	12 24
Brayton Point (BPT)	39163 60	1129.79	38865.80	9.04	8.28	9 39	270.00	105.00	120.33	12.34	8.28	9.49
Salem Harbor (SHB)	20534.10	1484.62	4886.93	9.45	11.67	11 64	1000.00	138.00	778.00	11.99	7.74	11 68
Salem Harbor (SHT)	56140.40	7111.69	9115.11	9.72	11.87	10 27	1000.00	164.00	567.67	12.39	6.44	10 31
Facility L (LAB)	2586.70	480.50	590.78	6.50	7.60	5.75	219.28	63.59	125.13	8.20	6.50	5.75
Facility L (LAT)	2105.44	398.66	517.82	5.50	7.50	5 00	168.04	59.36	116.33	7.30	6.70	5 00
Facility C (GAB)	12929.40	1148.41	5449.60	7.30	11.60	11 27	1007.89	59.60	569.83	11.70	7.80	11 27
Facility C (GAT)	11228.10	2993.11	7460.41	5.50	11.70	8.10	369.71	50.60	69.29	10.50	8.40	8.10
Pleasant Prairie (PPB)	29226 20	3846.36	9495.67	8.36	12.10	11 32	101000.00	1030.00	22933.33	12.09	5.56	11 22
Pleasant Prairie (PPT)	25901 80	348.38	565.16	11.46	12.35	11 96	11000.00	662.00	10766.67	11.95	8.13	11 86
Facility J (JAB)	17608 90	235.65	295.95	9.20	12.10	12.10	4801.77	246.26	853.55	11.70	9.60	12.10
Facility J (JAT)	17023.70	237.33	256.48	8.50	12.20	12 20	3197.81	1787.19	2453.01	10.40	9.70	12 20
Facility Ba (BaFA)	26354.10	1473.61	1867.05	6.88	11.82	11.70	53382.66	1347.63	11059.18	11.91	8.95	11.70
SDA												
Facility V (VSD)	23657 20	78.66	90.94	6.00	11.63	11 99	451497.14	3758.26	167632.20	12.18	8.19	11 99
Facility Y (YSD)	12743 50	143.17	144.02	5.98	12.11	12.10	6304.27	465.49	1271.34	8.73	12.33	12.10

Facility	Cd						Co					
	Cd max Val	Cd min Val	Cd ownpHVal	Cd pH at Max	Cd pH at Min	Cd ownph	Co max Val	Co min Val	Co ownpHVal	Co pH at Max	Co pH at Min	Co ownph
Fly Ash - With and without ACI												
Brayton Point (BPB)	70 60	22.70	24.07	12.37	12.14	12.24	223 00	0.50	0.86	9.19	12.06	12.24
Brayton Point (BPT)	126 00	3.20	42.77	7.91	5.48	9.49	106 00	0.21	0.29	5.60	11.24	9.49
Salem Harbor (SHB)	36 50	2.37	3.85	12.03	11.53	11.68	42 20	0.21	0.21	7.01	8.15	11.68
Salem Harbor (SHT)	323 00	54.50	75.77	9.72	6.44	10.31	31.10	0.21	0.21	5.72	10.20	10.31
Facility L (LAB)	1 86	0.33	0.46	6.50	7.60	5.75	30 80	0.21	6.25	6.50	7.60	5.75
Facility L (LAT)	1 29	0.29	0.33	5.50	6.70	5.00	21 37	0.21	5.08	5.50	12.10	5.00
Facility C (GAB)	34 89	0.09	0.09	11.20	6.60	11.27	78.16	0.21	0.21	5.60	9.30	11.27
Facility C (GAT)	10 98	0.58	0.64	5.50	8.30	8.10	135 90	0.21	1.19	5.50	9.60	8.10
Pleasant Prairie (PPB)	17 00	0.09	0.15	5.56	12.02	11.22	503 00	0.21	0.66	5.56	12.02	11.22
Pleasant Prairie (PPT)	15.40	0.09	4.21	7.91	11.92	11.86	153 00	0.21	0.32	5.57	12.19	11.86
Facility J (JAB)	3 59	0.46	0.58	12.20	11.60	12.10	74.78	0.21	0.21	5.50	11.80	12.10
Facility J (JAT)	1 24	0.45	0.45	12.10	12.20	12.20	65 00	0.21	0.21	5.80	12.10	12.20
Facility Ba (BaFA)	8 33	0.42	0.98	6.88	11.82	11.70	282.10	0.61	0.68	6.88	11.77	11.70
SDA												
Facility V (VSD)	10 05	0.09	0.82	5.74	9.09	11.99	1461 94	0.21	5.26	6.00	12.18	11.99
Facility Y (YSD)	39.70	1.67	1.83	5.79	12.11	12.10	2688 06	0.21	4.40	5.79	12.33	12.10

Facility	Cr						Hg					
	Cr max Val	**Cr min Val**	**Cr ownpHVal**	**Cr pH at Max**	**Cr pH at Min**	**Cr ownph**	**Hg max Val**	**Hg min Val**	**Hg ownpHVal**	**Hg pH at Max**	**Hg pH at Min**	**Hg ownph**
Fly Ash - With and without ACI												
Brayton Point (BPB)	42.70	2.56	27.38	9.19	12.39	12.24	0.12	0.00	0.04	11.71	12 06	12.24
Brayton Point (BPT)	74 60	2.07	15.27	11 34	7.65	9.49	0 02	0.00	0.01	9.52	7 91	9.49
Salem Harbor (SHB)	527 00	0.25	451.67	11 91	7.01	11.68	0 08	0.01	0.04	8.27	8.15	11.68
Salem Harbor (SHT)	260 00	3.25	76.57	9 68	7.62	10.31	0 03	0.00	0.01	11.82	9 68	10.31
Facility L (LAB)	18 96	0.25	1.29	12.10	5.70	5.75	0.12	0.00	0.01	6.70	10 30	5.75
Facility L (LAT)	27 67	0.25	0.50	12.10	5.50	5.00	0.16	0.00	0.01	10.40	12.10	5.00
Facility C (GAB)	86 57	0.25	0.25	11 20	7.30	11.27	0 05	0.00	0.02	9.90	8 80	11.27
Facility C (GAT)	65 59	0.25	29.32	8 60	5.50	8.10	0.13	0.00	0.02	8.60	11.70	8.10
Pleasant Prairie (PPB)	1400 00	1.27	2.93	5.40	11.60	11.22	0 21	0.00	0.01	11.40	12 09	11.22
Pleasant Prairie (PPT)	709.48	57.60	80.73	11.46	5.57	11.86	0 03	0.00	0.01	7.91	12 35	11.86
Facility J (JAB)	5457 59	269.56	612.45	12 20	11.60	12.10	0 05	0.00	0.03	12.10	11 90	12.10
Facility J (JAT)	2602 54	67.03	631.98	12.10	5.80	12.20	0 05	0.00	0.02	8.50	7.10	12.20
Facility Ba (BaFA)	834 05	23.48	425.46	10 67	11.91	11.70	0 02	0.00	0.01	6.88	11 91	11.70
SDA												
Facility V (VSD)	434.79	16.17	252.31	10.40	6.76	11.99	1 97	0.01	0.02	7.09	11 27	11.99
Facility Y (YSD)	9118 93	25.52	1741.96	12 33	5.79	12.10	0.70	0.00	0.02	6.59	9.18	12.10

Facility	**Mo**						**Pb**					
	Mo max Val	**Mo min Val**	**Mo ownpHVal**	**Mo pH at Max**	**Mo pH at Min**	**Mo ownph**	**Pb max Val**	**Pb min Val**	**Pb ownpHVal**	**Pb pH at Max**	**Pb pH at Min**	**Pb ownph**
Fly Ash - With and without ACI												
Brayton Point (BPB)	2419 09	859.01	772.19	12.39	12.18	12.88	8.65	0.29	5.20	12.18	12.39	12.24
Brayton Point (BPT)	2548 90	14.38	2548.90	9.39	5.48	9.39	3.37	0.23	1.81	9 56	8.89	9.49
Salem Harbor (SHB)	13129 20	1119.47	1826.51	12.10	7.10	11.64	3.48	0.24	0.46	11.75	9.45	11.68
Salem Harbor (SHT)	26762 60	1679.90	3111.61	9.72	6.44	10.27	1.72	0.24	0.76	12 39	10.53	10.31
Facility L (LAB)	788 02	221.80	243.18	6.50	6 50	5.75	0.71	0.12	0.32	6 50	6.40	5.75
Facility L (LAT)	651 82	172.05	202.57	5.50	6.40	5.00	2.28	0.12	0.49	6.40	5.50	5.00
Facility C (GAB)	14658 90	1317.36	3009.33	11.60	6.40	11.27	0.12	0.12	0.12	11 20	11.20	11.27
Facility C (GAT)	2046.71	350.10	1387.32	11.50	5 50	8.10	4.03	0.12	0.51	6.10	8.70	8.10
Pleasant Prairie (PPB)	774.44	0.50	0.50	8.36	11 60	11.32	4.82	0.71	3.74	12.17	5.71	11.22
Pleasant Prairie (PPT)	3290 24	0.50	94.61	11.46	11 34	11.96	5.78	0.63	3.49	11 92	6.86	11.86
Facility J (JAB)	4009.77	171.91	666.50	12.20	5 50	12.10	2.42	0.12	0.12	12 20	11.80	12.10
Facility J (JAT)	1548 68	234.50	687.16	12.20	5 80	12.20	12.16	0.37	3.50	5 80	12.20	12.20
Facility Ba (BaFA)	818 27	100.83	533.35	8.95	11 91	11.70	2.73	0.26	0.61	11 82	8.95	11.70
SDA												
Facility V (VSD)	764 04	182.96	188.12	9.09	12.13	11.99	26.58	0.12	6.89	12 39	8.19	11.99
Facility Y (YSD)	9202 95	354.13	1231.90	12.33	5.79	12.10	58.99	5.81	10.42	12 33	10.23	12.10

Facility	PH						Sb					
	PH max Val	PH min Val	PH ownpHVal	PH pH at Max	PH pH at Min	PH ownph	Sb max Val	Sb min Val	Sb ownpHVal	Sb pH at Max	Sb pH at Min	Sb ownph
Fly Ash - With and without ACI												
Brayton Point (BPB)	12 39	6.86	12.24	12.39	6 86	12.24	3328.38	1.94	6.94	7.01	12.18	12.88
Brayton Point (BPT)	12 35	5.48	9.49	12.35	5.48	9.49	4317.57	4.00	548.04	9.04	8 92	9.39
Salem Harbor (SHB)	12.10	7.01	11.68	12.10	7 01	11.68	162.22	4.00	13.03	8.08	11 93	11.64
Salem Harbor (SHT)	12 39	5.72	10.31	12.39	5.72	10.31	11145.85	26.78	392.68	5.72	10 20	10.27
Facility L (LAB)	12 20	5.70	5.75	12.20	5.70	5.75	148.50	4.00	57.62	12.10	6.40	5.75
Facility L (LAT)	12 20	5.50	5.00	12.20	5 50	5.00	135.74	4.00	54.48	12.10	5 50	5.00
Facility C (GAB)	11 80	5.60	11.27	11.80	5 60	11.27	129.52	4.00	30.86	8.30	11 60	11.27
Facility C (GAT)	11.70	5.50	8.10	11.70	5 50	8.10	96.40	8.31	53.42	6.10	11.70	8.10
Pleasant Prairie (PPB)	12 20	5.40	11.22	12.20	5.40	11.22	399.86	4.00	8.83	8.36	11 60	11.32
Pleasant Prairie (PPT)	12 35	5.57	11.86	12.35	5 57	11.86	361.64	4.00	5.71	5.57	11.46	11.96
Facility J (JAB)	12 20	5.50	12.10	12.20	5 50	12.10	56.64	2.26	7.45	11.80	9 60	12.10
Facility J (JAT)	12 20	5.80	12.20	12.20	5 80	12.20	17.14	2.45	5.86	12.20	10.40	12.20
Facility Ba (BaFA)	11 91	6.88	11.70	11.91	6 88	11.70	22.80	2.53	5.13	8.95	11 91	11.70
SDA												
Facility V (VSD)	12 39	5.74	11.99	12.39	5.74	11.99	15.63	0.04	0.67	5.74	11 30	11.99
Facility Y (YSD)	12 33	5.79	12.10	12.33	5.79	12.10	13.60	0.04	0.22	5.79	12 00	12.10

Facility	**Se**						**Tl**					
	Se max Val	**Se min Val**	**Se ownpHVal**	**Se pH at Max**	**Se pH at Min**	**Se ownph**	**Tl max Val**	**Tl min Val**	**Tl ownpHVal**	**Tl pH at Max**	**Tl pH at Min**	**Tl ownph**
Fly Ash - With and without ACI												
Brayton Point (BPB)	458 00	43.50	57.03	12.18	12.14	12.24	786.71	12.44	14 50	7.01	12.18	12 88
Brayton Point (BPT)	2700 00	91.50	164.33	12.35	8.28	9.49	184.82	23.83	54.40	9.04	9.84	9 39
Salem Harbor (SHB)	2070 00	96.20	1716.67	11.99	12.07	11.68	16.95	0.26	0 58	11.67	11.75	11 64
Salem Harbor (SHT)	3010 00	153.00	1496.67	9.68	6.44	10.31	143.98	0.91	1.40	5.72	10.66	10 27
Facility L (LAB)	45.79	8.90	8.29	12.10	6.30	5.75	446.79	1.59	6 30	6.50	8.80	5.75
Facility L (LAT)	41 57	5.70	5.85	12.20	5.90	5.00	216.56	1.83	6 84	6.40	9.70	5 00
Facility C (GAB)	3810.78	991.02	3079.77	11.20	11.60	11.27	327.44	2.50	50 89	8.50	11.60	11 27
Facility C (GAT)	12091.11	1035.91	3288.09	11.50	5.80	8.10	319.97	41.30	98 94	8.90	11.50	8.10
Pleasant Prairie (PPB)	369 00	35.10	110.90	12.09	11.71	11.22	182.32	0.66	5 58	5.71	8.95	11 32
Pleasant Prairie (PPT)	85.70	10.50	25.27	9.78	11.86	11.86	406.21	2.08	4 60	5.57	12.35	11 96
Facility J (JAB)	312 92	42.75	50.80	12.20	11.60	12.10	22.08	2.50	5 82	5.50	11.90	12.10
Facility J (JAT)	170 57	48.49	58.85	9.90	12.20	12.20	6.39	1.78	2 37	5.80	8.60	12 20
Facility Ba (BaFA)	720.15	40.05	133.22	8.95	11.91	11.70	4.98	0.26	0 26	6.88	11.70	11.70
SDA												
Facility V (VSD)	1142.48	73.96	83.14	5.74	11.63	11.99	12.03	0.26	1 69	5.74	7.09	11 99
Facility Y (YSD)	951.76	108.99	116.03	5.79	12.11	12.10	15.06	0.26	3 61	12.27	8.45	12.10

Facility	**Al**						**As**					
	Al max Val	**Al min Val**	**Al ownpHVal**	**Al pH at Max**	**Al pH at Min**	**Al ownph**	**As max Val**	**As min Val**	**As ownpHVal**	**As pH at Max**	**As pH at Min**	**As ownph**
Gypsum												
Facility U (UAU)	890 65	76.79	181.84	10 65	12.13	5.85	5 82	4.82	5.21	7 02	5.65	5.85
Facility T (TAU)	731.77	0.50	12.59	5.71	9.12	7.11	3 93	0.32	2.68	7 28	8.96	7.11
Facility T (TAW)	405.44	0.50	28.43	10 97	12.16	6.02	4 65	0.32	0.32	12.16	5.64	6.02
Facility W (WAU)	47 95	0.50	3.70	5 53	8.92	6.84	197 50	0.95	1.38	5 95	7.35	6.84
Facility W (WAW)	203.43	0.50	6.04	8 22	12.00	6.33	2 99	0.32	0.32	5 94	10.41	6.33
Facility Aa (AaAU)	1623 05	4.38	384.78	10 23	11.95	7.14	1 32	0.32	1.04	11 95	10.23	7.14
Facility Aa (AaAW)	2876 07	0.50	384.78	10 91	12.00	7.14	2.11	0.32	0.69	5 50	10.91	6.86
Facility Da (DaAW)	467.43	10.00	170.63	9 03	5.81	7.74	1213 97	1.05	1.05	5 54	7.74	7.74
Facility P (PAD)	571 25	50.05	62.70	5 68	11.76	6.66	6.12	0.32	0.32	5 82	6.05	6.66
Facility N (NAU)	2149 62	65.51	340.84	10 82	7.20	7.18	5 94	0.32	0.32	6 26	7.18	7.18
Facility N (NAW)	3442.44	65.37	324.86	5 65	7.18	7.13	10.16	0.32	5.24	7 25	6.87	7.13
Facility S (SAU)	2762 65	10.00	437.11	5.42	7.42	7.13	63.73	7.03	12.03	7.42	12.11	7.13
Facility S (SAW)	1801.48	10.00	1800.98	7 27	5.60	7.61	43 54	7.60	42.26	7 27	6.49	7.61
Facility O (OAU)	2155 36	0.48	414.70	5.49	10.22	7.53	6 56	0.32	1.29	7 29	9.53	7.53
Facility O (OAW)	2440 99	507.95	823.80	5 83	7.44	7.33	9 01	0.32	2.12	7 05	9.17	7.33
Facility R (RAU)	2029.43	16.53	119.18	5 57	12.05	6.92	5 96	0.32	1.18	11 04	9.45	6.92
Facility Q (QAU)	448 37	0.48	176.41	8.12	10.49	6.89	10 69	0.32	0.88	5 85	6.95	6.89
Facility X (XAU)	742 33	0.50	58.48	5 67	12.25	7.73	9 01	0.32	0.32	7 20	5.67	7.73
Facility X (XAW)	892 62	11.64	437.43	6 85	12.25	6.03	3 02	0.72	0.80	6 37	6.85	6.03
Facility Ca (CaAW)	10282.40	5.97	79.31	5 81	9.05	7.75	21 00	1.83	5.00	6 95	12.13	7.75
Scrubber Sludge												
Facility B (DGD)	3254 94	33.17	36.97	5 86	8.52	9.13	22.72	0.32	0.32	5 86	9.03	9.13
Facility A (CGD)	21565 05	260.83	495.95	5.74	7.28	7.30	3 07	0.32	0.46	10 86	6.70	7.30
Facility B (BGD)	14400 00	455.00	2340.00	12 21	7.23	10.11	63 90	5.54	5.80	7 03	10.70	10.11
Facility A (AGD)	3170 00	217.00	913.33	5.48	9.35	6.78	7 94	2.81	6.38	7.74	8.09	6.78
Facility K (KGD)	13860 01	71.91	2812.52	12 02	5.69	10.99	105 00	10.84	18.62	12 02	7.07	10.99
Blended CCRs												
Facility B (DCC)	321.40	9.33	9.51	12.17	12.26	12.19	184 53	0.32	2.09	6 31	12.17	12.19
Facility A (CCC)	10010 03	106.20	584.06	5 87	11.52	10.00	83.71	4.75	18.81	9.16	11.52	10.00
Facility B (BCC)	3270 00	250.00	551.00	12 04	8.10	8.00	40 60	7.26	16.60	7 03	12.04	8.00
Facility A (ACC)	15400 00	530.00	1920.00	5 83	8.88	8.43	76 60	21.20	41.30	7 91	11.39	8.43
Facility K (KCC)	3751 09	644.75	711.03	6 27	8.24	8.18	6 98	0.32	0.32	6 27	8.30	8.18
Facility M (MAD)	920 34	0.50	366.25	11 87	6.88	11.93	2818.75	1.20	7.20	5.74	12.05	11.93
Facility M (MAS)	15319.17	3.31	4048.82	11.14	7.13	11.58	3664.46	77.19	205.37	11 94	8.02	11.58
Facility U (UGF)	2309 30	12.69	82.20	5 61	12.07	7.12	44 25	4.73	12.98	5 61	12.07	7.12

Facility	B						Ba					
	B max Val	B min Val	B ownpHVal	B pH at Max	B pH at Min	B ownph	Ba max Val	Ba min Val	Ba ownpHVal	Ba pH at Max	Ba pH at Min	Ba ownph
Gypsum												
Facility U (UAU)	1268 87	541.87	574.10	5.65	8.21	5 85	141.07	106.49	123.66	5.65	12.13	5 85
Facility T (TAU)	94758 60	9374.62	10908.75	7.47	9.40	7.11	105.24	56.16	75.52	7.42	12.16	7.11
Facility T (TAW)	5435 68	638.86	701.25	5.52	9.93	6 02	71.86	58.54	69.65	6.39	12.15	6 02
Facility W (WAU)	113879 00	7479.40	9094.99	6.83	9.86	6 84	198.65	36.89	96.64	6.83	12.07	6 84
Facility W (WAW)	1437.11	208.82	210.72	5.99	8.22	6 33	99.45	29.99	59.39	5.75	12.00	6 33
Facility Aa (AaAU)	4142.44	695.22	716.07	5.86	11.95	7.14	86.82	70.81	76.03	5.86	11.95	7.14
Facility Aa (AaAW)	134 02	101.01	101.01	5.50	6.86	6 86	87.39	69.74	69.74	5.50	6.86	6 86
Facility Da (DaAW)	1702 84	158.04	158.04	5.54	7.74	7.74	257.40	95.11	95.11	5.81	7.74	7.74
Facility P (PAD)	1518 04	260.68	285.95	11.76	6.71	6 66	77.15	37.63	45.02	5.68	11.74	6 66
Facility N (NAU)	16490 02	1469.68	2214.49	7.16	7.65	7.18	148.02	50.43	67.00	7.20	11.96	7.18
Facility N (NAW)	978 34	42.83	48.63	7.18	7.25	7.13	80.49	46.26	58.38	7.31	11.31	7.13
Facility S (SAU)	268491 00	18975.00	21801.20	7.42	10.55	7.13	158.96	40.67	101.42	6.10	12.11	7.13
Facility S (SAW)	788 39	355.86	387.72	5.60	6.02	7 61	84.35	31.09	32.43	5.60	9.83	7 61
Facility O (OAU)	49574.17	4979.84	5234.54	7.44	7.50	7 53	159.25	75.59	83.52	5.49	12.01	7 53
Facility O (OAW)	3713 22	327.62	344.99	8.05	6.91	7 33	144.91	40.70	80.01	5.83	8.93	7 33
Facility R (RAU)	2664 52	58.48	59.72	11.95	6.98	6 92	123.62	62.00	81.77	5.57	12.05	6 92
Facility Q (QAU)	65034 94	2737.33	3592.31	6.41	9.31	6 89	421.86	114.93	128.93	5.81	6.41	6 89
Facility X (XAU)	5903 89	531.69	569.55	7.20	7.01	7.73	107.64	80.61	99.30	5.67	12.25	7.73
Facility X (XAW)	395 80	11.81	11.81	12.25	6.03	6 03	95.96	80.35	91.49	11.29	12.25	6 03
Facility Ca (CaAW)	77196 90	7034.84	7521.65	6.95	9.05	7.75	564.84	124.95	164.15	5.81	12.13	7.75
Scrubber Sludge												
Facility B (DGD)	62361.43	3120.08	3331.06	8.77	9.05	9.13	401.77	118.07	127.96	7.06	11.59	9.13
Facility A (CGD)	43149 82	4059.68	5373.95	7.28	12.13	7 30	82.67	21.75	30.43	7.25	10.79	7 30
Facility B (BGD)	14166 99	18.23	726.43	6.39	9.39	10.11	1760.00	156.00	176.00	7.03	9.51	10.11
Facility A (AGD)	213447.79	4750.32	6270.42	7.74	9.35	6.78	118.00	33.60	43.57	7.70	6.49	6.78
Facility K (KGD)	20929 26	1574.03	1845.13	6.03	11.00	10 99	2313.82	99.12	112.52	6.03	12.02	10 99
Blended CCRs												
Facility B (DCC)	13903.42	6.28	818.70	6.31	11.97	12.19	5991.09	624.94	2250.24	12.12	9.38	12.19
Facility A (CCC)	7950 30	7.57	112.32	6.08	11.52	10 00	1590.77	149.99	162.39	8.69	9.91	10 00
Facility B (BCC)	223287 90	1841.01	5616.40	7.93	10.85	8 00	178.00	46.70	49.70	7.93	7.91	8 00
Facility A (ACC)	10883 92	529.50	3215.59	7.10	11.39	8.43	494.00	122.00	130.00	8.88	8.72	8.43
Facility K (KCC)	44446 01	7827.50	10851.50	8.24	9.24	8.18	154.08	7.63	15.23	6.27	11.54	8.18
Facility M (MAD)	32923 84	172.30	305.35	6.55	11.87	11 93	10158.06	516.86	2227.47	7.87	9.13	11 93
Facility M (MAS)	28731 07	357.08	794.72	6.73	11.95	11 58	1180.41	32.33	67.28	6.73	11.60	11 58
Facility U (UGF)	3383 21	122.74	284.52	5.61	10.55	7.12	962.81	185.00	190.25	5.61	10.55	7.12

Facility	Cd						Co					
	Cd max Val	Cd min Val	Cd ownpHVal	Cd pH at Max	Cd pH at Min	Cd ownph	Co max Val	Co min Val	Co ownpHVal	Co pH at Max	Co pH at Min	Co ownph
Gypsum												
Facility U (UAU)	1 37	0.62	1.37	5.85	7.02	5.85	2.40	0.21	1.93	12.13	5.65	5.85
Facility T (TAU)	15 28	0.09	0.84	6.02	7.95	7.11	103.12	1.43	17.11	7.42	11.33	7.11
Facility T (TAW)	0 89	0.09	0.15	6.20	7.33	6.02	11.45	1.30	2.25	7.95	7.20	6.02
Facility W (WAU)	1 97	0.09	0.56	6.97	8.92	6.84	41 62	0.21	2.15	6.97	8.39	6.84
Facility W (WAW)	2.19	0.09	0.25	5.49	10.16	6.33	10.70	1.97	2.64	5.49	10.91	6.33
Facility Aa (AaAU)	0 09	0.09	0.09	11.95	11.95	7.14	0 21	0.21	0.21	11.95	11.95	7.14
Facility Aa (AaAW)	0 09	0.09	0.09	12.00	12.00	6.86	6.79	0.21	0.21	5.50	12.00	6.86
Facility Da (DaAW)	371.15	0.09	0.09	5.54	9.03	7.74	1147 29	0.21	0.21	5.54	9.03	7.74
Facility P (PAD)	0 50	0.09	0.09	5.68	6.37	6.66	2 59	1.12	1.16	5.68	6.71	6.66
Facility N (NAU)	7 26	0.09	0.17	7.16	10.98	7.18	4.15	1.36	1.83	6.26	8.19	7.18
Facility N (NAW)	7 91	0.09	0.09	5.70	8.15	7.13	4 08	1.00	2.31	5.70	10.08	7.13
Facility S (SAU)	32 99	0.09	4.91	7.42	12.11	7.13	63 54	0.21	11.78	7.47	12.11	7.13
Facility S (SAW)	0.71	0.09	0.09	5.60	9.83	7.61	2.11	1.33	1.41	12.08	10.92	7.61
Facility O (OAU)	12 23	0.09	1.08	5.49	9.51	7.53	17 32	1.19	1.65	5.49	7.16	7.53
Facility O (OAW)	6 69	0.09	0.09	5.83	8.42	7.33	14.43	0.57	1.52	5.83	8.93	7.33
Facility R (RAU)	2 35	0.09	0.57	5.57	10.28	6.92	30 29	1.68	3.28	5.57	10.90	6.92
Facility Q (QAU)	51 26	0.09	6.03	5.81	10.49	6.89	50.74	1.99	8.69	6.68	10.49	6.89
Facility X (XAU)	3.11	0.09	0.39	7.20	12.25	7.73	63 28	1.35	9.24	7.20	12.25	7.73
Facility X (XAW)	1 93	0.39	1.08	6.37	7.98	6.03	3 58	2.34	2.89	6.37	11.29	6.03
Facility Ca (CaAW)	5.77	0.09	0.56	5.81	9.05	7.75	69 20	0.21	1.28	5.81	12.13	7.75
Scrubber Sludge												
Facility B (DGD)	0 68	0.09	0.09	7.06	9.29	9.13	6.46	0.21	0.21	5.86	12.09	9.13
Facility A (CGD)	1.17	0.09	0.09	8.98	9.21	7.30	8.71	0.59	0.87	7.25	9.21	7.30
Facility B (BGD)	1.44	0.09	0.09	6.43	12.24	10.11	40 30	0.21	0.21	7.03	9.11	10.11
Facility A (AGD)	1 59	0.09	1.01	5.48	11.69	6.78	92 00	0.93	51.23	6.30	11.69	6.78
Facility K (KGD)	4.11	0.18	0.19	8.34	11.00	10.99	245 08	0.21	0.21	5.69	11.00	10.99
Blended CCRs												
Facility B (DCC)	1 09	0.09	0.09	6.31	12.12	12.19	47 04	0.78	0.94	6.25	12.12	12.19
Facility A (CCC)	9.12	0.21	0.28	6.08	10.81	10.00	124 87	0.21	0.49	6.08	10.75	10.00
Facility B (BCC)	11 80	0.34	2.08	7.06	8.10	8.00	93 00	2.31	5.06	6.34	12.04	8.00
Facility A (ACC)	8 95	0.55	0.63	5.70	11.39	8.43	111 00	3.33	4.15	5.70	11.39	8.43
Facility K (KCC)	1 08	0.09	0.09	8.30	7.98	8.18	7 82	0.21	0.21	6.27	8.30	8.18
Facility M (MAD)	11 00	0.09	1.49	7.37	12.03	11.93	149 82	0.21	1.78	6.16	12.03	11.93
Facility M (MAS)	20.15	3.02	3.30	11.94	11.50	11.58	117 94	0.45	1.40	6.73	11.76	11.58
Facility U (UGF)	31 99	0.09	0.09	5.61	10.21	7.12	48.46	0.21	0.21	5.61	6.77	7.12

Facility	**Cr**						**Hg**					
	Cr max Val	**Cr min Val**	**Cr ownpHVal**	**Cr pH at Max**	**Cr pH at Min**	**Cr ownph**	**Hg max Val**	**Hg min Val**	**Hg ownpHVal**	**Hg pH at Max**	**Hg pH at Min**	**Hg ownph**
Gypsum												
Facility U (UAU)	23.16	11.88	11.88	5 65	5.85	5.85	0 02	0.00	0.00	5.65	10 65	5.85
Facility T (TAU)	38 96	8.21	8.36	9.40	7.24	7.11	0 03	0.00	0.00	10.98	7 24	7.11
Facility T (TAW)	241.17	6.92	15.36	7 95	12.16	6.02	0 02	0.00	0.01	8.63	5 52	6.02
Facility W (WAU)	20 83	4.10	9.37	6 97	9.86	6.84	0 02	0.00	0.00	12.09	9.16	6.84
Facility W (WAW)	27 89	8.23	15.94	5.75	5.94	6.33	0 01	0.00	0.00	5.87	12 00	6.33
Facility Aa (AaAU)	9.41	5.04	5.69	11 95	6.06	7.14	0 01	0.00	0.00	6.06	9.14	7.14
Facility Aa (AaAW)	17 57	10.04	10.04	12 00	6.86	6.86	0 02	0.01	0.01	5.50	12 00	6.86
Facility Da (DaAW)	85 87	18.64	24.21	5 81	5.65	7.74	0 09	0.00	0.01	5.54	9 03	7.74
Facility P (PAD)	24 23	0.75	4.18	6 37	9.83	6.66	0 08	0.00	0.03	7.35	6 60	6.66
Facility N (NAU)	52 63	1.87	2.87	10 82	7.18	7.18	0 03	0.00	0.00	11.96	7 03	7.18
Facility N (NAW)	18.71	0.25	0.25	11.45	6.87	7.13	0.10	0.00	0.00	7.28	10.72	7.13
Facility S (SAU)	20 93	0.25	13.77	5.42	12.11	7.02	0.11	0.00	0.00	6.10	8 00	7.13
Facility S (SAW)	16 95	7.01	12.34	5 60	12.08	7.61	0 01	0.00	0.00	12.08	5 60	7.61
Facility O (OAU)	6.11	0.25	1.13	11.77	8.87	7.53	0 02	0.00	0.00	7.47	7.16	7.53
Facility O (OAW)	12.47	0.25	0.25	7 67	5.83	7.33	0 09	0.00	0.00	7.67	7.44	7.33
Facility R (RAU)	21 23	7.90	13.77	7 60	10.28	6.92	0 00	0.00	0.00	12.05	12 05	6.92
Facility Q (QAU)	17 29	1.21	4.20	10 62	6.42	6.89	0 66	0.00	0.00	5.81	6.42	6.89
Facility X (XAU)	35 03	11.17	17.21	6.42	5.67	7.73	0 06	0.00	0.00	5.67	8.70	7.73
Facility X (XAW)	34 87	27.33	34.42	11 29	6.37	6.03	0 04	0.01	0.02	7.98	11 29	6.03
Facility Ca (CaAW)	56 24	11.56	13.51	6 95	5.81	7.75	0 20	0.01	0.03	6.95	5 81	7.75
Scrubber Sludge												
Facility B (DGD)	24 28	0.80	10.08	9 03	11.49	9.13	8 99	0.02	0.04	5.86	6 53	9.13
Facility A (CGD)	9 85	2.91	4.33	11 99	9.21	7.30	0.10	0.02	0.03	12.13	6 20	7.30
Facility B (BGD)	794 00	203.00	228.00	8 99	7.31	10.11	5 30	0.01	0.03	7.02	9.40	10.11
Facility A (AGD)	831 00	574.00	592.33	7.70	7.39	6.78	0 08	0.00	0.02	7.37	7.13	6.78
Facility K (KGD)	16 85	3.54	10.55	5 69	9.70	10.99	1 58	0.00	0.06	8.00	10 58	10.99
Blended CCRs												
Facility B (DCC)	21 95	0.25	13.90	12 21	6.31	12.19	1.47	0.01	0.02	6.61	12 20	12.19
Facility A (CCC)	2259 67	88.38	211.16	8 96	5.87	10.00	0 22	0.01	0.10	10.03	7 94	10.00
Facility B (BCC)	952 00	680.00	714.67	7 34	12.14	8.00	5 50	0.01	0.02	7.06	8 33	8.00
Facility A (ACC)	2290 00	677.00	960.33	9.45	5.83	8.43	0.14	0.00	0.08	7.85	8 88	8.43
Facility K (KCC)	8.70	3.14	6.00	8 30	7.55	8.18	28.15	0.00	0.35	6.27	10 23	8.18
Facility M (MAD)	6.49	0.50	3.36	9 62	6.71	11.93	9 02	0.00	0.00	6.56	11 87	11.93
Facility M (MAS)	30 84	0.62	2.34	11 99	7.13	11.58	7.49	0.00	0.02	6.73	11.14	11.58
Facility U (UGF)	81 98	17.09	33.81	6.76	10.55	7.12	0 64	0.00	0.00	5.61	6.77	7.12

Facility	Mo						Pb					
	Mo max Val	Mo min Val	Mo ownpHVal	Mo pH at Max	Mo pH at Min	Mo ownph	Pb max Val	Pb min Val	Pb ownpHVal	Pb pH at Max	Pb pH at Min	Pb ownph
Gypsum												
Facility U (UAU)	505 82	52.79	61.43	5.65	10 65	5.85	1.24	0.37	0.49	12.13	9.19	5.85
Facility T (TAU)	58 50	0.98	11.30	7.42	6 25	7.11	16.85	0.12	0.53	7.47	7.24	7.11
Facility T (TAW)	84 88	0.38	9.09	7.95	7.19	6.02	6.03	0.12	0.12	5 52	11.07	6.02
Facility W (WAU)	53 69	4.89	7.75	6.83	5 95	6.84	16.33	1.55	4.04	12 07	7.74	6.84
Facility W (WAW)	21 57	3.40	4.52	12.00	5.75	6.33	2.26	0.12	0.12	5 87	10.41	6.33
Facility Aa (AaAU)	11 67	1.84	1.84	5.86	7.14	7.14	4.83	2.03	2.03	5 86	7.14	7.14
Facility Aa (AaAW)	13.41	2.45	3.47	12.00	5 50	6.86	1.48	0.12	0.12	12 00	5.50	6.86
Facility Da (DaAW)	1254 60	5.26	6.25	5.54	5 65	7.74	9.70	0.12	0.12	5 54	12.03	7.74
Facility P (PAD)	12.73	1.04	2.75	11.76	5 68	6.66	0.12	0.12	0.12	5 68	5.68	6.66
Facility N (NAU)	154.11	13.72	15.15	7.20	6 05	7.18	5.35	0.12	0.12	7 20	11.91	7.18
Facility N (NAW)	110.17	7.65	9.54	7.18	6 87	7.13	0.50	0.12	0.12	10.72	5.65	7.13
Facility S (SAU)	1944 08	119.16	187.31	7.42	5.42	7.13	14.40	0.12	0.27	12.11	9.02	7.13
Facility S (SAW)	135 21	65.28	79.45	5.60	6 02	7.61	1.28	0.12	0.12	12 09	5.60	7.61
Facility O (OAU)	174 94	3.37	18.76	7.44	5.49	7.53	0.48	0.12	0.19	5 84	7.44	7.53
Facility O (OAW)	130.12	2.19	12.29	8.05	5 83	7.33	0.47	0.12	0.12	7 31	7.44	7.33
Facility R (RAU)	27 32	2.05	5.36	11.95	5 57	6.92	2.40	0.93	1.35	5 57	11.04	6.92
Facility Q (QAU)	392 32	12.16	14.28	6.68	8.12	6.89	12.05	0.12	0.68	6.41	10.49	6.89
Facility X (XAU)	167 56	10.13	15.05	7.20	5 67	7.73	14.91	1.94	2.10	7 20	7.01	7.73
Facility X (XAW)	16 59	7.23	7.23	6.37	6 03	6.03	1.32	0.44	0.53	6 37	10.14	6.03
Facility Ca (CaAW)	967 52	58.72	91.55	6.95	5 81	7.75	12.67	2.60	2.60	6 95	7.75	7.75
Scrubber Sludge												
Facility B (DGD)	1313 98	58.82	134.74	8.24	11 59	9.13	2.01	0.12	0.32	8 51	7.75	9.13
Facility A (CGD)	115 31	2.11	10.24	7.28	5.74	7.30	0.93	0.12	0.12	8 98	7.23	7.30
Facility B (BGD)	418 23	52.77	61.93	9.40	10 06	10.11	1.64	0.12	0.33	12 21	7.19	10.11
Facility A (AGD)	749 81	0.38	36.53	7.70	5.48	6.78	0.50	0.28	0.35	7.13	11.67	6.78
Facility K (KGD)	1076.43	148.41	159.77	7.85	11 00	10.99	24.98	0.12	0.57	8 34	5.69	10.99
Blended CCRs												
Facility B (DCC)	458 35	136.56	138.36	12.12	12 26	12.19	7.20	0.12	3.69	12 21	9.49	12.19
Facility A (CCC)	15544 55	520.48	647.65	8.45	10 81	10.00	0.65	0.12	0.12	8 96	9.61	10.00
Facility B (BCC)	1717.79	74.39	116.15	5.84	10 83	8.00	1.24	0.35	0.56	7 34	8.89	8.00
Facility A (ACC)	38083 83	137.98	241.33	9.45	5 60	8.43	0.68	0.30	0.57	8.72	6.77	8.43
Facility K (KCC)	235.43	11.51	12.06	8.24	8 67	8.18	2.03	0.41	0.45	7.79	8.67	8.18
Facility M (MAD)	1082.17	159.62	574.76	7.90	12 09	11.93	46.53	0.12	35.06	12 28	6.16	11.93
Facility M (MAS)	11073 83	852.04	1164.91	11.94	7.13	11.58	5.40	0.12	1.14	11 99	10.26	11.58
Facility U (UGF)	1199 24	112.34	116.63	6.76	10 21	7.12	1.85	0.12	0.12	6.76	6.77	7.12

Facility	PH						Sb					
	PH max Val	PH min Val	PH ownpHVal	PH pH at Max	PH pH at Min	PH ownph	Sb max Val	Sb min Val	Sb ownpHVal	Sb pH at Max	Sb pH at Min	Sb ownph
Gypsum												
Facility U (UAU)	12.13	5.65	5.85	12.13	5 65	5.85	5.31	0.25	2.63	5.65	12.13	5.85
Facility T (TAU)	12 26	5.42	7.11	12.26	5.42	7.11	2.67	0.52	1.39	7.47	5.42	7.11
Facility T (TAW)	12.16	5.43	6.02	12.16	5.43	6.02	2.71	0.46	1.44	5.52	5 64	6.02
Facility W (WAU)	12 09	5.53	6.84	12.09	5 53	6.84	5.26	0.98	1.13	6.84	5 95	6.84
Facility W (WAW)	12 00	5.49	6.33	12.00	5.49	6.33	2.85	0.60	0.91	10.16	12 00	6.33
Facility Aa (AaAU)	11 95	5.86	7.14	11.95	5 86	7.14	0.86	0.04	0.04	5.86	11 95	7.14
Facility Aa (AaAW)	12 00	5.50	6.86	12.00	5 50	6.86	0.37	0.04	0.04	5.50	12 00	6.86
Facility Da (DaAW)	12 03	5.54	7.74	12.03	5 54	7.74	332.39	0.24	0.55	5.54	12 03	7.74
Facility P (PAD)	11.76	5.68	6.66	11.76	5 68	6.66	1.45	0.45	0.55	7.35	9.75	6.66
Facility N (NAU)	11 96	6.05	7.18	11.96	6 05	7.18	7.10	0.04	0.04	7.18	7.18	7.18
Facility N (NAW)	11.45	5.65	7.13	11.45	5 65	7.13	3.81	0.04	0.21	7.28	5 65	7.13
Facility S (SAU)	12.16	5.42	7.13	12.16	5.42	7.13	54.20	4.85	5.34	7.47	7 95	7.13
Facility S (SAW)	12 09	5.60	7.61	12.09	5 60	7.61	5.48	0.04	4.36	10.29	10 92	7.61
Facility O (OAU)	12 01	5.49	7.53	12.01	5.49	7.53	7.05	0.04	0.95	7.16	7 33	7.53
Facility O (OAW)	11 66	5.83	7.33	11.66	5 83	7.33	6.82	0.32	0.64	7.95	6 91	7.33
Facility R (RAU)	12 05	5.57	6.92	12.05	5 57	6.92	2.96	0.85	1.07	9.45	6 58	6.92
Facility Q (QAU)	11 92	5.75	6.89	11.92	5.75	6.89	11.75	2.48	2.53	6.41	6 82	6.89
Facility X (XAU)	12 25	5.67	7.73	12.25	5 67	7.73	13.29	1.16	1.16	7.20	7.73	7.73
Facility X (XAW)	12 25	6.03	6.03	12.25	6 03	6.03	2.72	0.75	0.75	11.29	6 03	6.03
Facility Ca (CaAW)	12.13	5.81	7.75	12.13	5 81	7.75	18.38	2.32	2.32	6.95	7.75	7.75
Scrubber Sludge												
Facility B (DGD)	12.16	5.86	9.13	12.16	5 86	9.13	12.91	0.99	5.44	8.00	12 09	9.13
Facility A (CGD)	12.14	5.74	7.30	12.14	5.74	7.30	95.15	0.86	1.41	7.19	8 99	7.30
Facility B (BGD)	12 24	6.39	10.11	12.24	6 39	10.11	12.79	0.48	3.05	7.19	9.40	10.11
Facility A (AGD)	12 04	5.48	6.78	12.04	5.48	6.78	9.44	1.21	2.94	7.70	11 69	6.78
Facility K (KGD)	12 02	5.69	10.99	12.02	5 69	10.99	10.72	1.21	1.25	8.00	11 00	10.99
Blended CCRs												
Facility B (DCC)	12 33	6.25	12.19	12.33	6 25	12.19	15.13	0.15	1.76	6.57	12 33	12.19
Facility A (CCC)	11 52	5.87	10.00	11.52	5 87	10.00	199.42	0.71	10.00	8.07	10 81	10.00
Facility B (BCC)	12.14	5.84	8.00	12.14	5 84	8.00	13.60	3.57	4.52	5.84	6 83	8.00
Facility A (ACC)	11 39	5.60	8.43	11.39	5 60	8.43	144.88	0.04	56.25	7.85	11 39	8.43
Facility K (KCC)	11 54	6.27	8.18	11.54	6 27	8.18	4.49	0.94	1.13	8.30	7 98	8.18
Facility M (MAD)	12 28	5.42	11.93	12.28	5.42	11.93	107.86	0.31	1.65	7.54	12 03	11.93
Facility M (MAS)	12 06	6.73	11.58	12.06	6.73	11.58	91.72	2.16	5.52	7.26	11.12	11.58
Facility U (UGF)	12 07	5.61	7.12	12.07	5 61	7.12	10.82	0.04	0.73	5.61	10 21	7.12

Facility	Se						Tl					
	Se max Val	Se min Val	Se ownpHVal	Se pH at Max	Se pH at Min	Se ownph	Tl max Val	Tl min Val	Tl ownpHVal	Tl pH at Max	Tl pH at Min	Tl ownph
Gypsum												
Facility U (UAU)	92 50	52.90	57.17	12.13	9.19	5.85	11.13	3.62	3 62	12.13	5.85	5 85
Facility T (TAU)	205 94	32.97	48.17	12.16	7.95	7.11	12.03	3.60	4.43	5.71	7.24	7.11
Facility T (TAW)	174.71	17.40	17.57	12.16	6.39	6.02	11.02	0.26	1.72	5.52	8.63	6 02
Facility W (WAU)	913 52	23.17	27.27	5.95	7.11	6.84	30.12	3.58	14.79	5.95	7.35	6 84
Facility W (WAW)	217.78	20.41	22.27	12.00	5.78	6.33	4.45	0.81	1.11	5.99	5.78	6 33
Facility Aa (AaAU)	795.77	248.42	251.48	5.86	9.14	7.14	10.20	5.33	5 33	5.86	7.14	7.14
Facility Aa (AaAW)	1514.72	183.63	183.63	12.00	6.86	6.86	0.26	0.26	0 26	12.00	12.00	6 86
Facility Da (DaAW)	805 54	37.98	38.44	5.54	9.03	7.74	1099.26	0.26	0 26	5.54	7.74	7.74
Facility P (PAD)	235 55	184.40	193.08	5.82	8.10	6.66	0.26	0.26	0 26	5.68	5.68	6 66
Facility N (NAU)	151 30	3.63	18.51	6.26	6.92	7.18	16.14	3.44	3 64	7.20	11.96	7.18
Facility N (NAW)	160 63	10.51	13.53	5.70	7.24	7.13	1.53	0.26	0 26	7.18	5.65	7.13
Facility S (SAU)	1682.45	139.09	254.59	7.47	6.10	7.13	18.16	1.62	10 84	7.47	12.11	7.13
Facility S (SAW)	99 51	18.05	19.81	10.89	9.02	7.61	3.68	0.26	1.48	9.46	6.49	7 61
Facility O (OAU)	670 62	83.43	88.76	7.33	8.49	7.53	11.99	1.24	1.44	7.33	7.50	7 53
Facility O (OAW)	151 38	23.31	26.08	8.05	8.93	7.33	1.35	0.26	0 26	8.05	6.91	7 33
Facility R (RAU)	137 81	71.64	71.78	11.04	6.86	6.92	3.30	0.71	0 83	9.45	6.86	6 92
Facility Q (QAU)	2995.47	292.96	324.89	6.68	8.12	6.89	3.99	1.00	1 60	8.12	9.35	6 89
Facility X (XAU)	3226 90	397.48	712.19	7.20	12.25	7.73	14.61	8.85	11 02	7.20	6.42	7.73
Facility X (XAW)	293 09	55.45	71.65	11.29	6.85	6.03	3.34	0.58	0 81	6.37	11.29	6 03
Facility Ca (CaAW)	15523 31	1670.10	2063.86	6.95	7.32	7.75	16.44	10.28	10 28	6.95	7.75	7.75
Scrubber Sludge												
Facility B (DGD)	197.70	19.01	21.89	8.24	9.29	9.13	25.63	4.10	4 90	7.06	10.32	9.13
Facility A (CGD)	162 94	6.99	7.54	5.74	7.03	7.30	19.85	0.26	2.44	7.25	6.21	7 30
Facility B (BGD)	54 20	2.22	2.31	7.03	11.54	10.11	34.32	4.20	4.46	9.50	10.70	10.11
Facility A (AGD)	27.70	7.01	18.20	5.48	8.09	6.78	87.59	4.39	6.75	8.15	11.67	6.78
Facility K (KGD)	276.73	5.54	7.21	5.69	10.97	10.99	109.92	14.02	14.48	6.03	11.00	10 99
Blended CCRs												
Facility B (DCC)	146.13	13.96	16.27	6.25	12.20	12.19	25.81	1.98	15 63	12.20	12.33	12 23
Facility A (CCC)	395 37	10.02	16.24	7.93	10.75	10.00	36.83	3.21	4 98	6.62	11.52	10 00
Facility B (BCC)	115 00	13.00	32.10	8.54	7.90	8.00	14.01	3.02	4 23	7.34	12.04	8 00
Facility A (ACC)	286 00	16.20	83.00	7.91	11.39	8.43	35.27	4.15	7.10	5.60	11.39	8.43
Facility K (KCC)	334 99	5.72	22.63	8.24	9.19	8.18	4.44	2.84	2 98	8.24	8.67	8.18
Facility M (MAD)	967 20	8.83	10.39	5.74	12.28	11.93	103.19	8.11	10 37	5.74	12.28	11 93
Facility M (MAS)	473 53	27.48	43.52	11.99	11.65	11.58	41.31	6.14	7 20	6.73	11.50	11 58
Facility U (UGF)	113 57	9.96	17.63	5.61	10.55	7.12	23.82	2.57	4 84	5.61	8.67	7.12

Appendix J
Summary of Statistics (Percentiles)

	Max Eluate Concentrations for 5.4 ≤ pH ≤ 12.4 [μg/L]					Eluate Concentrations at Own pH [μg/L]				
Al	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	515000	13100	10300	21600	15400	119000	7180	1800	2810	4050
95th percentile	271000	---	9940	21600	15400	106000	---	1750	2810	4050
90th percentile	114000	---	3390	21600	15400	61100	---	785	2810	4050
75th percentile	50400	---	2370	18000	14000	19500	---	407	2580	1620
50th percentile	25400	---	1260	13900	3510	8550	---	179	913	568
25th percentile	13500	---	493	3210	1270	1700	---	59.5	266	153
10th percentile	2560	---	224	3170	321	671	---	6.69	37	9.51
5th percentile	1710	---	55.7	3170	321	404	---	3.82	37	9.51
Min. Conc.	933	7180	48	3170	321	21.4	173	3.7	37	9.51

As	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	18200	32.2	1210	105	3660	3240	28	42.3	18.6	205
95th percentile	6050	---	1160	105	3660	1380	---	40.7	18.6	205
90th percentile	1890	---	184	105	3660	416	---	11.4	18.6	205
75th percentile	1210	---	18.4	84.4	2160	129	---	4.42	12.5	35.7
50th percentile	225	---	6.34	22.7	80.2	34	---	1.11	5.8	14.8
25th percentile	54.3	---	4.11	5.51	41.5	6.46	---	0.413	0.391	3.36
10th percentile	7.84	---	2.2	3.07	6.98	0.732	---	0.32	0.32	0.32
5th percentile	0.904	---	1.36	3.07	6.98	0.32	---	0.32	0.32	0.32
Min. Conc.	0.32	28	1.32	3.07	6.98	0.32	1.8	0.32	0.32	0.32

B	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	273000	23700	268000	213000	223000	38900	12700	21800	6270	10900
95th percentile	198000	---	261000	213000	223000	34100	---	21300	6270	10900
90th percentile	61700	---	112000	213000	223000	19200	---	10700	6270	10900
75th percentile	35900	---	61200	138000	41600	7650	---	4820	5820	5020
50th percentile	15000	---	3930	43100	21300	3030	---	572	3330	807
25th percentile	3270	---	1310	17500	8680	1520	---	171	1290	290
10th percentile	2160	---	435	14200	3380	419	---	49.7	726	112
5th percentile	1970	---	147	14200	3380	286	---	13.6	726	112
Min. Conc.	1550	12700	134	14200	3380	256	90.9	11.8	726	112

Ba	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	671000	451000	565	2310	10200	219000	168000	164	176	2250
95th percentile	288000	---	558	2310	10200	79600	---	162	176	2250
90th percentile	77200	---	405	2310	10200	17000	---	128	176	2250
75th percentile	3330	---	159	2040	4890	1730	---	98.6	152	1720
50th percentile	909	---	116	402	1070	349	---	80.9	113	146
25th percentile	292	---	87	100	257	116	---	67.7	37	54.1
10th percentile	212	---	77.5	82.7	154	79.1	---	46.4	30.4	15.2
5th percentile	175	---	72.1	82.7	154	69.2	---	33.1	30.4	15.2
Min. Conc.	168	6300	71.9	82.7	154	69	6300	32.4	30.4	15.2

	Max Eluate Concentrations for 5.4 ≤ pH ≤ 12.4 [µg/L]					Eluate Concentrations at Own pH [µg/L]				
Cd	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	323	39.7	371	4.11	32	75.8	39.7	6.03	1.01	3.3
95th percentile	193	---	355	4.11	32	55.8	---	5.97	1.01	3.3
90th percentile	116	---	49.4	4.11	32	40.7	---	4.56	1.01	3.3
75th percentile	36.8	---	11.2	2.85	18.1	10.2	---	1.02	0.603	1.93
50th percentile	15.2	---	2.73	1.44	10.1	3.64	---	0.318	0.085	0.457
25th percentile	3.28	---	1.01	0.925	3.05	0.458	---	0.085	0.085	0.085
10th percentile	1.04	---	0.127	0.677	1.08	0.085	---	0.085	0.085	0.085
5th percentile	0.803	---	0.085	0.677	1.08	0.085	---	0.085	0.085	0.085
Min. Conc.	0.698	10	0.085	0.677	1.08	0.085	0.822	0.085	0.085	0.085

Co	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	503	2690	1150	245	150	249	2690	17.1	51.2	5.06
95th percentile	407	---	1100	245	150	204	---	16.8	51.2	5.06
90th percentile	253	---	99.7	245	150	148	---	11.5	51.2	5.06
75th percentile	138	---	60.1	169	123	22.1	---	3.18	26.1	3.56
50th percentile	63.3	---	12.9	40.3	102	0.773	---	2.04	0.205	1.17
25th percentile	29	---	3.7	7.59	47.4	0.205	---	1.31	0.205	0.276
10th percentile	7.1	---	2.14	6.46	7.82	0.205	---	0.205	0.205	0.205
5th percentile	1.81	---	0.3	6.46	7.82	0.205	---	0.205	0.205	0.205
Min. Conc.	0.205	1460	0.205	6.46	7.82	0.205	5.26	0.205	0.205	0.205

Cr	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	7370	9120	241	831	2290	1880	9120	34.4	592	960
95th percentile	5940	---	233	831	2290	1300	---	33.9	592	960
90th percentile	3560	---	82.9	831	2290	741	---	23.5	592	960
75th percentile	1880	---	38	812	1930	324	---	15	410	589
50th percentile	394	---	22.2	24.3	56.4	48	---	11	10.6	23.9
25th percentile	93.4	---	17.4	13.4	12	14.8	---	4.18	7.2	4.02
10th percentile	44.7	---	9.71	9.85	6.49	1.07	---	0.338	4.33	2.34
5th percentile	25.5	---	6.28	9.85	6.49	0.439	---	0.25	4.33	2.34
Min. Conc.	19	435	6.11	9.85	6.49	0.25	252	0.25	4.33	2.34

Hg	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	0.489	1.97	0.657	8.99	28.1	0.116	0.703	0.0287	0.0611	0.348
95th percentile	0.437	---	0.634	8.99	28.1	0.087	---	0.0285	0.0611	0.348
90th percentile	0.198	---	0.188	8.99	28.1	0.0422	---	0.0244	0.0611	0.348
75th percentile	0.117	---	0.0859	7.15	8.64	0.0242	---	0.00848	0.0503	0.0946
50th percentile	0.0467	---	0.0318	1.58	3.48	0.0143	---	0.003	0.0347	0.0215
25th percentile	0.0151	---	0.0157	0.0898	0.321	0.00544	---	0.003	0.021	0.00655
10th percentile	0.003	---	0.00935	0.0791	0.137	0.003	---	0.00207	0.0168	0.00207
5th percentile	0.003	---	0.0033	0.0791	0.137	0.001	---	0.002	0.0168	0.00207
Min. Conc.	0.003	0.703	0.003	0.0791	0.137	0.001	0.0203	0.002	0.0168	0.00207

	Max Eluate Concentrations for 5.4 ≤ pH ≤ 12.4 [μg/L]					Eluate Concentrations at Own pH [μg/L]				
Mo	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	126000	9200	1940	1310	38100	14400	9200	187	160	1160
95th percentile	72900	---	1910	1310	38100	7010	---	183	160	1160
90th percentile	40800	---	1230	1310	38100	3070	---	90.3	160	1160
75th percentile	11900	---	338	1200	14400	1960	---	17.9	147	629
50th percentile	3020	---	120	750	1460	587	---	10.4	61.9	190
25th percentile	1930	---	23	267	614	115	---	5.58	23.4	116
10th percentile	781	---	12.8	115	235	20.8	---	2.83	10.2	12.1
5th percentile	692	---	11.7	115	235	6.19	---	1.88	10.2	12.1
Min. Conc.	652	764	11.7	115	235	0.5	188	1.84	10.2	12.1

Pb	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	35.3	59	16.9	25	46.5	11.5	59	4.04	0.567	35.1
95th percentile	18	---	16.8	25	46.5	6.77	---	3.97	0.567	35.1
90th percentile	7.83	---	16.2	25	46.5	4.17	---	2.55	0.567	35.1
75th percentile	4.08	---	12.5	13.5	6.75	2	---	1.18	0.46	3.05
50th percentile	2.15	---	3.62	1.64	1.94	0.46	---	0.229	0.333	0.566
25th percentile	0.831	---	1.25	0.715	0.821	0.115	---	0.115	0.217	0.198
10th percentile	0.363	---	0.471	0.499	0.649	0.115	---	0.115	0.115	0.115
5th percentile	0.224	---	0.133	0.499	0.649	0.115	---	0.115	0.115	0.115
Min. Conc.	0.115	26.6	0.115	0.499	0.649	0.115	6.89	0.115	0.115	0.115

Sb	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	11100	15.6	332	95.2	199	548	13.6	5.34	5.44	56.3
95th percentile	6020	---	318	95.2	199	432	---	5.29	5.44	56.3
90th percentile	2250	---	50.6	95.2	199	131	---	4.19	5.44	56.3
75th percentile	202	---	10.6	54	136	55.3	---	2.1	4.25	8.88
50th percentile	133	---	5.29	12.8	53.4	29.3	---	1.01	2.94	3.14
25th percentile	59	---	2.71	10.1	11.5	6.28	---	0.551	1.33	1.26
10th percentile	20	---	0.915	9.44	4.49	3.46	---	0.04	1.25	0.732
5th percentile	4.41	---	0.391	9.44	4.49	0.612	---	0.04	1.25	0.732
Min. Conc.	1.96	13.6	0.366	9.44	4.49	0.565	0.673	0.04	1.25	0.732

Se	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	28800	1140	15500	277	967	3290	952	2060	21.9	83
95th percentile	16300	---	14900	277	967	3130	---	2000	21.9	83
90th percentile	5600	---	3200	277	967	2290	---	673	21.9	83
75th percentile	2500	---	1360	237	454	273	---	237	20	40.7
50th percentile	634	---	264	163	310	57.9	---	64.4	7.54	20.1
25th percentile	212	---	154	41	123	24.9	---	23.2	4.76	16.2
10th percentile	80.2	---	103	27.7	114	12.3	---	17.7	2.31	10.4
5th percentile	44.7	---	92.8	27.7	114	7.68	---	13.7	2.31	10.4
Min. Conc.	41.6	952	92.5	27.7	114	5.85	83.1	13.5	2.31	10.4

I/A

	Max Eluate Concentrations for 5.4 ≤ pH ≤ 12.4 [μg/L]					Eluate Concentrations at Own pH [μg/L]				
Tl	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs	Fly Ash	SDA	Gypsum	FGD Residue	Blended CCRs
Max. Conc.	787	15.1	1100	110	103	193	15.1	14.8	14.5	15.6
95th percentile	620	---	1050	110	103	137	---	14.6	14.5	15.6
90th percentile	426	---	28.9	110	103	95.6	---	11	14.5	15.6
75th percentile	193	---	15.8	98.8	40.2	36.2	---	5.1	10.6	9.58
50th percentile	40.9	---	10.6	34.3	30.5	6.06	---	1.54	4.9	6.04
25th percentile	14.6	---	3.31	22.7	16.5	2.13	---	0.395	3.45	4.38
10th percentile	5.34	---	0.365	19.8	4.44	0.255	---	0.255	2.44	2.98
5th percentile	3.05	---	0.255	19.8	4.44	0.255	---	0.255	2.44	2.98
Min. Conc.	1.54	12	0.255	19.8	4.44	0.255	1.69	0.255	2.44	2.98

Appendix K
Outliers

Eluate Observations Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
CFA	SR02	A	Cd	22.3
CFA	SR02	A	Co	0.73
CGD	SR02	B	Mo	9.42
CGD	SR02	B	Sb	11.1
FFA	SR03	B	Ba	1180
FFA	SR03	B	Cd	306
FFA	SR03	B	Co	0.205
FFA	SR03	B	Pb	708
FFA	SR03	B	Se	2380
GAT	SR02	B	Ba	1370
GAT	SR02	B	Cd	194
GAT	SR02	B	Co	5.62
GAT	SR02	B	Cr	51.6
GAT	SR02	B	Pb	11.9
GAT	SR02	B	Pb	211
GAT	SR02	B	Tl	15.8
JAB	SR02	B	Cd	507
JAB	SR02	B	Pb	134
JAT	SR02	B	Cd	129
JAT	SR02	B	Cd	595
JAT	SR02	B	Cd	458
KFA	SR03	B	As	2710
KFA	SR03	B	Se	15800
PPB	SR02	B	Sb	2.35
QAU	SR02	B	Al	47200
TAW	SR02	B	Cr	292
WFC	SR02	A	Co	12.4
WFC	SR02	A	Cr	36.5

pH Outlier Observations

Material	Leaching Test	Replicate Code	pH
AFA	SR02	A	8.401
AGD	SR02	C	1.849
AGD	SR02	C	2.578
AGD	SR02	C	2.029
AGD	SR02	C	2.322
AGD	SR02	C	1.651
AGD	SR02	C	1.345
AGD	SR02	C	3.761
BCC	SR02	C	2.713
BCC	SR02	C	3.742
BFA	SR02	C	8.358
BGD	SR02	B	7.614
BPB	SR02	A	14.319
BPB	SR02	B	14.191
BPB	SR02	C	13.497
EFA	SR02	B	5.3
KFA	SR02	B	5.05
MAD	SR02	C	3.63
NAU	SR02	B	4.12
VSD	SR02	B	2.88

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
AFA	SR02	A	Al	7570
AFA	SR02	A	As	57.9
AFA	SR02	A	B	557
AFA	SR02	A	Ba	312
AFA	SR02	A	Cd	0.608
AFA	SR02	A	Co	8.43
AFA	SR02	A	Cr	1310
AFA	SR02	A	Hg	0.213
AFA	SR02	A	Mo	877
AFA	SR02	A	Pb	0.494
AFA	SR02	A	Sb	31.4
AFA	SR02	A	Se	83
AFA	SR02	A	Tl	3.33
AGD	SR02	C	Al	34800
AGD	SR02	C	Al	24700
AGD	SR02	C	Al	22000
AGD	SR02	C	Al	43800
AGD	SR02	C	Al	9580
AGD	SR02	C	Al	52800
AGD	SR02	C	Al	39700
AGD	SR02	C	As	13.3
AGD	SR02	C	As	243
AGD	SR02	C	As	6.11
AGD	SR02	C	As	6.12
AGD	SR02	C	As	129
AGD	SR02	C	As	7.16
AGD	SR02	C	As	9.26
AGD	SR02	C	B	6630
AGD	SR02	C	B	7650
AGD	SR02	C	B	7270
AGD	SR02	C	B	8150
AGD	SR02	C	B	7100
AGD	SR02	C	B	7860
AGD	SR02	C	B	7190
AGD	SR02	C	Ba	80
AGD	SR02	C	Ba	69.7
AGD	SR02	C	Ba	70.4
AGD	SR02	C	Ba	83.8
AGD	SR02	C	Ba	37.2
AGD	SR02	C	Ba	93.7
AGD	SR02	C	Ba	61.8
AGD	SR02	C	Cd	1.7
AGD	SR02	C	Cd	1.97
AGD	SR02	C	Cd	1.66
AGD	SR02	C	Cd	1.93
AGD	SR02	C	Cd	1.77
AGD	SR02	C	Cd	1.75
AGD	SR02	C	Cd	1.96
AGD	SR02	C	Co	79

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
AGD	SR02	C	Co	77
AGD	SR02	C	Co	63.2
AGD	SR02	C	Co	106.00
AGD	SR02	C	Co	90.3
AGD	SR02	C	Co	85
AGD	SR02	C	Co	81.9
AGD	SR02	C	Cr	719
AGD	SR02	C	Cr	787
AGD	SR02	C	Cr	732
AGD	SR02	C	Cr	882
AGD	SR02	C	Cr	848
AGD	SR02	C	Cr	900
AGD	SR02	C	Cr	869
AGD	SR02	C	Hg	0.025
AGD	SR02	C	Hg	0.0281
AGD	SR02	C	Hg	0.0125
AGD	SR02	C	Hg	0.0094
AGD	SR02	C	Hg	0.0094
AGD	SR02	C	Hg	0.0188
AGD	SR02	C	Hg	0.0063
AGD	SR02	C	Mo	61.9
AGD	SR02	C	Mo	117
AGD	SR02	C	Mo	21.6
AGD	SR02	C	Mo	0.38
AGD	SR02	C	Mo	7.91
AGD	SR02	C	Mo	4.09
AGD	SR02	C	Mo	0.38
AGD	SR02	C	Pb	64.4
AGD	SR02	C	Pb	8.28
AGD	SR02	C	Pb	0.338
AGD	SR02	C	Pb	0.475
AGD	SR02	C	Pb	3.28
AGD	SR02	C	Pb	0.463
AGD	SR02	C	Pb	35.2
AGD	SR02	C	Sb	5.01
AGD	SR02	C	Sb	9.55
AGD	SR02	C	Sb	3.65
AGD	SR02	C	Sb	4.15
AGD	SR02	C	Sb	61.3
AGD	SR02	C	Sb	16.1
AGD	SR02	C	Sb	20.6
AGD	SR02	C	Se	119
AGD	SR02	C	Se	19.7
AGD	SR02	C	Se	68
AGD	SR02	C	Se	25.3
AGD	SR02	C	Se	21.1
AGD	SR02	C	Se	37
AGD	SR02	C	Se	20.1
AGD	SR02	C	Tl	6.56

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
AGD	SR02	C	Tl	7.96
AGD	SR02	C	Tl	8.65
AGD	SR02	C	Tl	7.15
AGD	SR02	C	Tl	7.38
AGD	SR02	C	Tl	6.5
AGD	SR02	C	Tl	7.45
BCC	SR02	C	Al	3780
BCC	SR02	C	Al	808
BCC	SR02	C	As	28.4
BCC	SR02	C	As	69.1
BCC	SR02	C	B	7120
BCC	SR02	C	B	8430
BCC	SR02	C	Ba	83.8
BCC	SR02	C	Ba	188
BCC	SR02	C	Cd	7.36
BCC	SR02	C	Cd	9.41
BCC	SR02	C	Co	168
BCC	SR02	C	Co	83.8
BCC	SR02	C	Cr	712
BCC	SR02	C	Cr	703
BCC	SR02	C	Hg	1.52
BCC	SR02	C	Hg	1.3
BCC	SR02	C	Mo	77.4
BCC	SR02	C	Mo	103
BCC	SR02	C	Pb	0.691
BCC	SR02	C	Pb	0.604
BCC	SR02	C	Sb	4.73
BCC	SR02	C	Sb	6.02
BCC	SR02	C	Se	47.4
BCC	SR02	C	Se	60.6
BCC	SR02	C	Tl	7.07
BCC	SR02	C	Tl	9.91
BFA	SR02	C	Al	1210
BFA	SR02	C	As	29.3
BFA	SR02	C	B	7530
BFA	SR02	C	Ba	142
BFA	SR02	C	Cd	1.19
BFA	SR02	C	Co	6.96
BFA	SR02	C	Cr	873
BFA	SR02	C	Hg	0.0125
BFA	SR02	C	Mo	1870
BFA	SR02	C	Pb	0.265
BFA	SR02	C	Sb	6.17
BFA	SR02	C	Se	14.1
BFA	SR02	C	Tl	1.94
BGD	SR02	B	Al	2440
BGD	SR02	B	As	5.54
BGD	SR02	B	B	583
BGD	SR02	B	Ba	162

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
BGD	SR02	B	Cd	0.085
BGD	SR02	B	Co	0.205
BGD	SR02	B	Cr	220
BGD	SR02	B	Hg	0.0219
BGD	SR02	B	Mo	61.4
BGD	SR02	B	Pb	0.345
BGD	SR02	B	Sb	2.79
BGD	SR02	B	Se	2.54
BGD	SR02	B	Tl	4.15
BPB	SR02	A	Al	15.4
BPB	SR02	A	As	2190
BPB	SR02	A	Ba	432
BPB	SR02	A	Cd	43.4
BPB	SR02	A	Co	0.775
BPB	SR02	A	Cr	0.5
BPB	SR02	A	Hg	0.104
BPB	SR02	A	Pb	161
BPB	SR02	A	Se	3230
BPB	SR02	B	Al	14.4
BPB	SR02	B	As	2260
BPB	SR02	B	B	14.8
BPB	SR02	B	Ba	398
BPB	SR02	B	Cd	42.1
BPB	SR02	B	Co	0.752
BPB	SR02	B	Cr	0.5
BPB	SR02	B	Hg	0.0018
BPB	SR02	B	Mo	1.13
BPB	SR02	B	Pb	159
BPB	SR02	B	Sb	4360
BPB	SR02	B	Se	3060
BPB	SR02	B	Tl	189
BPB	SR02	C	Al	9.04
BPB	SR02	C	As	2770
BPB	SR02	C	Ba	413
BPB	SR02	C	Cd	48.8
BPB	SR02	C	Co	0.422
BPB	SR02	C	Cr	0.5
BPB	SR02	C	Hg	0.0018
BPB	SR02	C	Pb	189
BPB	SR02	C	Se	2550
EFA	SR02	B	Al	1.62
EFA	SR02	B	As	20.3
EFA	SR02	B	B	2.46
EFA	SR02	B	Ba	83.4
EFA	SR02	B	Cd	0.482
EFA	SR02	B	Co	1.31
EFA	SR02	B	Cr	4.45
EFA	SR02	B	Hg	0.0018
EFA	SR02	B	Mo	1480

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
EFA	SR02	B	Pb	0.115
EFA	SR02	B	Sb	57.1
EFA	SR02	B	Se	332
EFA	SR02	B	Tl	3.25
KFA	SR02	B	Al	359
KFA	SR02	B	As	114
KFA	SR02	B	B	37700
KFA	SR02	B	Ba	87.4
KFA	SR02	B	Cd	0.085
KFA	SR02	B	Co	1.78
KFA	SR02	B	Cr	6.21
KFA	SR02	B	Hg	0.0156
KFA	SR02	B	Mo	2070
KFA	SR02	B	Pb	0.115
KFA	SR02	B	Sb	34.9
KFA	SR02	B	Se	40.9
KFA	SR02	B	Tl	87.9
MAD	SR02	C	Al	73.5
MAD	SR02	C	As	4320
MAD	SR02	C	B	26300
MAD	SR02	C	Ba	2730
MAD	SR02	C	Cd	4.81
MAD	SR02	C	Co	190
MAD	SR02	C	Cr	0.5
MAD	SR02	C	Hg	7.16
MAD	SR02	C	Mo	0.5
MAD	SR02	C	Pb	8.33
MAD	SR02	C	Sb	75.6
MAD	SR02	C	Se	873
MAD	SR02	C	Tl	182
NAU	SR02	B	Al	341
NAU	SR02	B	As	0.32
NAU	SR02	B	B	2160
NAU	SR02	B	Ba	65.9
NAU	SR02	B	Cd	0.359
NAU	SR02	B	Co	1.44
NAU	SR02	B	Cr	6.04
NAU	SR02	B	Hg	0.0018
NAU	SR02	B	Mo	14.5
NAU	SR02	B	Pb	0.435
NAU	SR02	B	Sb	0.971
NAU	SR02	B	Se	17
NAU	SR02	B	Tl	4.36
VSD	SR02	B	Al	3.92
VSD	SR02	B	As	37.4
VSD	SR02	B	B	27.9
VSD	SR02	B	Ba	8890
VSD	SR02	B	Cd	62.4
VSD	SR02	B	Co	2850

Eluate Concentration Outliers Due to pH Outliers

Material	Leaching Test	Replicate Code	Constituent	Concentration [µg/L]
VSD	SR02	B	Cr	91.1
VSD	SR02	B	Hg	9.58
VSD	SR02	B	Mo	129
VSD	SR02	B	Pb	5.08
VSD	SR02	B	Sb	7.34
VSD	SR02	B	Se	1800
VSD	SR02	B	Tl	8.56

Appendix L

Minimum Attenuation Factors

Individual COPCs

Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

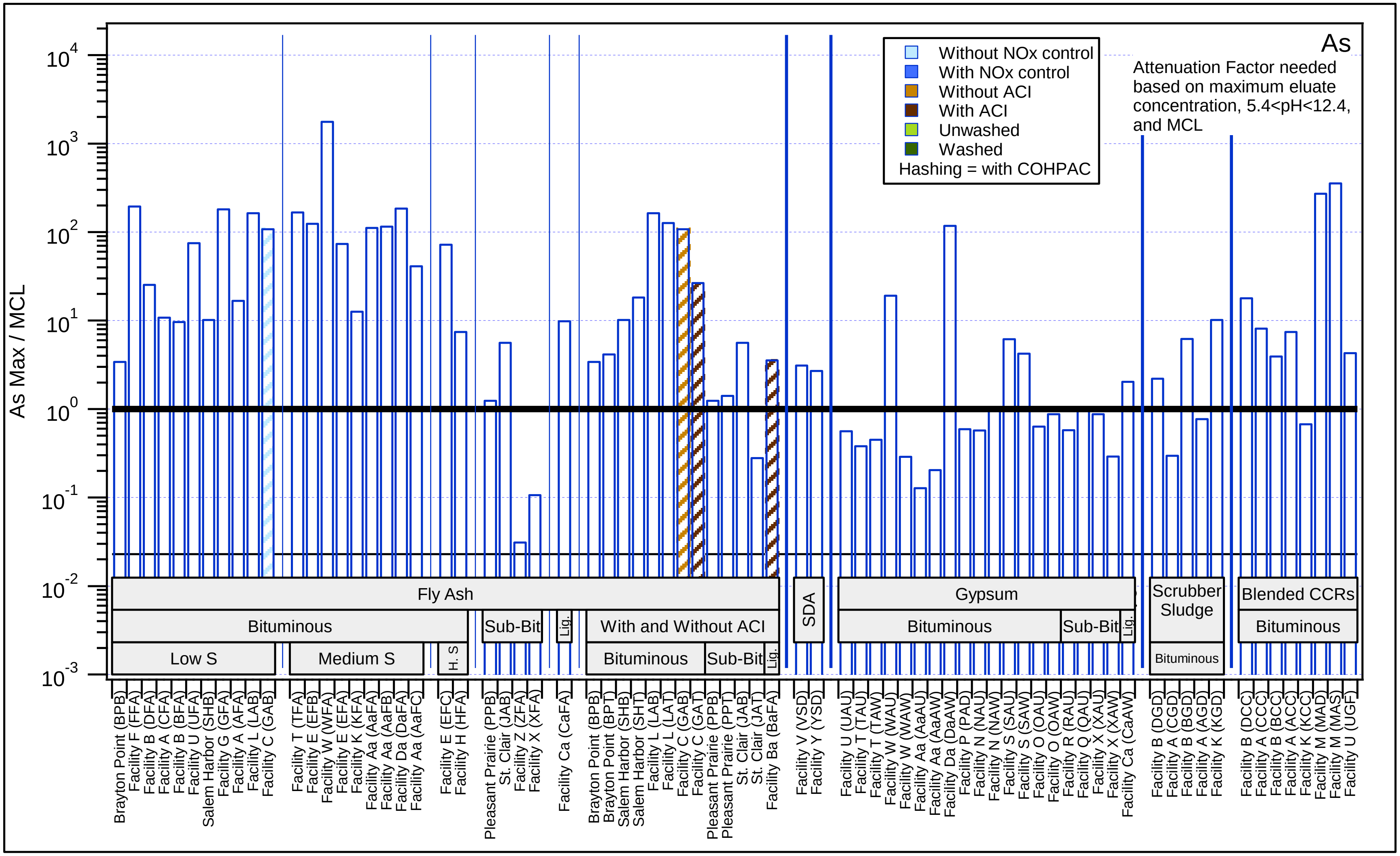


Figure L-1. Arsenic - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

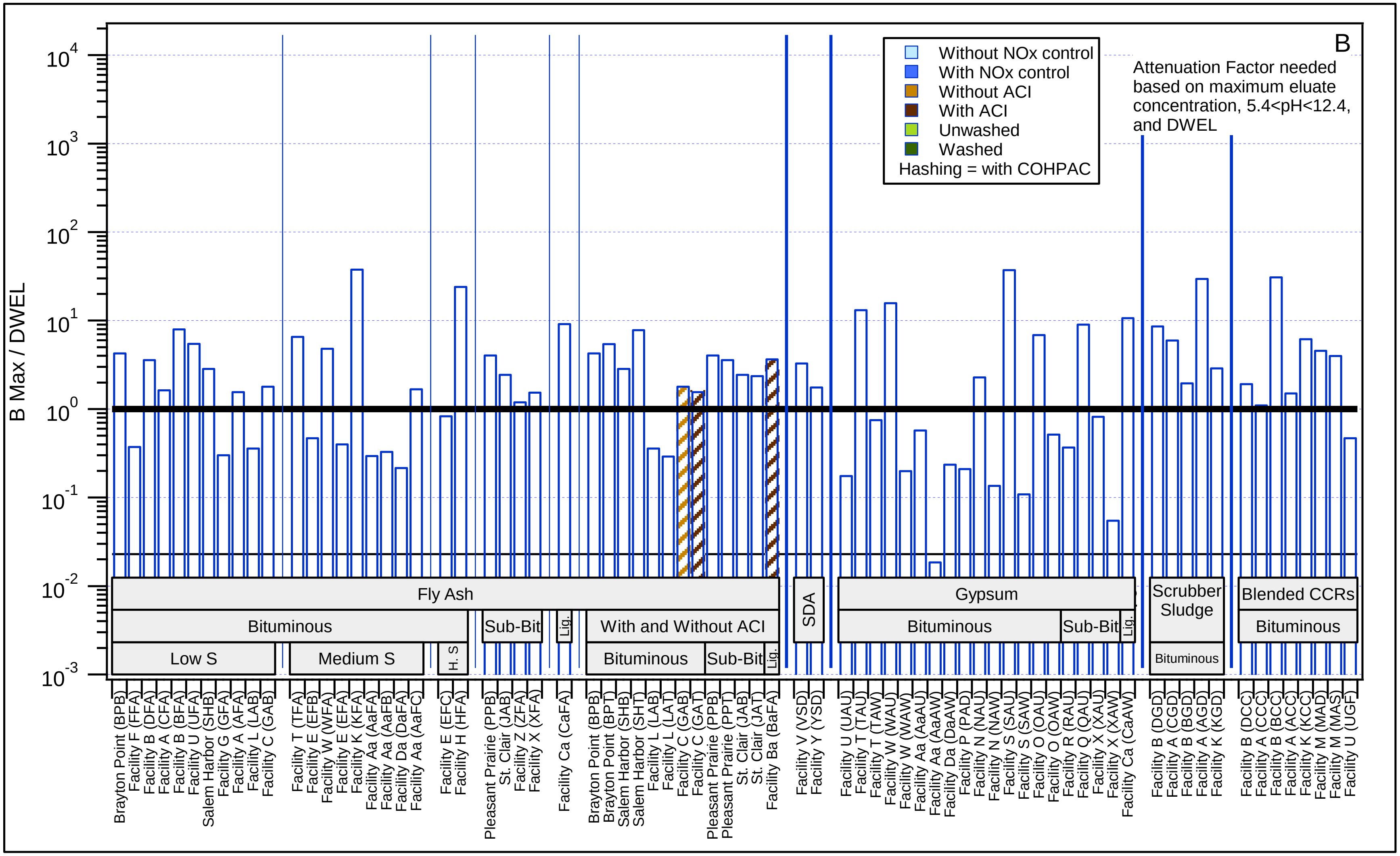


Figure L-2. Boron - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the DWEL for each CCR evaluated in this study.

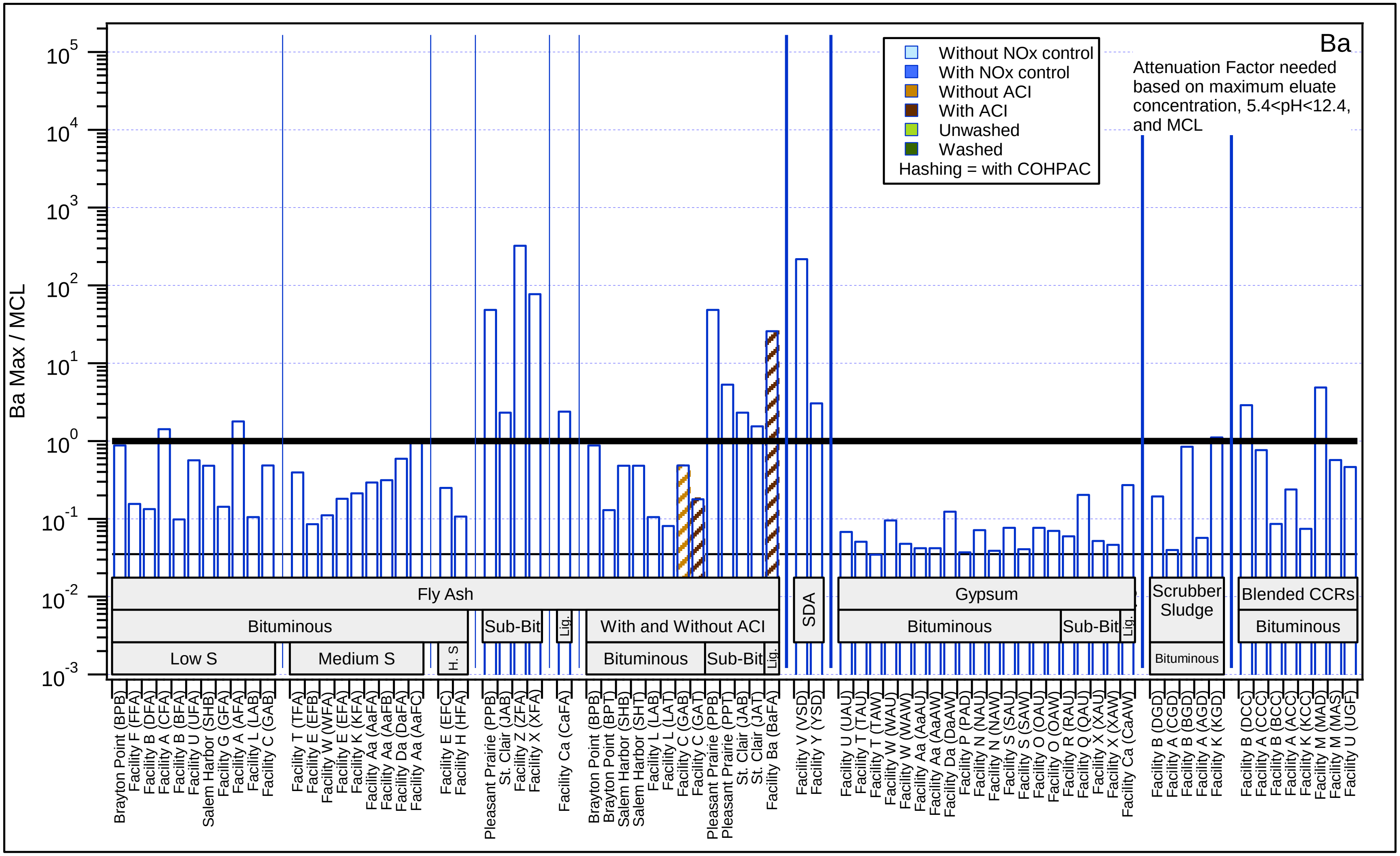


Figure L-3. Barium - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

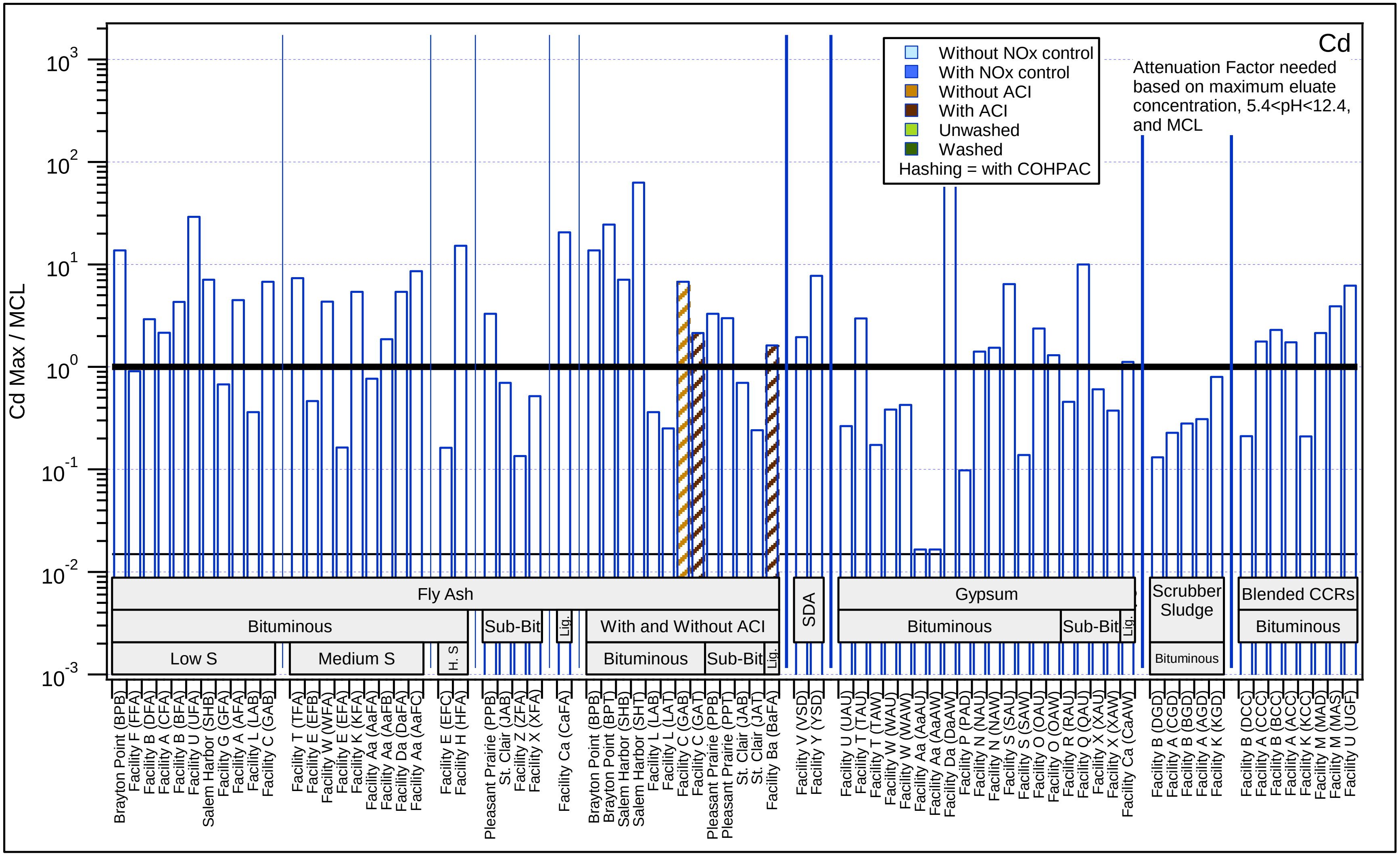


Figure L-4. Cadmium - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

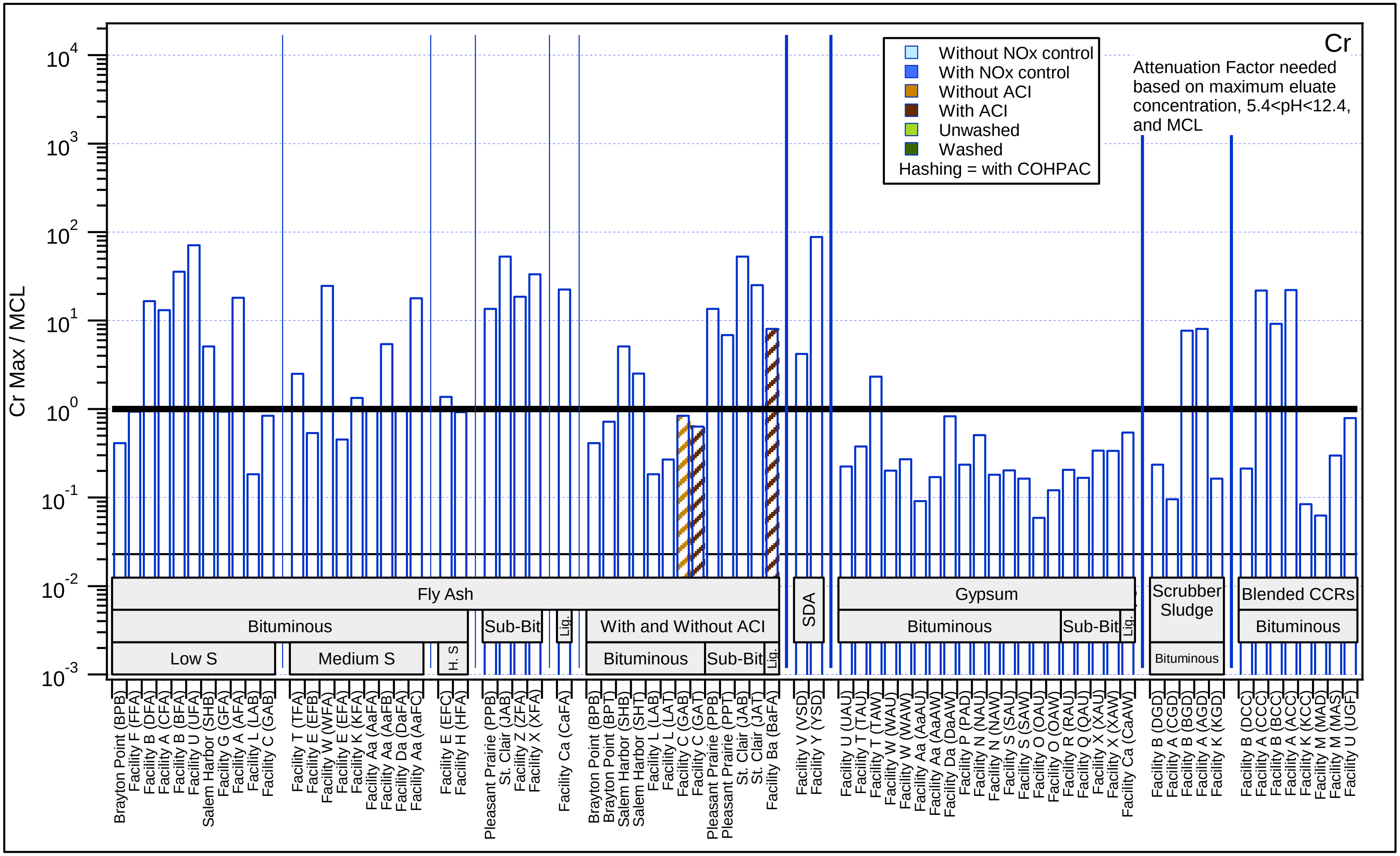


Figure L-5. Chromium - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

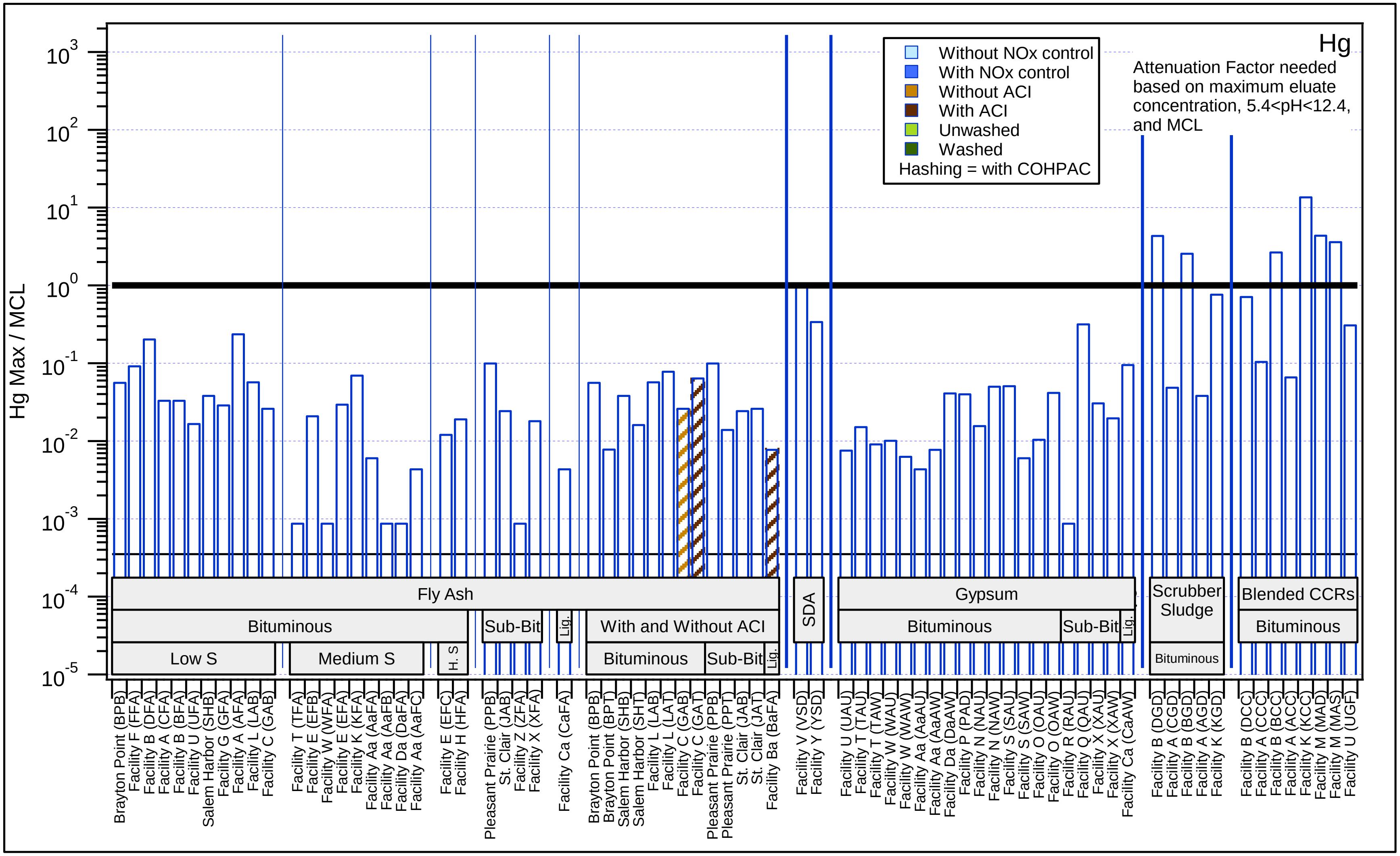


Figure L-6. Mercury - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

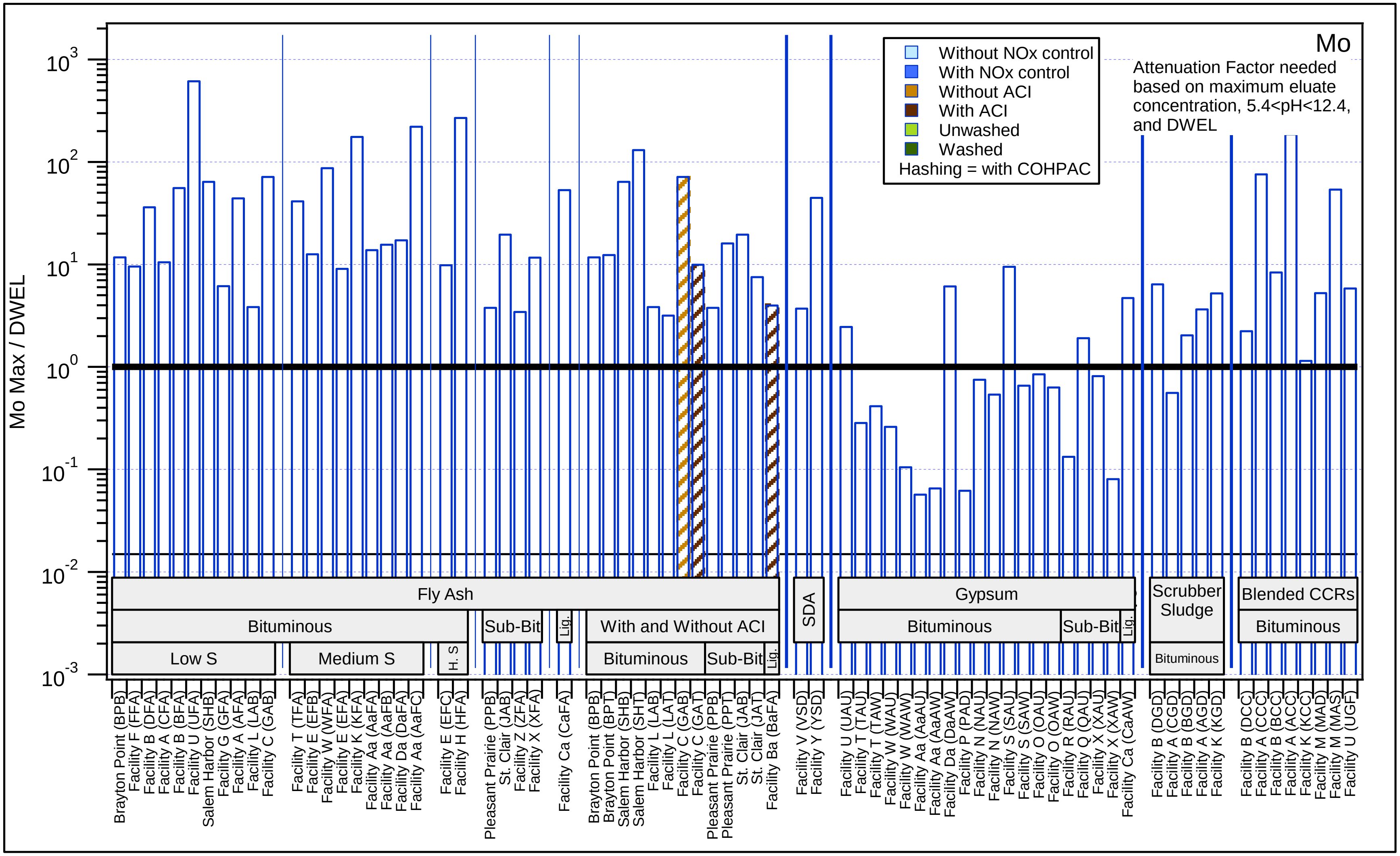


Figure L-7. Molybdenum - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the DWEL for each CCR evaluated in this study.

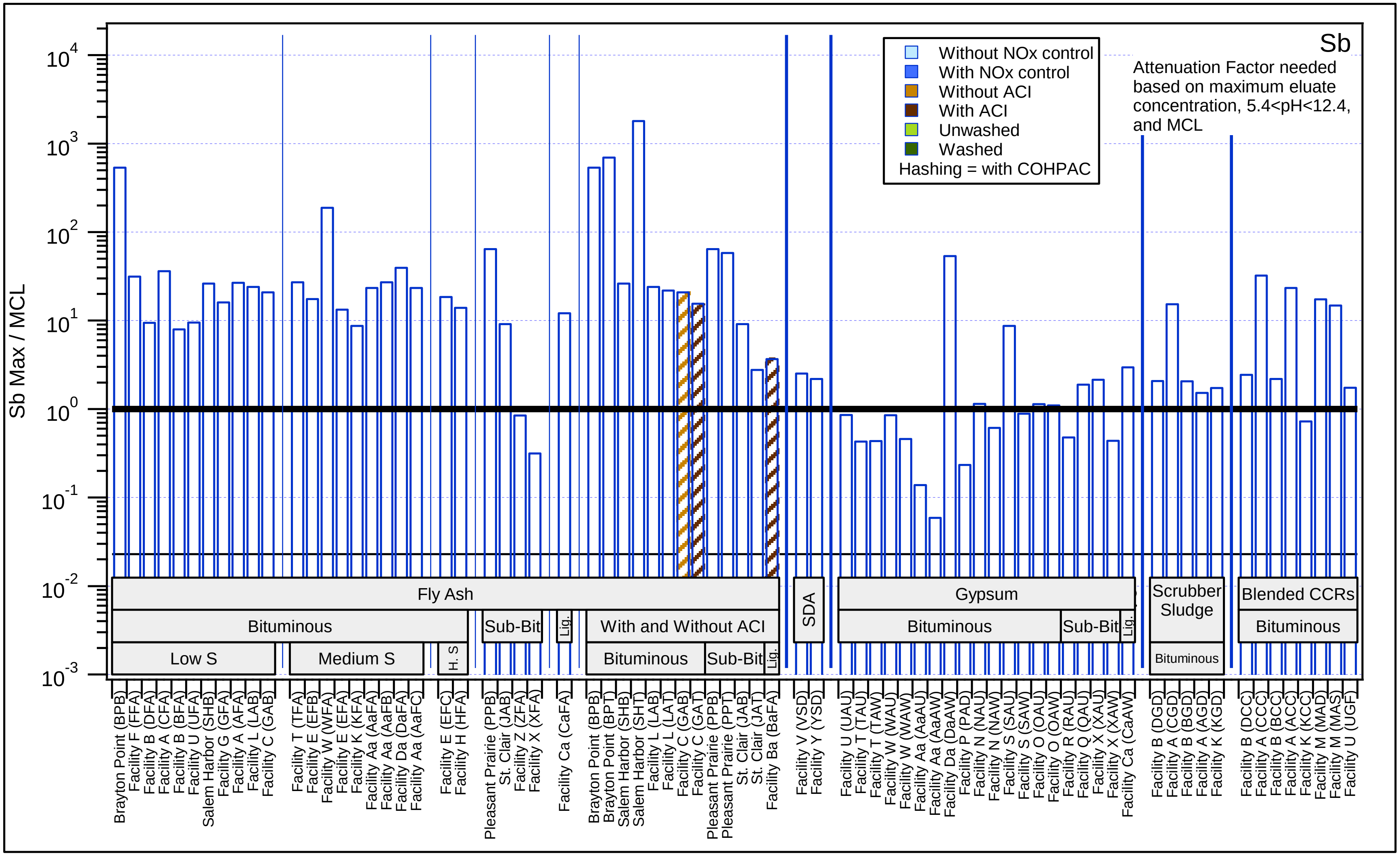


Figure L-8. Antimony - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

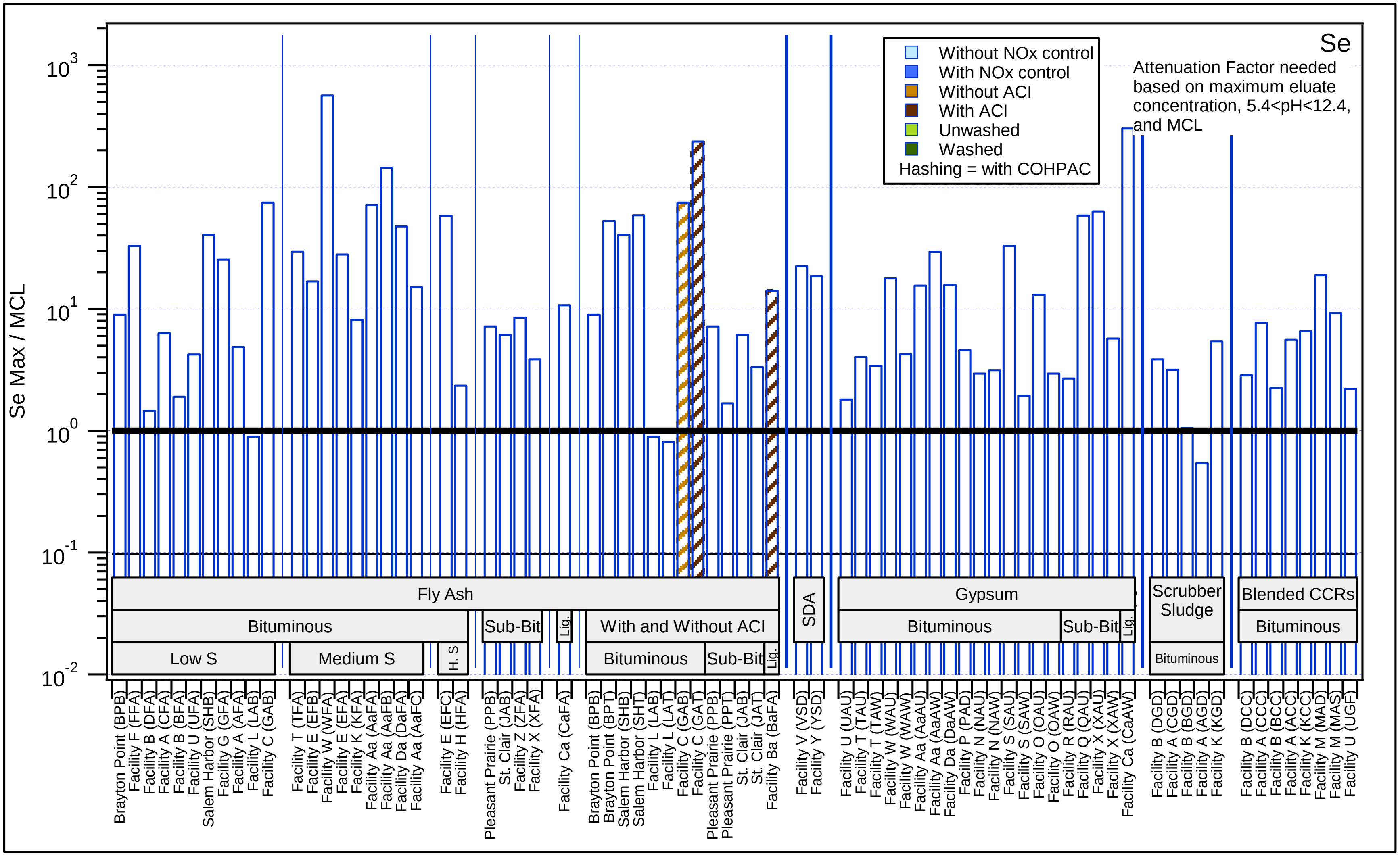


Figure L-9. Selenium - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

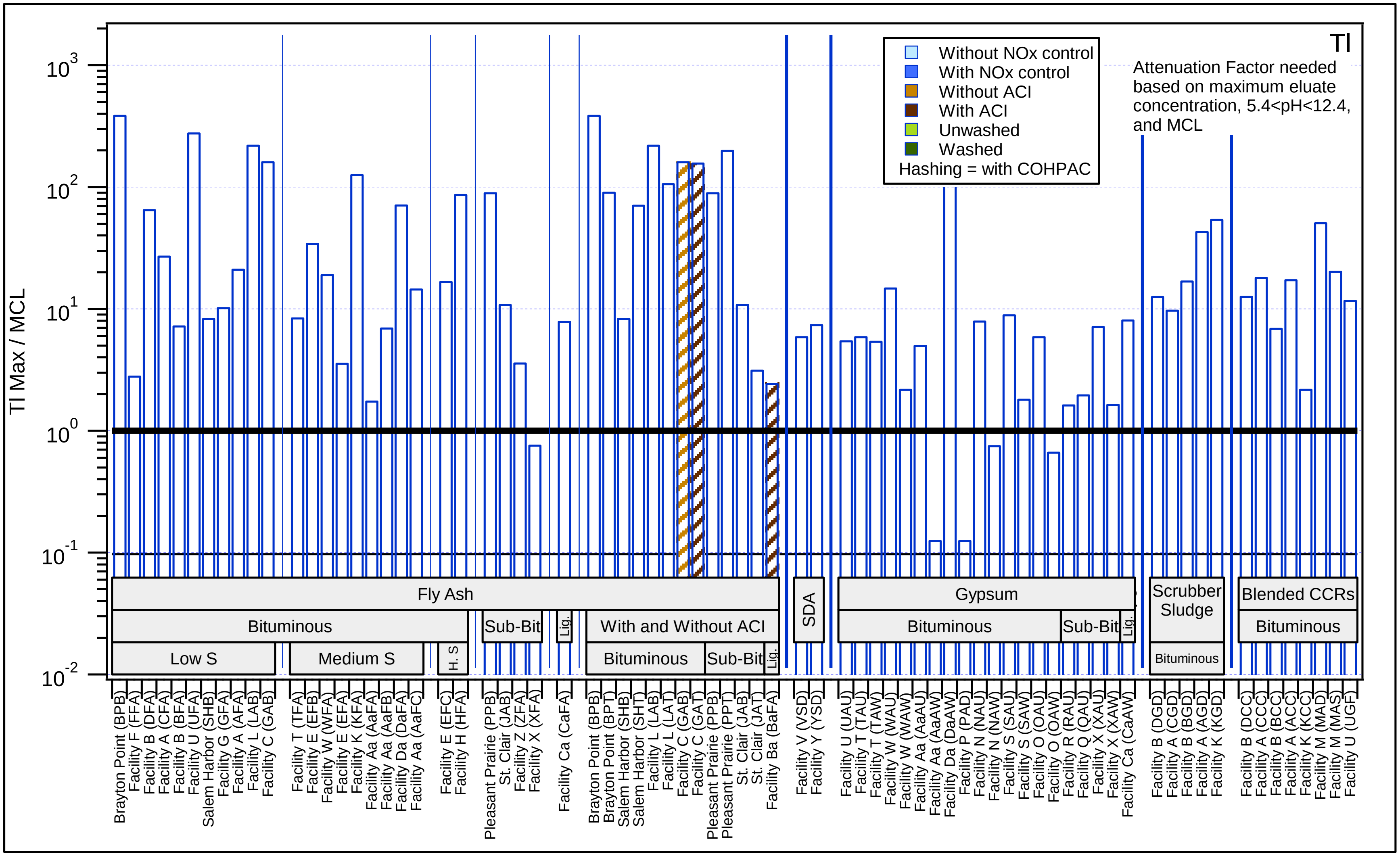


Figure L-10. Thallium - Minimum attenuation factor needed for the **maximum eluate concentration** (5.4 ≤pH≤12.4) to be reduced to less than the MCL for each CCR evaluated in this study.

Individual COPCs

Minimum attenuation factor needed for the **own eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

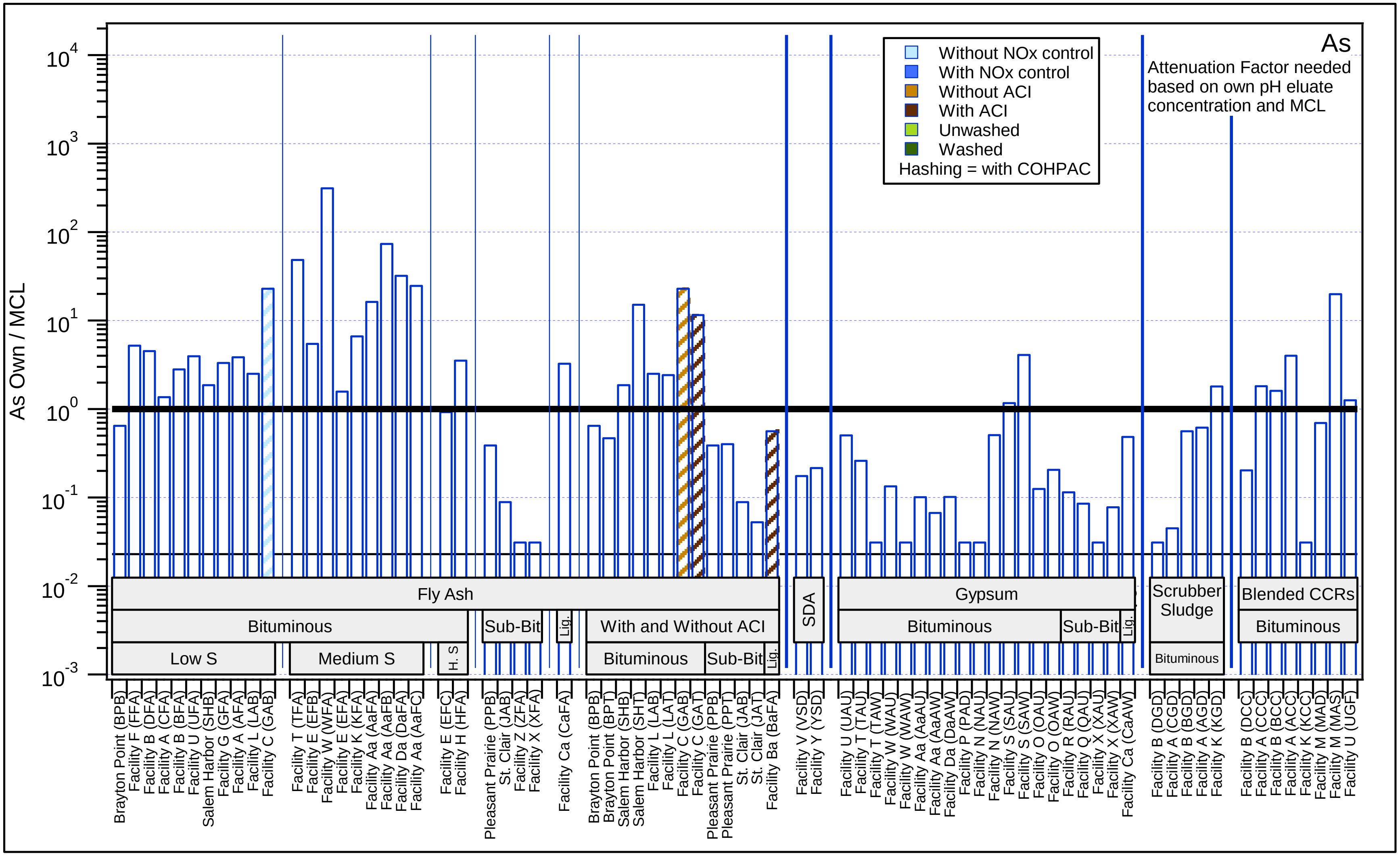


Figure L-11. Arsenic - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

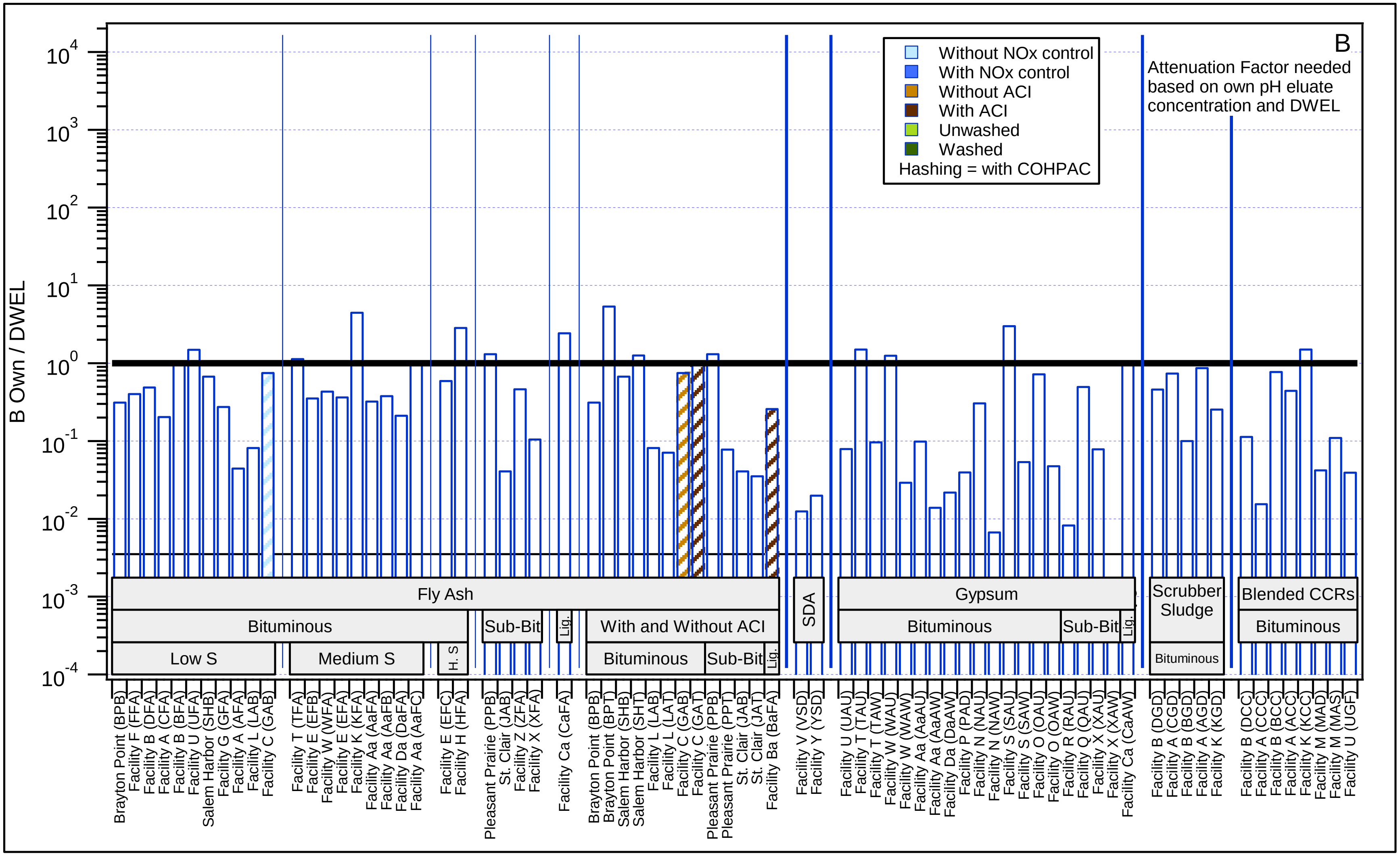


Figure L-12. Boron - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the DWEL for each CCR evaluated in this study.

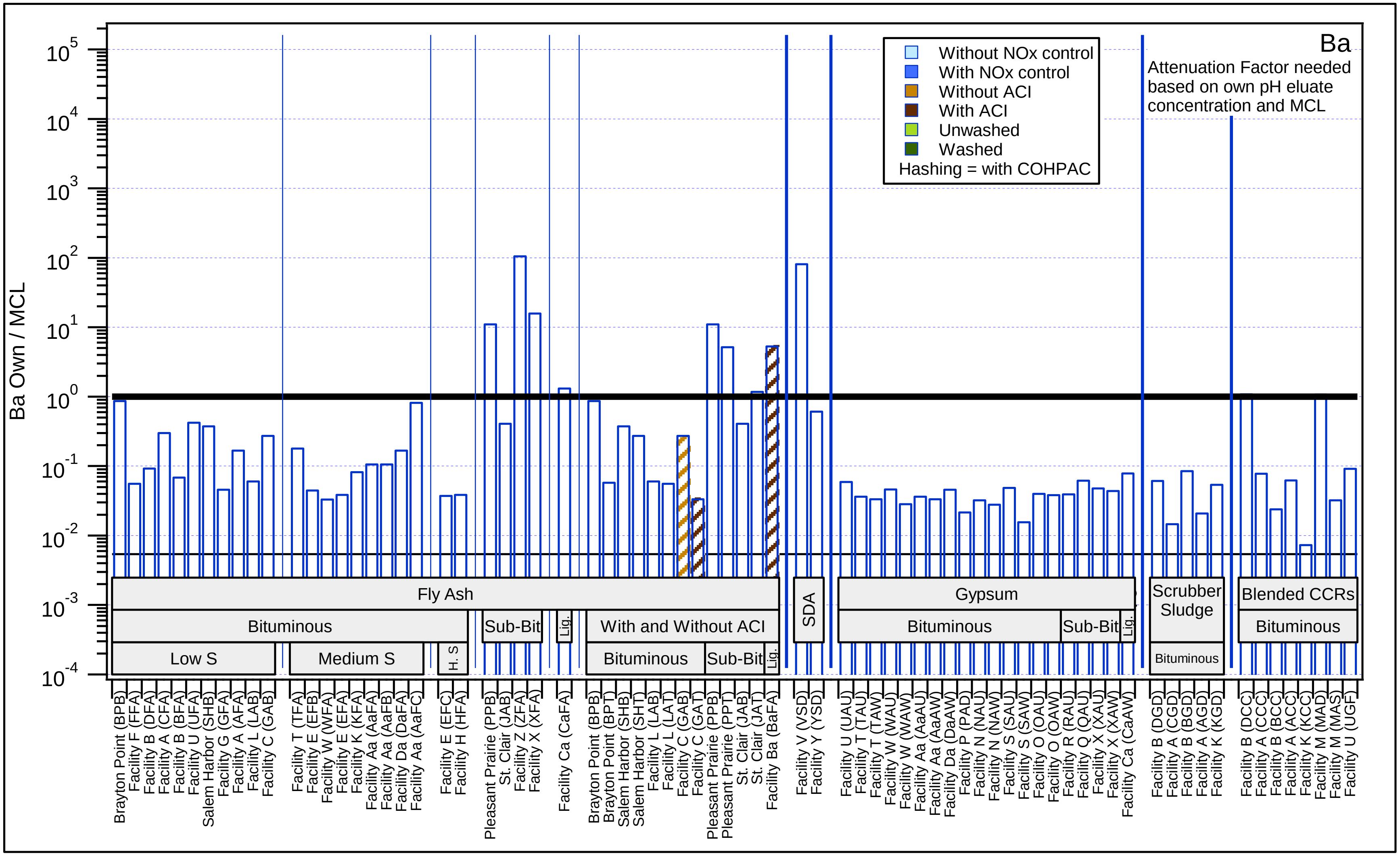


Figure L-13. Barium - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

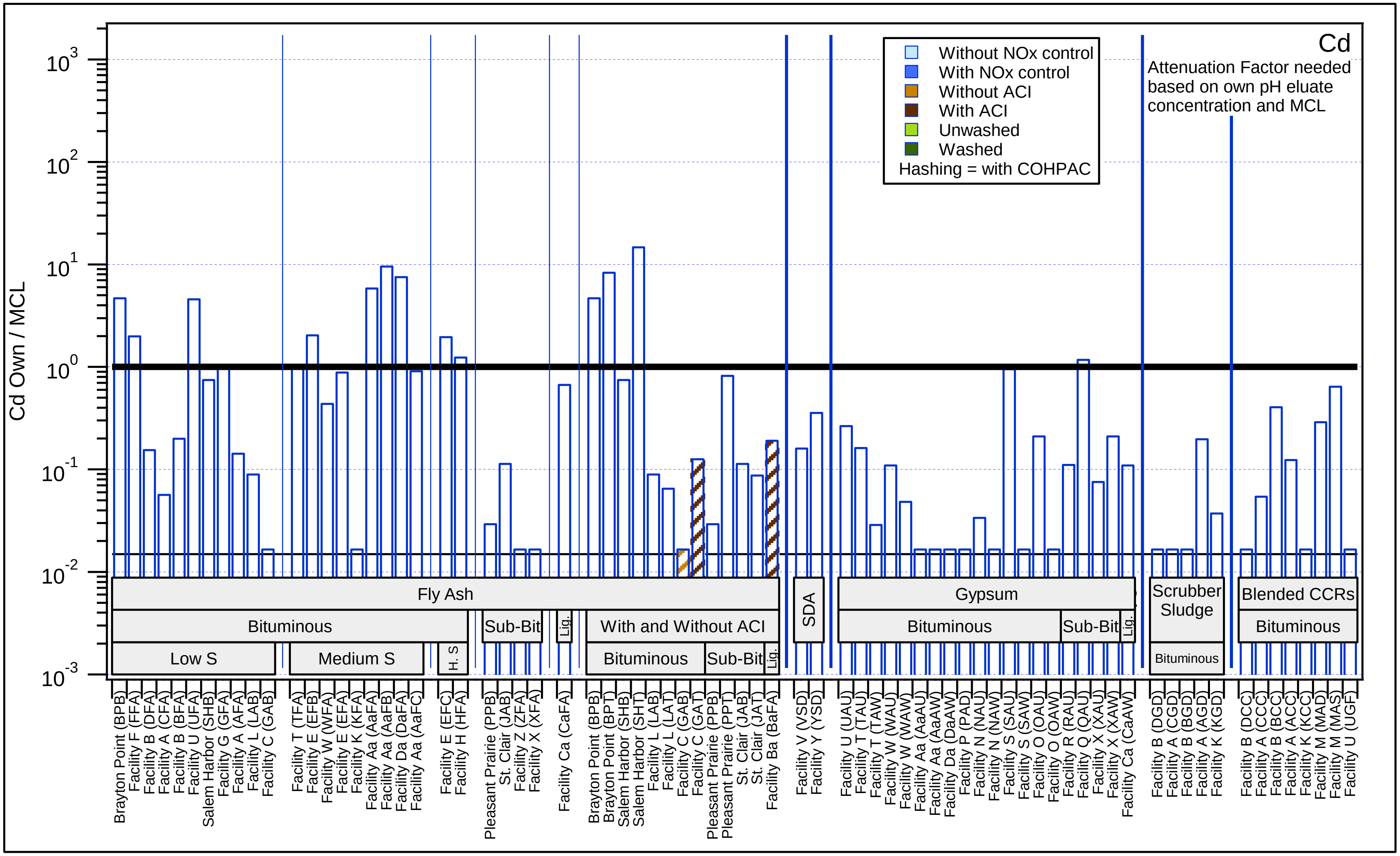


Figure L-14. Cadmium - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

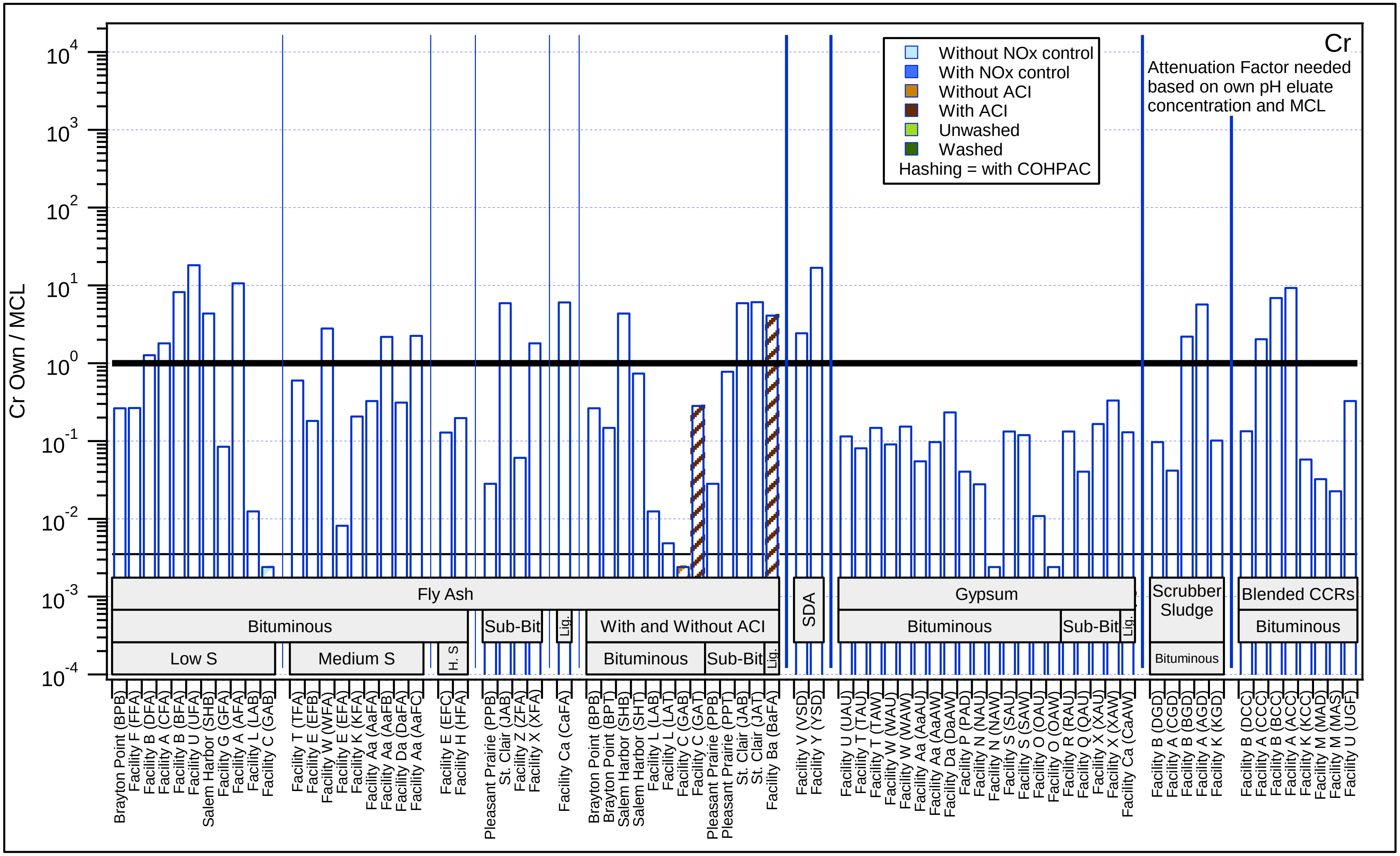


Figure L-15. Chromium - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

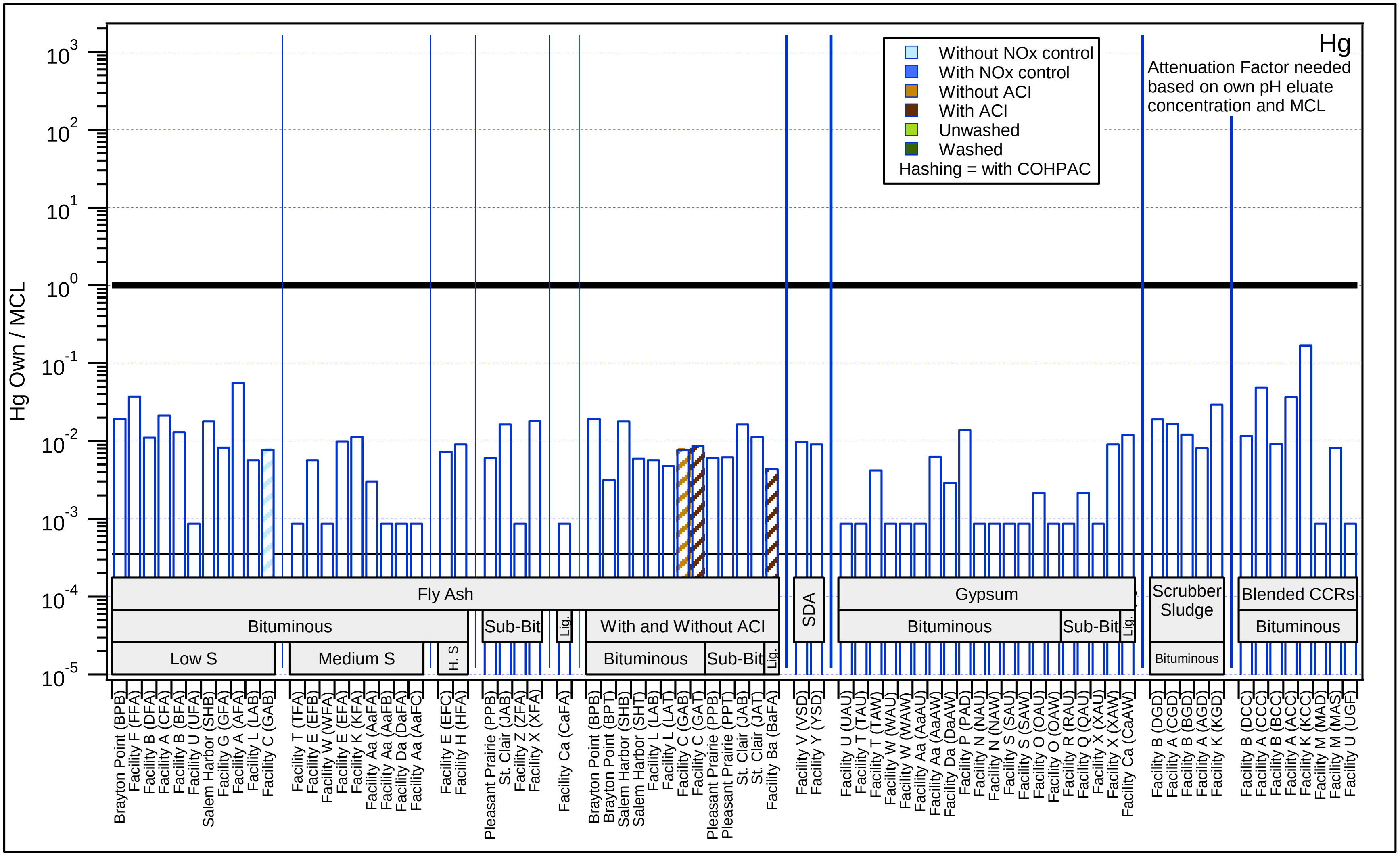


Figure L-16. Mercury - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

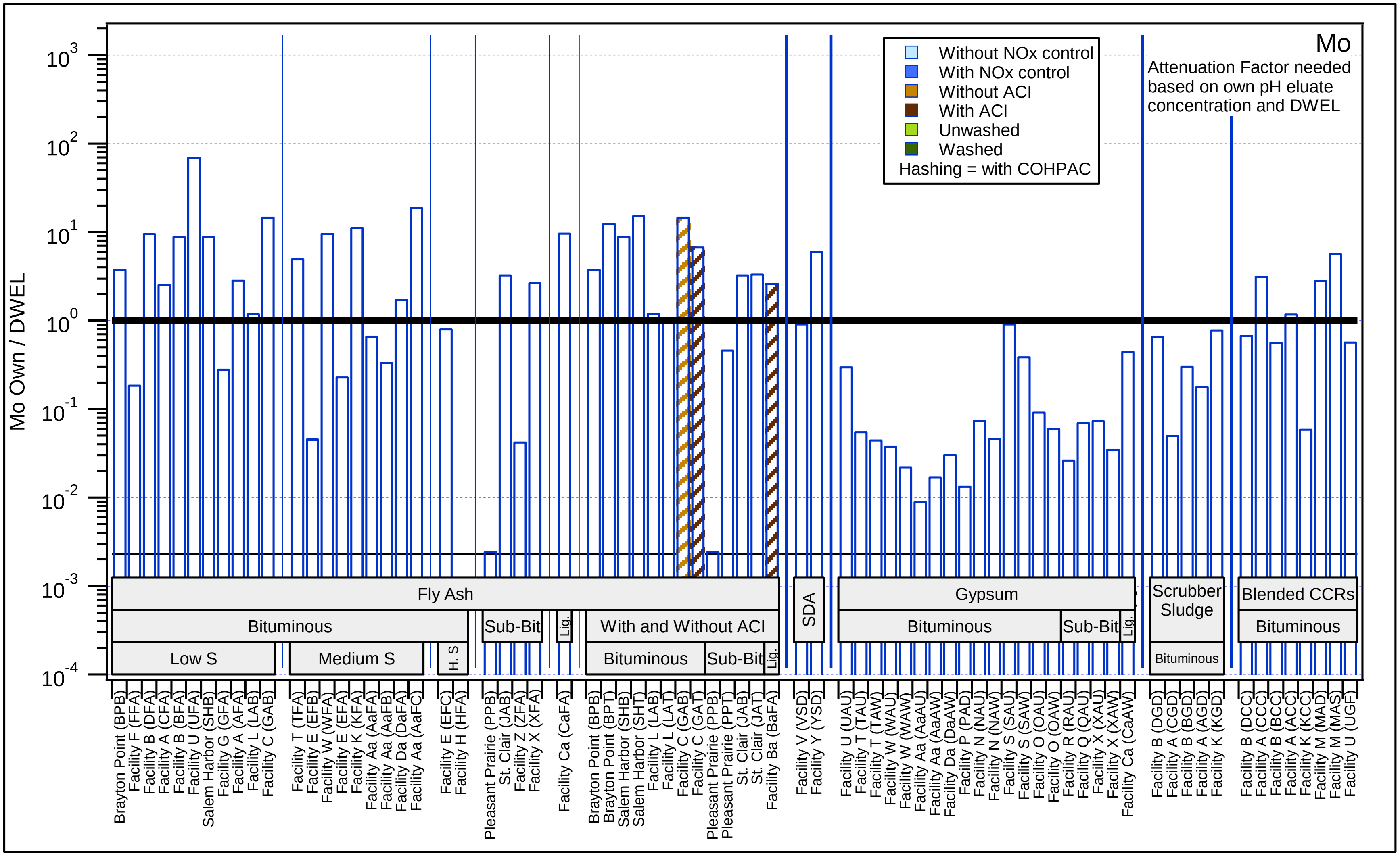


Figure L-17. Molybdenum - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the DWEL for each CCR evaluated in this study.

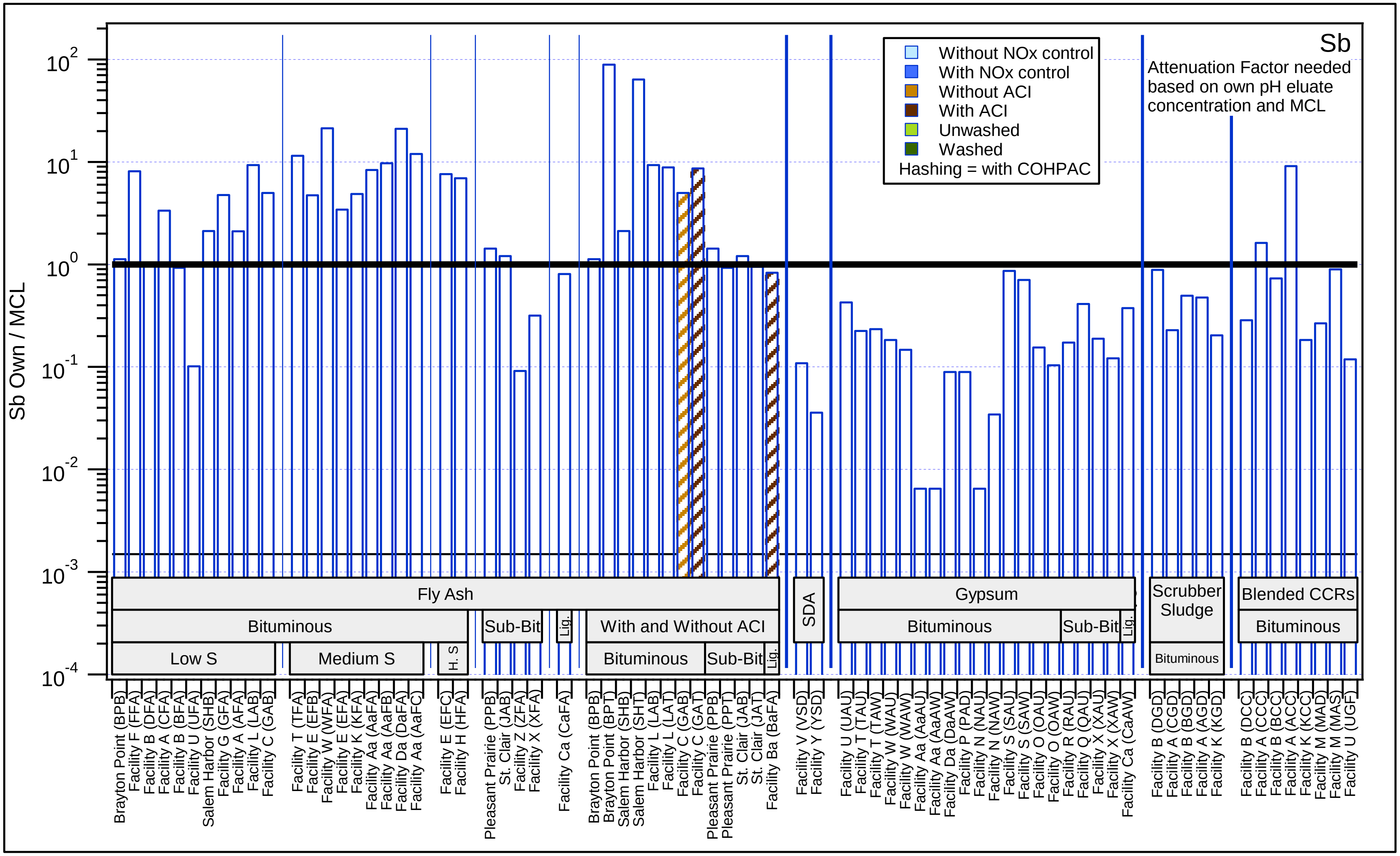


Figure L-18. Antimony - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

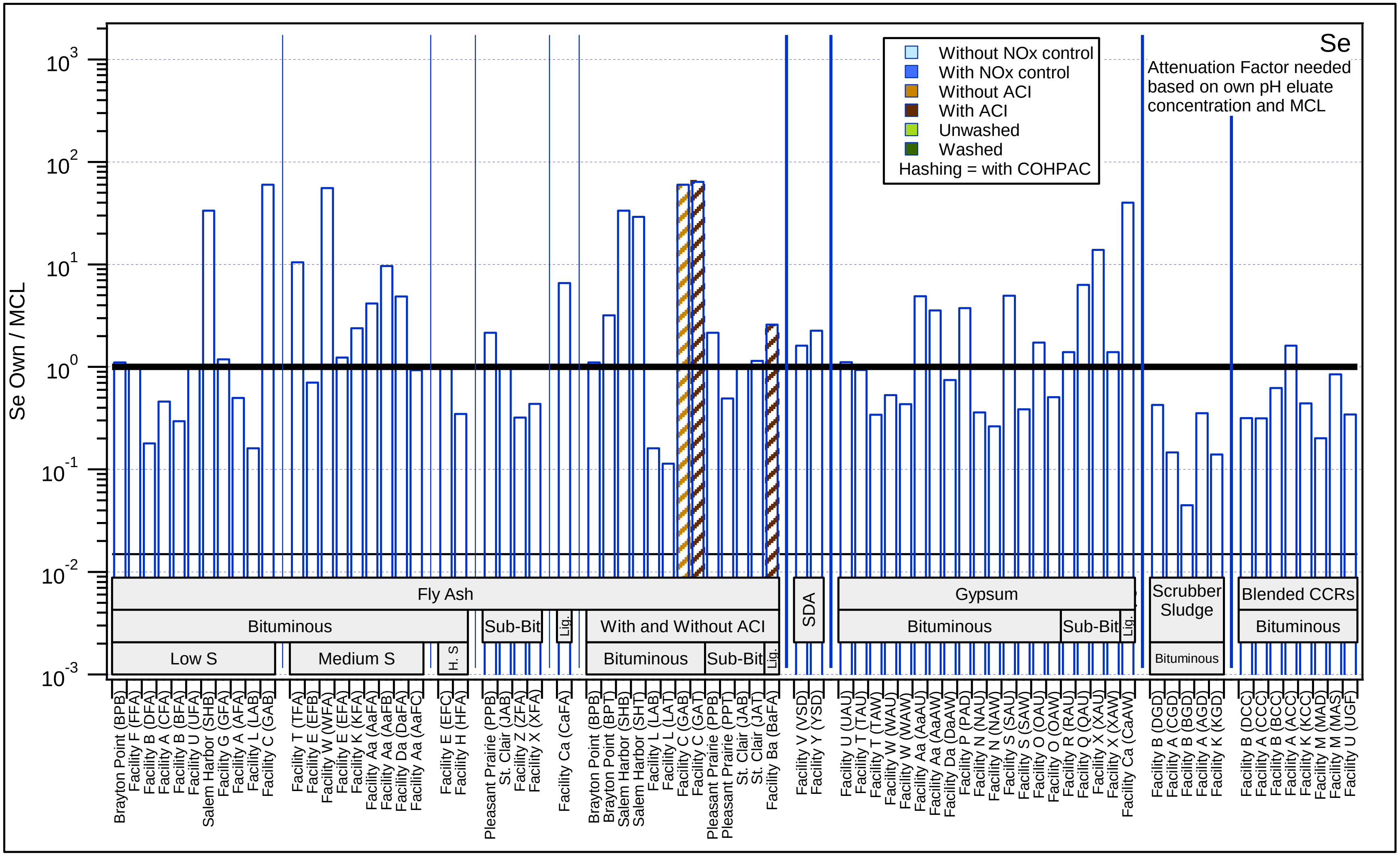


Figure L-19. Selenium - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

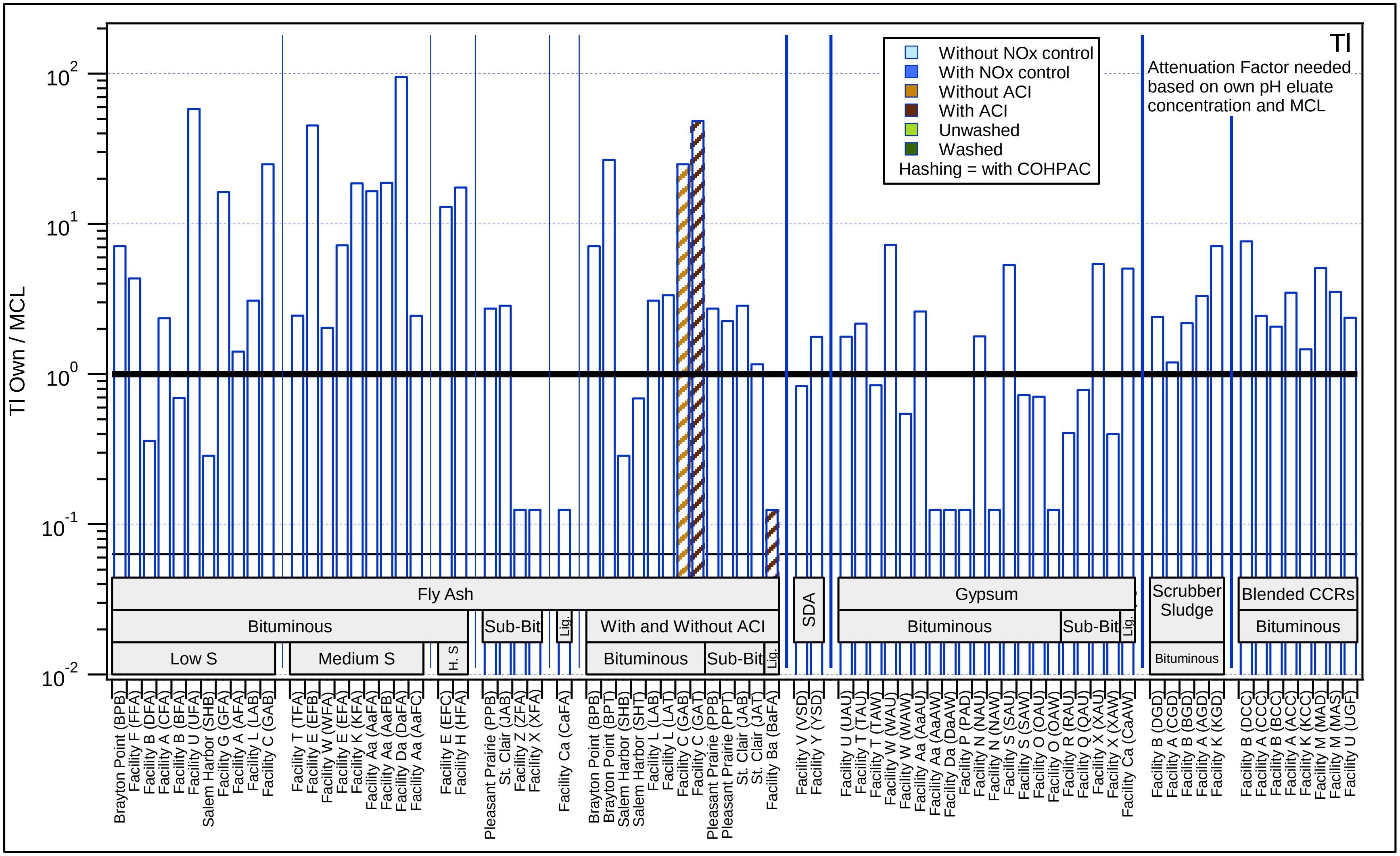


Figure L-20. Thallium - Minimum attenuation factor needed for the **own pH eluate concentration** to be reduced to less than the MCL for each CCR evaluated in this study.

						Attenuation factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	**Sample ID**	**PM Capture**	**NOx Control**	**Hg Sorbent Injection**	**SO_3 Control**	**Hg**	**As**	**B**	**Ba**	**Cd**	**Cr**	**Mo**	**Se**	**Sb**	**Tl**	**Maximum Attenuation Factor**	**Controlling COPC**
Fly Ash without Hg Sorbent Injection																	
Bituminous, Low S																	
Brayton Point	BPB	CS ESP	None	None	None	0.058	3.5	4.4	0.92	14	0.43	12	9.2	550	390	550	Sb
Facility F	FFA	CS ESP	None	None	None	0.095	200	0.39	0.16	0.94	0.96	9.8	34	32	2.9	200	As
Facility B	DFA	CS ESP	SCR-BP	None	None	0.21	26	3.7	0.14	3.0	17	37	1.5	9.7	66	66	Tl
Facility A	CFA	Fabric F.	SNCR-BP	None	None	0.034	11	1.7	1.5	2.2	14	11	6.5	37	28	37	Sb
Facility B	BFA	CS ESP	SCR	None	None	0.034	9.9	8.2	0.10	4.4	37	57	2.0	8.2	7.4	37	Cr
Facility U	UFA	CS ESP	SCR	None	None	0.017	77	5.6	0.59	30	74	630	4.3	9.9	280	280	Tl
Salem Harbor	SHB	CS ESP	SNCR	None	None	0.040	11	2.9	0.50	7.3	5.3	66	41	27	8.5	41	Se
Facility G	GFA	CS ESP	SNCR	None	None	0.030	190	0.31	0.15	0.70	0.96	6.3	26	17	10	190	As
Facility A	AFA	Fabric F.	SNCR	None	None	0.24	17	1.6	1.9	4.6	19	45	5.0	28	21	28	Sb
Facility L	LAB	HS ESP	SOFA	None	None	0.059	170	0.37	0.11	0.37	0.19	3.9	0.92	25	220	220	Tl
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.027	110	1.8	0.50	7.0	0.87	73	76	22	160	160	Tl
Bituminous, Med S																	
Facility T	TFA	CS ESP	None	None	None	0.00090	170	6.7	0.41	7.5	2.6	42	30	28	8.6	170	As
Facility E	EFB	CS ESP	SCR-BP	None	None	0.022	130	0.49	0.089	0.48	0.55	13	17	18	35	130	As
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	0.00090	1800	5.0	0.12	4.4	26	90	580	190	19	1800	As
Facility E	EFA	CS ESP	SCR	None	None	0.031	76	0.41	0.19	0.17	0.47	9.3	29	14	3.6	76	As
Facility K	KFA	CS ESP	None	None	None	0.072	13	39	0.22	5.6	1.4	180	8.4	9.0	130	130	Tl
Facility Aa	AaFA	CS ESP	SCR	None	None	0.0063	120	0.30	0.31	0.79	1.1	14	73	24	1.8	120	As
Facility Aa	AaFB	CS ESP	SCR	None	None	0.00090	120	0.34	0.33	1.9	5.6	16	150	28	7.1	150	Se
Facility Da	DaFA	CS ESP	SCR	None	None	0.00090	190	0.22	0.61	5.6	1.1	18	49	41	72	190	As
Facility Aa	AaFC	HS ESP	SCR	None	None	0.0045	43	1.7	1.1	8.8	19	230	15	24	15	43	As

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟥	100 ≤ AF	

						Attenuation factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	**Sample ID**	**PM Capture**	**NOx Control**	**Hg Sorbent Injection**	**SO_3 Control**	**Hg**	**As**	**B**	**Ba**	**Cd**	**Cr**	**Mo**	**Se**	**Sb**	**Tl**	**Maximum Attenuation Factor**	**Controlling COPC**
Fly Ash without Hg Sorbent Injection																	
Bituminous, High S																	
Facility E	EFC	CS ESP	SCR	None	None	0.013	75	0.86	0.26	0.17	1.4	10	59	19	17	75	As
Facility H	HFA	CS ESP	SCR	None	None	0.020	7.7	25	0.11	16	0.96	280	2.4	14	88	88	Tl
Sub-Bituminous & Sub-bit/bituminous mix																	
Pleasant Prairie	PPB	CS ESP	None	None	None	0.10	1.3	4.2	51	3.4	14	3.9	7.4	67	91	91	Tl
St. Clair	JAB	CS ESP	None	None	None	0.025	5.8	2.5	2.4	0.72	55	20	6.3	9.4	11	55	Cr
Facility Z	ZFA	CS ESP	None	None	None	0.00090	0.032	1.2	340	0.14	19	3.5	8.7	0.87	3.7	340	Ba
Facility X	XFA	CS ESP	SCR	None	None	0.019	0.11	1.6	80	0.53	34	12	3.9	0.33	0.77	80	Ba
Lignite																	
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	0.0045	10	9.4	2.5	21	23	55	11	13	8.1	23	Cr

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟥	100 ≤ AF	

						Attenuation factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	**Sample ID**	**PM Capture**	**NOx Control**	**Hg Sorbent Injection**	**SO_3 Control**	**Hg**	**As**	**B**	**Ba**	**Cd**	**Cr**	**Mo**	**Se**	**Sb**	**Tl**	**Maximum Attenuation Factor**	**Controlling COPC**
Fly Ash without and with Hg Sorbent Injection Pairs																	
Bituminous, Low S (Class F)																	
Brayton Point	BPB	CS ESP	None	None	None	0.058	3.5	4.4	0.92	14	0.43	12	9.2	550	390	550	Sb
Brayton Point	BPT	CS ESP	None	PAC	None	0.0080	4.3	5.6	0.14	25	0.75	13	54	720	92	720	Sb
Salem Harbor	SHB	CS ESP	SNCR	None	None	0.040	11	2.9	0.50	7.3	5.3	66	41	27	8.5	41	Se
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	0.017	19	8.0	0.50	65	2.6	130	60	1900	72	1900	Sb
Facility L	LAB	HS ESP	SOFA	None	None	0.059	170	0.37	0.11	0.37	0.19	3.9	0.92	25	220	220	Tl
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	0.081	130	0.30	0.084	0.26	0.28	3.3	0.83	23	110	130	As
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.027	110	1.8	0.50	7.0	0.87	73	76	22	160	160	Tl
Mixed Fly Ash and Scr	GAT	HS ESP w/ COHPAC	None	PAC	None	0.066	27	1.6	0.18	2.2	0.66	10	240	16	160	240	Se
Sub-bituminous (Class C)																	
Pleasant Prairie	PPB	CS ESP	None	None	None	0.10	1.3	4.2	51	3.4	14	3.9	7.4	67	91	91	Tl
Pleasant Prairie	PPT	CS ESP	None	PAC	None	0.014	1.5	3.7	5.5	3.1	7.1	16	1.7	60	200	200	Tl
St. Clair	JAB	CS ESP	None	None	None	0.025	5.8	2.5	2.4	0.72	55	20	6.3	9.4	11	55	Cr
St. Clair	JAT	CS ESP	None	Br-PAC	None	0.027	0.29	2.4	1.6	0.25	26	7.7	3.4	2.9	3.2	26	Cr
Lignite (Class C)																	
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	0.0080	3.7	3.8	27	1.7	8.3	4.1	14	3.8	2.5	27	Ba

🟩	AF < 1
🟨	1 ≤ AF < 10
🟧	10 ≤ AF < 100
🟪	100 ≤ AF

AF = Attenuation Factor

						Attenuation factor needed based on maximum eluate concentration, 5.4 ≤pH≤12.4, and MCL or DWEL											
Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Mixed Fly Ash and Gypsum (as managed)																	
Sub-bituminous																	
Facility V	VSD	Fabric F.	SCR	None	None	0.99	3.2	3.4	230	2.0	4.3	3.8	23	2.6	6.0	230	Ba
Facility Y	YSD	Fabric F.	SCR	None	None	0.35	2.8	1.8	3.2	7.9	91	46	19	2.3	7.5	91	Cr

🟩	AF < 1
🟨	1 ≤ AF < 10
🟧	10 ≤ AF < 100
🟥	100 ≤ AF

AF = Attenuation Factor

I/A

								Attenuation Factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO$_3$ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Gypsum, unwashed and washed																			
Bituminous, Low S																			
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.0078	0.58	0.18	0.071	0.27	0.23	2.5	1.8	0.88	5.6	5.6	Tl
Bituminous, Med S																			
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.016	0.39	14	0.053	3.1	0.39	0.29	4.1	0.44	6.0	6.0	Tl
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.0094	0.47	0.78	0.036	0.18	2.4	0.42	3.5	0.45	5.5	5.5	Tl
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.011	20	16	0.099	0.39	0.21	0.27	18	0.88	15	20	As
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.0065	0.30	0.21	0.050	0.44	0.28	0.11	4.4	0.48	2.2	4.4	Se
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.0045	0.13	0.59	0.043	0.017	0.094	0.058	16	0.14	5.1	16	Se
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.0080	0.21	0.019	0.044	0.017	0.18	0.067	30	0.061	0.13	30	Se
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.043	120	0.24	0.13	74	0.86	6.3	16	55	550	550	Tl
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	0.041	0.61	0.22	0.039	0.10	0.24	0.064	4.7	0.24	0.13	4.7	Se

🟩	AF < 1
🟨	1 ≤ AF < 10
🟧	10 ≤ AF < 100
🟪	100 ≤ AF

AF = Attenuation Factor

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Attenuation Factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Gypsum, unwashed and washed																			
Bituminous, High S																			
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.016	0.59	2.4	0.074	1.5	0.53	0.77	3.0	1.2	8.1	8.1	Tl
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.052	1.0	0.14	0.040	1.6	0.19	0.55	3.2	0.63	0.77	3.2	Se
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.053	6.4	38	0.079	6.6	0.21	9.7	34	9.0	9.1	34	Se
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.0063	4.4	0.11	0.042	0.14	0.17	0.68	2.0	0.91	1.8	4.4	As
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.011	0.66	7.1	0.080	2.4	0.061	0.87	13	1.2	6.0	13	Se
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.043	0.90	0.53	0.072	1.3	0.12	0.65	3.0	1.1	0.68	3.0	Se
Sub-bituminous																			
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.00090	0.60	0.38	0.062	0.47	0.21	0.14	2.8	0.49	1.6	2.8	Se
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	0.33	1.1	9.3	0.21	10	0.17	2.0	60	2.0	2.0	60	Se
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.032	0.90	0.84	0.054	0.62	0.35	0.84	65	2.2	7.3	65	Se
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.020	0.30	0.057	0.048	0.39	0.35	0.083	5.9	0.45	1.7	5.9	Se
Lignite																			
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.099	2.1	11	0.28	1.2	0.56	4.8	310	3.1	8.2	310	Se

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟪	100 ≤ AF	

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Attenuation Factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
								Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Scrubber Sludge																			
Bituminous, Low S																			
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	4.5	2.3	8.9	0.20	0.14	0.24	6.6	4.0	2.2	13	13	Tl
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.050	0.31	6.2	0.041	0.23	0.099	0.58	3.3	16	9.9	16	Sb
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	2.7	6.4	2.0	0.88	0.29	7.9	2.1	1.1	2.1	17	17	Tl
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.040	0.79	30	0.059	0.32	8.3	3.7	0.55	1.6	44	44	Tl
Bituminous, Med S																			
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	0.79	10	3.0	1.2	0.82	0.17	5.4	5.5	1.8	55	55	Tl

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟪	100 ≤ AF	

								Attenuation Factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Mixed Fly Ash and Scrubber Sludge (as managed)																			
Bituminous, Low S																			
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.73	18	2.0	3.0	0.22	0.22	2.3	2.9	2.5	13	18	As
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.11	8.4	1.1	0.80	1.8	23	78	7.9	33	18	33	Sb
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	2.7	4.1	32	0.089	2.4	9.5	8.6	2.3	2.3	7.0	9.5	Cr
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.068	7.7	1.6	0.25	1.8	23	190	5.7	24	18	24	Sb
Bituminous, Med S																			
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	14	0.70	6.3	0.077	0.22	0.087	1.2	6.7	0.75	2.2	14	Hg
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	4.5	280	4.7	5.1	2.2	0.065	5.4	19	18	52	280	As
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	3.7	370	4.1	0.59	4.0	0.31	55	9.5	15	21	370	As

🟩	AF < 1
🟨	1 ≤ AF < 10
🟧	10 ≤ AF < 100
🟪	100 ≤ AF

AF = Attenuation Factor

								Attenuation Factor needed based on maximum eluate concentration, 5.4≤pH≤12.4, and MCL or DWEL											
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Mixed Fly Ash and Gypsum (as managed)																			
Bituminous, Low S																			
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	0.32	4.4	0.48	0.48	6.4	0.82	6.0	2.3	1.8	12	12	Tl

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟥	100 ≤ AF	

Attenuation factor needed based on own pH eluate concentration and MCL or DWEL

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Brayton Point	BPB	CS ESP	None	None	None	0.020	0.67	0.32	0.91	4.8	0.27	3.9	1.1	1.2	7.2	7.2	Tl
Facility F	FFA	CS ESP	None	None	None	0.039	5.4	0.42	0.058	2.0	0.28	0.19	1.0	8.4	4.4	8.4	Sb
Facility B	DFA	CS ESP	SCR-BP	None	None	0.011	4.7	0.51	0.096	0.16	1.3	9.8	0.19	1.1	0.37	4.7	As
Facility A	CFA	Fabric F.	SNCR-BP	None	None	0.022	1.4	0.21	0.31	0.058	1.9	2.6	0.47	3.4	2.4	3.4	Sb
Facility B	BFA	CS ESP	SCR	None	None	0.013	2.9	1.0	0.072	0.21	8.5	9.1	0.31	0.95	0.71	8.5	Cr
Facility U	UFA	CS ESP	SCR	None	None	0.00090	4.1	1.5	0.44	4.7	19	72	1.0	0.10	59	59	Tl
Salem Harbor	SHB	CS ESP	SNCR	None	None	0.018	1.9	0.70	0.39	0.77	4.5	9.1	34	2.2	0.29	34	Se
Facility G	GFA	CS ESP	SNCR	None	None	0.0086	3.4	0.28	0.048	1.1	0.088	0.29	1.2	4.9	17	17	Tl
Facility A	AFA	Fabric F.	SNCR	None	None	0.058	4.0	0.046	0.17	0.15	11	2.9	0.51	2.2	1.4	11	Cr
Facility L	LAB	HS ESP	SOFA	None	None	0.0058	2.6	0.084	0.063	0.092	0.013	1.2	0.17	9.6	3.2	9.6	Sb
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.0081	24	0.78	0.28	0.017	0.0025	15	62	5.1	25	62	Se

Bituminous, Med S

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Facility T	TFA	CS ESP	None	None	None	0.00090	50	1.2	0.19	0.99	0.62	5.1	11	12	2.5	50	As
Facility E	EFB	CS ESP	SCR-BP	None	None	0.0058	5.6	0.37	0.046	2.1	0.19	0.047	0.73	4.9	46	46	Tl
Facility W	WFA	CS ESP	SCR-BP	None	Duct Sorbent inj. - Troana	0.00090	320	0.45	0.035	0.45	2.9	9.9	57	22	2.1	320	As
Facility E	EFA	CS ESP	SCR	None	None	0.010	1.6	0.38	0.040	0.91	0.0085	0.24	1.3	3.5	7.4	7.4	Tl
Facility K	KFA	CS ESP	None	None	None	0.012	6.8	4.6	0.085	0.017	0.21	11	2.5	5.0	19	19	Tl
Facility Aa	AaFA	CS ESP	SCR	None	None	0.0031	17	0.33	0.11	6.0	0.34	0.68	4.3	8.6	17	17	Tl
Facility Aa	AaFB	CS ESP	SCR	None	None	0.00090	76	0.39	0.11	9.8	2.3	0.34	9.9	10	19	76	As
Facility Da	DaFA	CS ESP	SCR	None	None	0.00090	33	0.22	0.17	7.7	0.32	1.8	5.0	22	97	97	Tl
Facility Aa	AaFC	HS ESP	SCR	None	None	0.00090	25	1.1	0.85	0.94	2.3	19	0.96	12	2.5	25	As

🟩	AF < 1	AF = Attenuation Factor
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🟪	100 ≤ AF	

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
						Attenuation factor needed based on own pH eluate concentration and MCL or DWEL											
Fly Ash without Hg Sorbent Injection																	
Bituminous, High S																	
Facility E	EFC	CS ESP	SCR	None	None	0.0076	0.95	0.61	0.039	2.0	0.13	0.82	1.0	7.8	13	13	Tl
Facility H	HFA	CS ESP	SCR	None	None	0.0094	3.6	3.0	0.040	1.3	0.20	0.0	0.36	7.1	18	18	Tl
Sub-Bituminous & Sub-bit/bituminous mix																	
Pleasant Prairie	PPB	CS ESP	None	None	None	0.0062	0.40	1.4	11	0.030	0.029	0.0025	2.2	1.5	2.8	11	Ba
St. Clair	JAB	CS ESP	None	None	None	0.017	0.092	0.042	0.43	0.12	6.1	3.3	1.0	1.2	2.9	6.1	Cr
Facility Z	ZFA	CS ESP	None	None	None	0.00090	0.032	0.48	110	0.017	0.063	0.043	0.33	0.094	0.13	110	Ba
Facility X	XFA	CS ESP	SCR	None	None	0.019	0.032	0.11	16	0.017	1.9	2.7	0.45	0.33	0.13	16	Ba
Lignite																	
Facility Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	0.00090	3.4	2.5	1.4	0.69	6.3	9.9	6.8	0.83	0.13	6.8	Se

🟩	AF < 1	AF = Attenuation Factor
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Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
						Attenuation factor needed based on own pH eluate concentration and MCL or DWEL											
Fly Ash without and with Hg Sorbent Injection Pairs																	
Bituminous, Low S (Class F)																	
Brayton Point	BPB	CS ESP	None	None	None	0.020	0.67	0.32	0.91	4.8	0.27	3.9	1.1	1.2	7.2	7.2	Tl
Brayton Point	BPT	CS ESP	None	PAC	None	0.0033	0.48	5.6	0.060	8.6	0.15	13	3.3	91	27	91	Sb
Salem Harbor	SHB	CS ESP	SNCR	None	None	0.018	1.9	0.70	0.39	0.77	4.5	9.1	34	2.2	0.29	34	Se
Salem Harbor	SHT	CS ESP	SNCR	PAC	None	0.0062	16	1.3	0.28	15	0.77	16	30	65	0.70	65	Sb
Facility L	LAB	HS ESP	SOFA	None	None	0.0058	2.6	0.084	0.063	0.092	0.013	1.2	0.17	9.6	3.2	9.6	Sb
Facility L	LAT	HS ESP	SOFA	Br-PAC	None	0.0049	2.5	0.074	0.058	0.067	0.0050	1.0	0.12	9.1	3.4	9.1	Sb
Facility C	GAB	HS ESP w/ COHPAC	None	None	None	0.0081	24	0.78	0.28	0.017	0.0025	15	62	5.1	25	62	Se
Mixed Fly Ash and Scr	GAT	HS ESP w/ COHPAC	None	PAC	None	0.0090	12	1.1	0.035	0.13	0.29	6.9	66	8.9	49	66	Se
Sub-bituminous (Class C)																	
Pleasant Prairie	PPB	CS ESP	None	None	None	0.0062	0.40	1.4	11	0.030	0.029	0.0025	2.2	1.5	2.8	11	Ba
Pleasant Prairie	PPT	CS ESP	None	PAC	None	0.0064	0.42	0.081	5.4	0.84	0.81	0.47	0.51	0.95	2.3	5.4	Ba
St. Clair	JAB	CS ESP	None	None	None	0.017	0.092	0.042	0.43	0.12	6.1	3.3	1.0	1.2	2.9	6.1	Cr
St. Clair	JAT	CS ESP	None	Br-PAC	None	0.012	0.054	0.037	1.2	0.090	6.3	3.4	1.2	0.98	1.2	6.3	Cr
Lignite (Class C)																	
Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	0.0045	0.58	0.27	5.5	0.20	4.3	2.7	2.7	0.85	0.13	5.5	Ba

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
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🟥	100 ≤ AF	

Attenuation factor needed based on own pH eluate concentration and MCL or DWEL

Mixed Fly Ash and Gypsum (as managed)

Sub-bituminous

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Facility V	VSD	Fabric F.	SCR	None	None	0.010	0.18	0.013	84	0.16	2.5	0.94	1.7	0.11	0.85	84	Ba
Facility Y	YSD	Fabric F.	SCR	None	None	0.0094	0.22	0.021	0.64	0.37	17	6.2	2.3	0.037	1.8	17	Cr

🟩	AF < 1
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🟪	100 ≤ AF

AF = Attenuation Factor

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL										Maximum Attenuation Factor	Controlling COPC
								Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl		
Gypsum, unwashed and washed																			
Bituminous, Low S																			
Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	0.52	0.082	0.062	0.27	0.12	0.31	1.1	0.44	1.8	1.8	Tl
Bituminous, Med S																			
Facility T	TAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.00090	0.27	1.6	0.038	0.17	0.084	0.057	0.96	0.23	2.2	2.2	Tl
Facility T	TAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.0044	0.032	0.10	0.035	0.029	0.15	0.045	0.35	0.24	0.86	0.86	Tl
Facility W	WAU	Gyp-U	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.00090	0.14	1.3	0.048	0.11	0.094	0.039	0.55	0.19	7.4	7.4	Tl
Facility W	WAW	Gyp-W	CS ESP	SCR-BP	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.00090	0.032	0.030	0.030	0.050	0.16	0.023	0.45	0.15	0.56	0.56	Tl
Facility Aa	AaAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	0.10	0.10	0.038	0.017	0.057	0.0092	5.0	0.0067	2.7	5.0	Se
Facility Aa	AaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.0065	0.069	0.014	0.035	0.017	0.10	0.017	3.7	0.0067	0.13	3.7	Se
Facility Da	DaAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.0030	0.10	0.023	0.048	0.017	0.24	0.031	0.77	0.092	0.13	0.77	Se
Facility P	PAD	Gyp-U	CS ESP	SCR & SNCR	Forced Ox.	Limestone	None	0.014	0.032	0.041	0.023	0.017	0.042	0.014	3.9	0.092	0.13	3.9	Se

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
🟧	10 ≤ AF < 100	
🟥	100 ≤ AF	

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL										Maximum Attenuation Factor	Controlling COPC
								Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl		
Gypsum, unwashed and washed																			
Bituminous, High S																			
Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.00090	0.032	0.32	0.033	0.035	0.029	0.076	0.37	0.0067	1.8	1.8	Tl
Facility N	NAW	Gyp-W	CS ESP	None	Forced Ox.	Limestone	None	0.00090	0.52	0.0069	0.029	0.017	0.0025	0.048	0.27	0.035	0.13	0.52	As
Facility S	SAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	1.2	3.1	0.051	0.98	0.14	0.94	5.1	0.89	5.4	5.4	Tl
Facility S	SAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	4.2	0.055	0.016	0.017	0.12	0.40	0.40	0.73	0.74	4.2	As
Facility O	OAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.0022	0.13	0.75	0.042	0.22	0.011	0.094	1.8	0.16	0.72	1.8	Se
Facility O	OAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	0.21	0.049	0.040	0.017	0.0025	0.061	0.52	0.11	0.13	0.52	Se
Sub-bituminous																			
Facility R	RAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.00090	0.12	0.0085	0.041	0.11	0.14	0.027	1.4	0.18	0.41	1.4	Se
Facility Q	QAU	Gyp-U	HS ESP	None	Forced Ox.	Limestone	Other	0.0022	0.088	0.51	0.064	1.2	0.042	0.071	6.5	0.42	0.80	6.5	Se
Facility X	XAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	0.032	0.081	0.050	0.077	0.17	0.075	14	0.19	5.5	14	Se
Facility X	XAW	Gyp-W	CS ESP	SCR	Forced Ox.	Limestone	None	0.0094	0.080	0.0017	0.046	0.22	0.34	0.036	1.4	0.12	0.41	1.4	Se
Lignite																			
Facility Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	0.013	0.50	1.1	0.082	0.11	0.14	0.46	41	0.39	5.1	41	Se

🟩	AF < 1
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🟪	100 ≤ AF

AF = Attenuation Factor

Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Scrubber Sludge																			
Bituminous, Low S																			
Facility B	DGD	Scrubber sludge	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.020	0.032	0.48	0.064	0.017	0.10	0.67	0.44	0.91	2.5	2.5	Tl
Facility A	CGD	Scrubber sludge	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.017	0.046	0.77	0.015	0.017	0.043	0.051	0.15	0.23	1.2	1.2	Tl
Facility B	BGD	Scrubber sludge	CS ESP	SCR	Natural Ox.	Mg lime	None	0.013	0.58	0.10	0.088	0.017	2.3	0.31	0.046	0.51	2.2	2.3	Cr
Facility A	AGD	Scrubber sludge	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.0084	0.64	0.90	0.022	0.20	5.9	0.18	0.36	0.49	3.4	5.9	Cr
Bituminous, Med S																			
Facility K	KGD	Scrubber sludge	CS ESP	None	Natural Ox.	Mg lime	None	0.031	1.9	0.26	0.056	0.038	0.11	0.80	0.14	0.21	7.2	7.2	Tl

🟩	AF < 1	AF = Attenuation Factor
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								Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL											
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Mixed Fly Ash and Scrubber Sludge (as managed)																			
Bituminous, Low S																			
Facility B	DCC	FA+ScS+ lime	CS ESP	SCR-BP	Natural Ox.	Mg lime	None	0.012	0.21	0.12	1.1	0.017	0.14	0.69	0.33	0.29	7.8	7.8	Tl
Facility A	CCC	FA+ScS	Fabric F.	SNCR-BP	Natural Ox.	Limestone	None	0.050	1.9	0.016	0.081	0.056	2.1	3.2	0.32	1.7	2.5	2.5	Tl
Facility B	BCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	0.0096	1.7	0.80	0.025	0.42	7.1	0.58	0.64	0.75	2.1	7.1	Cr
Facility A	ACC	FA+ScS	Fabric F.	SNCR	Natural Ox.	Limestone	None	0.038	4.1	0.46	0.065	0.13	9.6	1.2	1.7	9.4	3.6	9.6	Cr
Bituminous, Med S																			
Facility K	KCC	FA+ScS+ lime	CS ESP	SCR	Natural Ox.	Mg lime	None	0.17	0.032	1.6	0.0076	0.017	0.060	0.060	0.45	0.19	1.5	1.5	Tl
Facility M	MAD	FA+ScS+ lime	CS ESP	SCR-BP	Inhibited Ox.	Limestone	None	0.00090	0.72	0.044	1.1	0.30	0.034	2.9	0.21	0.27	5.2	5.2	Tl
Facility M	MAS	FA+ScS+ lime	CS ESP	SCR	Inhibited Ox.	Limestone	None	0.0085	21	0.11	0.034	0.66	0.023	5.8	0.87	0.92	3.6	21	As

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🟪	100 ≤ AF	

								Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL											
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet Scrubber type	FGD Scrubber additive	SO_3 Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
Mixed Fly Ash and Gypsum (as managed)																			
Bituminous, Low S																			
Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	0.00090	1.3	0.041	0.095	0.017	0.34	0.58	0.35	0.12	2.4	2.4	Tl

🟩	AF < 1	AF = Attenuation Factor
🟨	1 ≤ AF < 10	
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I/A

Hart Exhibit 7
Docket No. E-2, Sub 1219

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Apr 13 2020

Coal Combustion Waste Damage Case Assessments

U.S. Environmental Protection Agency
Office of Solid Waste

July 9, 2007

With the exception of the documents listed below, the documents referenced throughout this assessment are available from the docket to the Notice of Data Availability on the Disposal of Coal Combustion Wastes in Landfills and Surface Impoundments at www.regulations.gov, docket ID EPA-HQ-RCRA-2006-0796, through internet links provided, or from other identified sources.

1. Application of Don Frame Trucking, Inc. Petitioner for a Judgment Pursuant to Article 78 of the CPLR against the New York State Department of Environmental Conservation Respondent; Supreme Court of the State of New York County of Chautauqua (July 22, 1988). Order G11278.
2. Selenium Posting on Hyco Lake Rescinded, North Carolina Department of Health and Human Services (NCDHHS), August 2001.
3. Feasibility Study for the Y-12 Chestnut Ridge Operable Unit 2 Filled Coal Ash Pond, Oak Ridge, Tennessee. DOE/OR/02-1259&D1. August 1994.
4. Final Site Investigation Report on Groundwater Contamination, Township of Pines, Porter County, Indiana. December 2002.
5. Texas Bureau of Health (TBH). 1992. Fish Advisory: Brandy Branch Reservoir. May 1992.
6. Texas Commission on Environmental Quality (TCEQ). 2003. Improving Water Quality in Brandy Branch Reservoir; One TMDL for Selenium. February 2003.
7. Report: Sulfate Investigation, Miamiview Landfill, Hamilton County, Ohio. Prepared for the Cincinnati Gas & Electric Company by Dames & Moore. December 13, 1994. Available in the docket titled Availability of Report to Congress on Fossil Fuel Combustion; Request for Comments and Announcement of Public Hearing, EPA-HQ-RCRA-1999-0022-0632.

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Summary of Coal Combustion Waste Damage Case Assessments

I. Summary

Under the Bevill Amendment for the "special waste" categories of the Solid Waste Disposal Act, EPA was statutorily required to examine "documented cases in which danger to human health or the environment has been proved" from the disposal of coal combustion wastes. The criteria used to determine whether danger to human health and the environment has been proven are described in detail in the May 2000 Regulatory Determination at 65 FR 32224. For the May 2000 Regulatory Determination for Wastes from the Combustion of Fossil Fuels (Regulatory Determination), the Agency determined there were approximately 300 CCW landfills and 300 CCW surface impoundments used by 440 coal fired utilities.

In comments on the March 1999 Report to Congress on Wastes from the Combustion of Fossil Fuels, public interest groups identified 59 cases in which they alleged damage to human health or the environment had been caused by fossil fuel combustion wastes[1]. The Agency reviewed each of the cases. That review resulted in identifying nine of the 11 damage cases cited in the May 2000 Regulatory Determination[2] (see Table 1 below for complete listing of the 11 proven damage cases[3]). Of the remaining 50 cases, 25 were classified as "potential" damage cases as

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[1] Letter from the Hoosier Environmental Council to the RCRA Docket Information Center regarding the CCW RTC, June 11, 1999, Letter from the Hoosier Environmental Council and the Citizens Coal Council to the RCRA Docket Information Center regarding the CCW RTC, June 14, 1999 and Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

[2] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[3] Per the May 2000 Regulatory Determination, 65 FR 32224 (http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000_register&docid=fr22my00-22.pdf) and Section 1.4.4 of the 1999 Report to Congress (http://www.epa.gov/epaoswer/other/fossil/volume_2.pdf), proven damage cases are those with (i)documented exceedances of primary MCLs or other health-based standards measured in ground water at sufficient distance from the waste management unit to indicate that hazardous constituents have migrated to the extent that they could cause human health concerns, and/or (ii) where a scientific study demonstrates there is documented evidence of another type of damage to human health or the environment (e.g., ecological damage), and/or (iii) where there has been an administrative ruling or court decision with an explicit finding of specific damage to human health or the environment. In cases of co-management of CCWs with other industrial waste types, CCWs must be clearly implicated in the reported damage.

The May 2000 Regulatory Determination falls short of providing a comprehensive definition of the review criteria ("test of proof") for assessing the validity of damage case allegations; it only discusses the review criteria in response to public comments on the review process of the Cement Kiln Dust (CKD) proposed rule, and focuses only on the location of the exceedance point with respect to the source term (32224 CFR 65):

"Proven damage cases were those with documented MCL exceedances that were measured in ground water at a sufficient distance from the waste management unit to indicate that hazardous constituents had migrated to the extent that they could cause human health concerns."

The "test of proof" criteria were fully defined on pp. 3-4 of the *Technical Background Document to the Report to Congress on Remaining Waste from Fossil Fuel Combustion: Potential Damage Cases* (1999):

defined in the Regulatory Determination[4] and five cases were determined to be not applicable to the Regulatory Determination. Four of these five cases could not be linked to coal combustion wastes and the other was at a coal mine, which is outside the scope of this NODA. Of the remaining 20 cases, one damage case was the result of wastes other than coal combustion wastes; one was not considered because it was an illegal, unpermitted dump; and 18 cases were indeterminate due to insufficient information[5].

Table 1. Eleven Damage Cases Cited in the May 2000 Regulatory Determination

Damage Case	Wastes Present	Event	Criteria (Test of Proof)	Comment
Coal-Fired Utility Comanaged Wastes				
Chisman Creek (VA)	Coal ash and petroleum coke landfill.	Se primary MCL exceedance; V, Se, and sulfate in residential drinking water wells.	Scientific[6]/Administrative[7]	Was put on NPL. EPA required remediation: new water supply to nearby residents, capping disposal area, ground water treatment, relocation of surface water tributary; other possible sources of contamination.

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http://www.epa.gov/epaoswer/other/fossil/ffc2_397.pdf. This language, in turn, is derived from the 1993 *Report to Congress on Cement Kiln Dust Waste*: http://www.epa.gov/epaoswer/other/ckd/cement2.htm.

According to the 1993 CKD Report to Congress (Chapter Five), Section 8002(o)(4) of RCRA requires that EPA's study of CKD waste examine "documented cases in which danger to human health or the environment has been proved." In order to address this requirement, EPA defined danger to human health to include both acute and chronic effects (e.g., directly observed health effects such as elevated blood lead levels or loss of life) associated with management of CKD waste. Danger to the environment includes the following types of impacts: (1) Significant impairment of natural resources; (2) Ecological effects resulting in degradation of the structure or function of natural ecosystems and habitats; and (3) Effects on wildlife resulting in damage to terrestrial or aquatic fauna.

[4] Per the May 2000 Regulatory Determination, 65 FR 3224, potential damage cases are those with (1) documented exceedances of primary MCLs or other health-based standards only directly beneath or in very close proximity to the waste source, and/or (2) documented exceedances of secondary MCLs or other health-based standards on-site or off-site.

[5] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[6] Where a scientific study demonstrates there is documented evidence of damage to human health or the environment other than ground water contamination (e.g., ecological damage).

[7] Where there has been an administrative ruling by a state or federal agency, or court decision with an explicit finding of specific damage to human health or the environment [e.g., listing on EPA's National Priorities List (NPL)].

Damage Case	Wastes Present	Event	Criteria (Test of Proof)	Comment
Faulkner Offsite Disposal Facility (MD)	Coal ash and pyritic mill rejects.	Low pH; exceedance of State standard; landfill and collection pond seepage and discharges resulted in plant and fish impacts to adjacent wetlands.	Scientific/Administrative	State required remediation included pond liners, landfill cover, and sequestration of pyrites.
DPC – Old E.J. Stoneman Ash Pond (WI)	Coal ash, demineralizer regenerant, other water treatment wastes.	Cd and Cr primary MCL exceedance; 'gross contamination' by pond cited by State – Elevated levels of Zn and sulfate; Boron near 5 mg/L in private drinking water well.	Administrative	State required Closure plan and relocation of town water supply well.
Basin Electric W.J. Neal Station (ND)	Coal ash and sludge; comanaged wastes probable.	Cr exceeded state standard and other metals detected at elevated levels in downgradient sediments and ground water.	Administrative (limited information available)	State required the site closed and capped, NFRAP (No Further Remedial Action Planned).
VEPCO – Possum Point (VA)	Coal ash, pyrites, oil ash, water treatment wastes, and boiler cleaning wastes	Cd primary MCL exceedance in ground water; ground water contaminated with Cd and Ni, attributed to pyrites and oil ash.	Administrative	Response included sequestration of oil ash, pyrites, and metal cleaning wastes to separate lined units.
WEPCO Hwy 59 Ash Landfill (WI)	Coal ash and mill rejects; other comanaged wastes probable.	Boron exceedance of state standard in down gradient ground water; elevated levels of As, Fe, Se, Mn, sulfate in private drinking water wells.	Scientific / Administrative	State required additional monitoring for problem/damage assessment.
Alliant Nelson Dewey (WI)	Coal ash, comanaged wastes.	Boron exceedance of state standard in down gradient ground water; elevated levels of As, Se, Fl, sulfate in ground water.	Administrative	State required company to investigate and assess problem; remedial action change to dry ash handling and modify landfill cover to reduce infiltration.

Damage Case	Wastes Present	Event	Criteria (Test of Proof)	Comment
Coal Creek Station (ND)	Coal ash, comanaged wastes.	Se and As exceedance of primary MCL in ground water on site; elevated sulfate and chloride levels in down gradient ground water.	Administrative	Impacted shallow ground water aquifer. State required additional impoundment liners.
Non-Utility Coal Combustion Waste Sites				
Salem Acres (MA)	Large volume; many other wastes present including municipal solid waste and industrial solid waste.	PAHs, VOCs, PCBs, metals including As and Cr; in soils, surface-waters, and ground water.	Administrative (on NPL)[8]	Contribution of FFC wastes to damage not separable from other wastes. Remedial measures taken including excavation, treatment, removal of sludges and soils.
Lemberger Landfill, Inc.[9] (WI)	Comanaged wastes; many other materials including municipal solid waste; adjacent site contains industrial solid waste.	Elevated levels of As, Cr, and Pb onsite, VOCs, PCBs. VOCs in private water wells initiated action.	Administrative (on NPL)[10]	Contribution of FFC wastes to damage not separable from other wastes.
Don Frame Trucking Fly Ash Landfill (NY)	Coal ash, other materials.	Pb exceedance of primary MCL action level in down gradient ground water; elevated levels of Mn, sulfate, TDS in a water supply well.	Administrative	State required remedial action: site closure landfill cover; post-closure care and monitoring.

Soon after the publication of the Regulatory Determination, the Agency conducted a reevaluation of the damage cases identified in the Regulatory Determination, including the 11 proven damage

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[8] http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5c31fa8f5c885256adc0050b631/C8A4A5BEC0121F048525691F0063F6F3?OpenDocument

[9] Reclassified as a potential damage case. See Section III., Potential Damage Cases. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[10] http://www.epa.gov/superfund/sites/npl/nar735.htm

cases, the four additional ecological damage cases[11] which were identified in comments on the 1999 Report to Congress, the illegal disposal case, and the two potential damage cases attributed to non-utility coal combustion waste in the 1999 Report to Congress. As a result of this review, one of the cases identified in the Regulatory Determination as an ecological damage case, and the case identified as an illegal disposal case were reclassified as proven damage cases due to contamination of ground water from the disposal of CCW in sand and gravel pits and another site, the Lemberger Landfill, was reclassified as a potential damage case [12].

In October 2000, the Agency began collecting additional information from its own experience, from state agencies, and from commenters to clarify the details of the 18 previously indeterminate cases, which were included as part of the 59 cases identified by the public interest groups in their comments on the March 1999 Report to Congress. After analyzing this additional information, EPA classified three of the 18 cases as proven damage cases, nine as potential damage cases, and six as cases without documented evidence of proven or potential damage or where the damage could not be clearly attributed to CCW. Two of the three proven damage cases involved management of CCW in sand and gravel pits and the third - a surface impoundment[13].

Finally, in February 2002, environmental- and citizen-organizations submitted to the Agency 16 alleged cases of damage[14]. Some of these cases had been submitted to EPA previously and evaluated for the 1999 Report to Congress. The Agency evaluated ten of the 16 cases[15]; one case was not evaluated because it involves minefilling of CCW, which, while under the scope of the 2000 Regulatory Determination, is outside the scope of this NODA that deals exclusively with surface disposal. The other five cases were not evaluated because they involved allegations with little or no supporting information. Of the ten cases evaluated, one case has been categorized as a proven damage case with documented off-site damages to ground water, while six cases were categorized as potential damage cases due to on-site exceedances of primary or secondary MCLs[16]. Another damage case was determined to be a proven ecological damage case as a result of documented impacts to fish and other wildlife on-site; this case also has been categorized as a potential (human health) damage case due to documented exceedances of primary and secondary MCLs attributable to an inactive CCW surface impoundment detected in on-site monitoring wells. Finally, one case was rejected because monitoring data for the site

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[11] Ecological damages are damages to mammals, amphibians, fish, benthic layer organisms and plants.

[12] Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[13] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[14] Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

[15] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[16] See Potential DCs, Section III of this document.

revealed no exceedances of primary or secondary MCLs attributable to coal combustion waste placement at the site, while another site is an oil burning facility and, therefore, is not covered by the May 2000 Regulatory Determination[17].

In August 2005, another damage case was recorded when a dam confining a surface impoundment in eastern Pennsylvania failed. This damage case resulted in discharge of coal-ash contaminated water into the Delaware River and concomitant pollution of ground water when an unlined surface impoundment was temporarily used to divert the ash from the breached impoundment. Other than obtaining verification of the event from state authorities, the Agency did not conduct an independent evaluation of this case[18].

In summary, EPA gathered or received information on 135 possible damage cases and has evaluated 85 of these cases. Six of the 50 cases that were not evaluated were minefills and outside the scope of this NODA. The remaining 44 cases that were not evaluated involved allegations with little or no supporting information. (See Table 2: Fossil Fuel Combustion (FFC) Damage Case Resolution, excluding minefills)

Of the 85 cases evaluated, EPA determined that 24 were proven cases of damage[19]. Sixteen were determined to be proven damages to ground water and eight were determined to be proven damages to surface water. Four of the proven damages to ground water were from unlined landfills, five were from unlined surface impoundments, one was due to a liner failure at a surface impoundment, and the remaining six were from unlined sand and gravel pits. Another 43 cases were determined to be potential damages to ground water or surface water. Four of the potential damage cases were attributable to oil combustion wastes. The remaining 18 alleged damage cases were not considered to be proven or potential damage cases; they were, therefore, rejected due to either (1) lack of any evidence of damage or (2) lack of evidence that damages were uniquely associated with CCW[20].

Of the 16 proven cases of damages to ground water, the Agency has been able to confirm that corrective actions have been completed in six cases and are ongoing in nine cases. The Agency has not received information regarding the one remaining case. Corrective actions measures at these CCW management units vary depending on site specific circumstances and include formal closure of the unit, capping, the installation of new liners, ground water treatment, ground water monitoring, and combinations of these measures.

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[17] Status of Alleged Damage Cases Submitted by HEC, et. al., to Dennis Ruddy, February, 2002.

[18] PA DEP Press Release, December 27, 2005.

[19] See Proven Damage Cases, Section II of this document. In addition to the documents previously cited, additional discussions of proven damages can be found in the Memorandum from SAIC to Dennis Ruddy regarding Additional Information Regarding Fossil Fuel Combustion Waste Damage Cases, April 20, 2000; and Ecological Assessment of Ash Deposition and Removal, Euharlee Creek, Georgia Power Bowen Plant.

[20] See Rejected Cases Excluding Minefills, Section IV of this document.

Table 2. Fossil Fuel Combustion (FFC) Damage Case Resolution, excluding minefills (Updated 2/03/05)

Occurence	State	Final Proven	Final Potential	Final Rejected	Indeter-minate	Not re-evaluated	Non-FFC	Sand & Gravel Pit	Non-Utility	Oil Comb. Waste	Eco-Damage
TVA Widows Creek	AL		X								
TVA Colbert Plant	AL		X								
Arizona Public Serv Cholla Station	AZ		X								
Comanche, PSCC	CO				X						
Pierce Site	CT				X						
Hunts Brook Watershed (3 sites)	CT				X						
FP&L - Lansing Smith Plant (part 1)	FL		X								
TECO Big Bend Electric Plant	FL										
TECO Polk Power Station	FL										
FP&L Port Everglades (EPRI #6)	FL		X (oil)							X	
FP&L Riviera (EPRI #10)	FL		X (oil)							X	
FPC P.L. Bartow (EPRI #66)	FL		X (oil)							X	
Georgia Power Bowen	GA	X									
Muscatine County	IA		X								
American Coal Corp. #5 CCR Landfill	IA			X							
Star Coal Co. #6 CCR Landfill	IA			X							
Star Coal Co. #14 CCR Landfill	IA			X							
Powerton Plant	IL		X					X			
ntral IL Light Duck Creek	IL		X								
ower Hennepin Station	IL		X								
IL Power Havana Plant	IL		X								
IL Power - Vermillion	IL		X								
Cent. IL PSC - Hutsonville Station	IL		X								
IL Power - Wood River	IL		X								
Cofeen, White, Brewer Ash Landfill	IL		X								
Turris Coal Company Elkhart Mine	IL			X							
Michigan City Site	IN		X								
Bailly Station	IN		X								
RM Schaffer Station (Schahfer)	IN		X								
SIGECO - AB Brown	IN		X								
IP&L - Petersburg Station	IN		X								
Hoosier Energy Merom Landfill	IN		X								
Yard 520 Landfill Pines	IN	X									
Indiana-Kentucky Electric Clifty Creek Station	IN				X						
Cinergy/Cinn. G&E - East Bend/Boon County - FGD	KY		X								
LG&E Mill Creek Plant	KY				X						
LG&E Cane Run Plant	KY				X						
Salem Acres	MA	X									
Vitale Fly Ash Pit	MA	X						X			
Rezendes Ash Landfill (South Main Street Site/Freetown)	MA		X					X			
Copicut Road Monofill, Freetown	MA			X				X			
E Salem Harbor, Salem	MA				X						
Brayton Point (EPRI #27)	MA		X (oil)							X	

I/A

Table 2. Fossil Fuel Combustion (FFC) Damage Case Resolution, excluding minefills (Updated 2/03/05)

Occurence	State	Final Proven	Final Potential	Final Rejected	Indeter-minate	Not re-evaluated	Non-FFC	Sand & Gravel Pit	Non-Utility	Oil Comb. Waste	Eco-Damage
PEPCO Faulkner	MD	X									
Constellation Energy Crofton	MD				X						
Brandywine Disposal Site	MD				X						
Lansing Board P&L - N. Lansing Landfill	MI	X						X			
Thompson Landfill	MI			X							
Motor Wheel, Inc	MI							X			
Dagget Sand & Gravel, Inc	MI				X			X			
Sherburne County Plant	MN		X								
Colstrip Power Plant	MT										
Hyco Lake (CP&L Roxboro)	NC	X									X
Belews Lake	NC	X									X
Duke Power - Allen Plant	NC		X								
Ecusta Ash Monofill	NC					X			X		
BASF Industrial Landfill	NC					X			X		
Neal Station BESI	ND	X									
Coop Power & United Power - Coal Creek	ND	X									
Montana-Dakota - Heskett Station	ND		X								
Stanton Site, United Power	ND				X						
Leland Olds Site, Basin Electric	ND				X						
Don Frame Trucking	NY	X									
AES Creative Weber Site	NY		X								
Central Hudson G&E - Danskammer Site	NY		X								
C.R. Huntley Ash Landfill	NY		X								
Cinergy/Cinn. G&E - Miamiview Landfill	OH		X					X			
Cinergy/Cinn. G&E - Beckjord Station	OH		X								
Muskingum River Power Plant Impoundments	OH			X							
Cardinal Fly Ash Reservoir II Impoundment	OH			X							
Cardinal PFBC Monofill	OH			X							
Stuart Station Monofill	OH			X							
Gavin Impoundments	OH			X							
Kyger Creek Power Plant Impoundments	OH			X							
Lake Erie	OH			X							X
Conesville FGD Landfill (part 1)	OH		X								
Tristate Asphalt Flyash Landfill	OH				X						
Muskogee Env. Ash Site	OK			X							
Western Farmers Ash Site	OK			X							
Public Service Ash Site	OK			X							
Fort Gibson Fly Ash Monofill	OK				X						
Grand River Dam Authority	OK				X						
IMCO	OK				X						
Elrama Plant	PA		X								
Hatsfield Ferry Power Plant, Greene County	PA				X						
Zullinger Quarry	PA				X						

Table 2. Fossil Fuel Combustion (FFC) Damage Case Resolution, excluding minefills (Updated 2/03/05)

Occurence	State	Final Proven	Final Potential	Final Rejected	Indeterminate	Not re-evaluated	Non-FFC	Sand & Gravel Pit	Non-Utility	Oil Comb. Waste	Eco-Damage
Veterans Quarry, Domino Salvage	PA				X						
Shawville Site, Penelec	PA				X						
Montour Ash Disposal Area	PA				X						
SC Elec & Gas Canadys Plant	SC	X									
Savannah Riv. Project	SC	X									X
SCE&G McMeekin Station	SC				X						
Chestnut Ridge Y-12 Steam Plant Operable Unit 2	TN	X									X
TVA Bull Run Steam Plant	TN		X								
Brandy Branch Reservoir	TX	X									X
Welsh Reservoir	TX	X									X
Martin Creek Reservoir	TX	X									X
JT Deely Power Plant, San Antonio Public Services	TX				X						
VEPCO Possum Pt (Virginia Power)	VA	X								OCW & CCW	
VEPCO Chisman (Virginia Power)	VA	X						X			
Clinch River (part 1)	VA			X							X
Dixie Caverns Landfill	VA			X			X				
Chesterfield, Virginia Power	VA				X						
Georgia Pacific Industrial Waste Landfill, Big Island	VA					X			X		
airyland Power Stoneman (Old E.J. oneman)	WI	X									
WEPCO Hwy 59	WI	X						X			
Alliant Nelson Dewey	WI	X									
WEPCO Cedar Sauk Landfill (part 1)	WI	X						X			
WEPCO Port Washington	WI	X						X			
Alliant Rock River	WI		X								
Alliant Edgewater 1-4	WI		X								
Wisconsin Power Pulliam Ash	WI		X								
Dairyland Power Alma On-site Landfill	WI		X								
Dairyland Power Alma Off-site Landfill	WI		X								
Lemberger Landfill	WI		X					X			
Genoa #3, Dairyland Power Cooperative (DPC)	WI				X						
Old Columbia, WPL	WI				X						
Oak Creek, WEPCO	WI				X						
New Columbia, WPL	WI				X						
Locks Mill Landfill	WI					X			X		
Biron On-site Landfill	WI					X			X		
Kraft Division Off-site Landfill	WI					X			X		
Niagara of Wisconsin Paper Corporation Flyash Landfill	WI					X			X		
RPC Landfill #1	WI					X			X		
RPC Landfill #2	WI					X			X		
RPC Pine Lake Landfill	WI					X			X		
Ward Paper Company Landfill	WI					X			X		
easant Prairie, WEPCO	WI				X						
Dave Johnston Power Plant	WY		X								

Proven Coal Combustion Waste Damage Cases

II. Proven Damage Cases

Per the 2000 Regulatory Determination, 65 FR 32224 and the *Technical Background Document to the Report to Congress on Remaining Waste from Fossil Fuel Combustion: Potential Damage Cases* (1999), classifying damage to groundwater as a proven damage case requires the satisfaction of at least one of the following "tests of proof"[21]:

> 1) Scientific investigation: Damages that are found to exist as part of the findings of a scientific study. Such studies should include both formal investigations supporting litigation or a state enforcement action, and the results of technical tests (such as monitoring of wells). Scientific studies must demonstrate that damages are significant in terms of impacts on human health or the environment. For example, information on contamination of drinking water aquifer must indicate that contaminant levels exceed drinking water standards.
> (2) Administrative ruling. Damages are found to exist through a formal administrative ruling, such as the conclusions of a site report by a field inspector, or through existence of an enforcement that cited specific health or environmental damages.
> (3) Court decision. Damages are found to exist through the ruling of a court or through an out-of-court settlement.
> (4) As a practical matter, EPA employed a fourth criterion in determining whether damages are proven: available information needed to clearly implicate fossil fuel combustion wastes in the damage observed.

The above definition does not limit proven damage cases only to those sites with a primary MCL exceedance(s) in ground water distant from the waste management unit. A case still may be considered proven under the scientific investigation test if a scientific study demonstrates there is

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[21] The May 2000 Regulatory Determination falls short of providing a comprehensive definition of the review criteria ("test of proof") for assessing the validity of damage case allegations; it only discusses the review criteria in response to public comments on the review process of the Cement Kiln Dust (CKD) proposed rule, and focuses only on the location of the exceedance point with respect to the source term (32224 CFR 65):

"Proven damage cases were those with documented MCL exceedances that were measured in ground water at a sufficient distance from the waste management unit to indicate that hazardous constituents had migrated to the extent that they could cause human health concerns."

The "test of proof" criteria were fully defined on pp. 3-4 of the *Technical Background Document to the Report to Congress on Remaining Waste from Fossil Fuel Combustion: Potential Damage Cases* (1999): http://www.epa.gov/epaoswer/other/fossil/ffc2_397.pdf. This language, in turn, is derived from the 1993 *Report to Congress on Cement Kiln Dust Waste*: http://www.epa.gov/epaoswer/other/ckd/cement2.htm.

According to the 1993 CKD Report to Congress (Chapter Five), Section 8002(o)(4) of RCRA requires that EPA's study of CKD waste examine "documented cases in which danger to human health or the environment has been proved." In order to address this requirement, EPA defined danger to human health to include both acute and chronic effects (e.g., directly observed health effects such as elevated blood lead levels or loss of life) associated with management of CKD waste. Danger to the environment includes the following types of impacts: (1) Significant impairment of natural resources; (2) Ecological effects resulting in degradation of the structure or function of natural ecosystems and habitats; and (3) Effects on wildlife resulting in damage to terrestrial or aquatic fauna.

documented evidence of another type of damage to human health or the environment (e.g., ecological damage).

1. Salem Acres Site, Massachusetts[22]

History: Fly ash disposal occurred at this site from at least 1952 to 1969. The site was originally contaminated by fly ash, sewage sludge, tannery waste and materials from a landfill on the site. The contamination was confined to the southernmost 13 acres of the 235 acre parcel and consisted of polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans, volatile organic compounds (VOCs), chromium, arsenic, beryllium, vanadium and thallium.

EPA proposed adding the Salem Acres site to the NPL on October 15, 1984, and added it to the final list on June 10, 1986[23]. On May 26, 1987, EPA signed a Consent Order with the South Essex Sewerage District (SESD) to perform the studies to examine the nature and extent of contamination and present technical options for cleanup. In December 1993, EPA signed a Consent Decree with the SESD to clean up the lagoons. The EPA also signed a separate Consent Decree with the Massachusetts Electric Company to clean up the fly ash pile on site. In October 1994, the EPA signed a Consent Order with DiBase Salem Realty Trust, the owner of the property and remaining party, to clean up the landfill and three debris piles.

Cleanup of the site was addressed in two stages: initial actions and a long-term remedial phase focusing on cleanup of the entire site. In 1987, lagoon water was removed and disposed of, the slurry wall at the disposal areas was capped and a fence was installed. In 1988, EPA covered the sludge pits with a high density polyethylene synthetic cap, removed the liquid wastes from the disposal pits to an off-site storage facility, and constructed concrete cut-off walls to prevent further releases into the wetlands. In 1990, repairs were made to a monitoring well and a security fence on site, and signs were posted to further restrict access.

The South Essex Sewerage District completed an investigation into the nature and extent of the soil and sludge contamination in early 1993. The investigation defined the contaminants of concern and recommended alternatives for final cleanup. Ground water at the site and adjacent wetlands demonstrated only minor contamination and therefore, no further remedial actions were planned. EPA selected a final remedy for the site, including sludge-fixation with fly ash and other substances such as cement and soil, as necessary and disposed of off-site to a secured landfill. A contingent remedy includes the installation of an EPA-approved cap. In 1995, the fly ash area and "old landfill" on site were excavated and the contaminated material was taken off site to a municipal landfill. Final site restoration of these areas occurred in 1996. The sludge lagoon cleanup was completed in the fall of 1997 and final site restoration was completed in the

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[22] Memorandum from SAIC to Dennis Ruddy regarding Additional Information Regarding Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[23] http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5c31fa8f5c885256adc0050b631/C8A4A5BEC0121F048525691F0063F6F3?OpenDocument

spring of 1998. In the summer of 1999, fly ash was removed from the wetland adjacent to the former fly ash pile. The wetland was restored at this time. The site was officially deleted from the National Priorities List (NPL) effective July 23, 2001[24]. The site now allows for unrestricted land use

Basis for Consideration as a Proven Damage Case: The criteria for classifying this site as a proven damage case were (1) Scientific – Arsenic and chromium exceeded (health-based) primary MCLs, and (2) Administrative – The site has been placed on the NPL list, and EPA signed a Consent Order with the owner to clean up the lagoons.

2. City of Beverly/Vitale Brothers Fly Ash Pit, Massachusetts[25]

History: This site is an abandoned gravel and sand mine that was used as an unpermitted landfill from the 1950's until the mid-1970s. The site was operated by the Vitale Brothers until 1980, when the City of Beverly Conservation Commission gained ownership because of failure to pay property taxes. On the site, the Vitale Brothers accepted and disposed saltwater-quenched fly ash from New England Power Company along with other wastes. Leaking underground storage tanks containing petroleum products were also located at the site. In 1973, fly ash at the site eroded into a nearby swamp and a stream that is a tributary to a surface drinking water supply. The erosion created a damming effect and resulted in flooding of neighboring property. In 1988, surface water sampling of the stream revealed levels of iron and manganese significantly greater than upstream levels. Additionally, there were complaints of fugitive dust from the site from neighbors located 500 feet away. Air sampling on one occasion in 1988 revealed arsenic concentrations of 2 parts per billion. Finally, 1988 ground water sampling found arsenic and selenium in excess of their primary MCLs and aluminum, iron, and manganese in excess of secondary MCLs. According to the State, fly ash is the suspected source of contamination in all of these media.

Fly ash is disposed at the site at depths from 14 to 36 feet. Not only is the site unlined, but ground water depth at the site is between 10 and 21 feet, indicating the likelihood of direct contact with fly ash. Fly ash also is observed to be present at the surface of the site with no cover or other surface runoff, erosion, or fugitive dust controls. Finally, the site is located in close proximity to a wetland and a surface water body.

The site has a long history of noncompliance with local and State laws and regulations. Following the completion of a Comprehensive Site Assessment and Risk Characterization in preparation for potential remedial action under Massachusetts regulations for the assessment and cleanup of hazardous waste sites, the fly ash was removed and the site was redesigned with special attention to protecting the adjacent water courses from erosion[26]. The Vitale Flyash site

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[24] Ibid

[25] Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[26] http://www.erosioncontrol.com/ecm_0603_erosion.html

submitted a site closure report February 1, 2007, and a preliminary screening of the site closure report is underway[27].

Basis for Consideration as a Proven Damage Case: This case was not counted as a proven damage case in the 1999 Regulatory Determination because it was a case of illegal disposal not representative of historical or current disposal practices. The case, however, otherwise meets the criteria for a proven damage case for the following reasons: (1) Scientific – (i) selenium and arsenic exceeded (health-based) primary MCLs, and (ii) there is evidence of contamination of nearby wetlands and surface waters; and (2) Administrative - the facility was the subject of several citations and the State has enforced remedial actions.

3. Don Frame Trucking, Inc. Fly Ash Landfill, New York[28]

History: This solid waste management facility had been used for disposal of fly ash, bottom ash, and other material including yard sweepings generated by the Niagara Mohawk Power Corporation's Dunkirk Steam Station. The age of the facility was not identified in the materials provided. The available monitoring data for this facility include quarterly water quality analysis and various miscellaneous data collected at the facility from March 1989 through September 1998. These data show down-gradient levels of lead greater than the primary MCL Action Level. These exceedances occurred in 1989 and 1996. The data also document elevations from background of sulfate, total dissolved solids, and manganese, including levels of manganese in a water supply well greater than the secondary MCL.

As a result of the contamination, Don Frame Trucking recommended to the New York State Department of Environmental Conservation (NYSDEC) that the affected water supply well should immediately be connected to a public water supply. Also, on September 16, 1988, Don Frame Trucking, Inc. was directed to cease receiving the aforementioned wastes at the facility no later than October 15, 1988, in accordance with the standards contained in 6 NYCRR Part 360.[29] The site was divided into five separate sections. The NYSDEC directed Don Frame Trucking, Inc. to place two feet of a "final cover" over Section I. The soil should have a coefficient of permeability of 1×10^{-5} cm/sec. NYSDEC directed Section II to be covered with 18 inches of clay cover with a coefficient of permeability of 1×10^{-7} in two shifts. Once the permeability was tested and considered acceptable, NYSDEC directed Don Frame Trucking, Inc. to place six additional inches of topsoil was over the clay cover and then seed and mulch the section. Eighteen inches of clay with a coefficient of permeability of 1×10^{-7} was also directed to be placed on Sections III, IV, and V, followed by reseeding and mulching. Don Frame Trucking, Inc. was instructed to finish all remediation procedures by October 15, 1988, and then provide

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[27] MADEP tracking number 3-00230; email message from Patricia Donahue, MADEP, July 9, 2007.

[28] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[29] Application of Don Frame Trucking, Inc. Petitioner for a Judgment Pursuant to Article 78 of the CPLR against the New York State Department of Environmental Conservation Respondent; Supreme Court of the State of New York County of Chautauqua (July 22, 1988). Order G11278.

certification by a licensed professional engineer that the facility was closed in accordance with the rules and regulations as stipulated by the NYSDEC by October 21, 1988. Post-closure ground water and surface water monitoring and maintenance were also expected to continue for 30 years after final closure of the entire facility.

Basis for Consideration as a Proven Damage Case:(1) Scientific - The lead levels found in down-gradient wells exceed the primary MCL Action Level; (2) Administrative - The State has required remedial action as a result of the contamination; and (3) Court order – The owner was directed, by the Supreme Court of the State of New York County of Chautauqua (July 22, 1988), to cease receiving the aforementioned wastes at the facility no later than October 15, 1988.

4. Virginia Electric Power Co. (VEPCO) Possum Point, VA[30]

History: EPA identified this site as a proven damage case in the March 1999 Report to Congress. It is described in detail in the Report and supporting technical background documents in the rulemaking docket.

The technical background document[31] states: "One additional documented damage case is the Virginia Electric and Power Company (VEPCO) Possum Point Site, described in the 1993 Regulatory Determination. This is an active facility with 40-acre unlined ash ponds with solids dredged to 80-acre lined ponds. These ponds received coal ash, pyrites, water treatment wastes, boiler cleaning wastes, and oil ash. Ground water monitoring found cadmium at concentrations 3.6 times and nickel, at 26.4 times the primary MCLs. Monitoring for vanadium was conducted but no results were given. The elevated concentrations were attributed to the pyrites and oil ash. These wastes, along with metal cleaning wastes, were ordered sequestered to separate lined units."

The 1999 Report to Congress[32] states: "**Possum Point, Virginia** (described in the 1993 Supplemental Analysis). At this site, oil ash, pyrites, boiler chemical cleaning wastes, coal fly ash, and coal bottom ash were comanaged in an unlined pond, with solids dredged to a second pond. Levels of cadmium above 0.01 mg/L were recorded prior to 1986 (the primary MCL is 0.005 mg/L). After that time, remedial actions were undertaken to segregate wastes (oil ash and low volume wastes were believed to be the source of contamination). Following this action, cadmium concentrations were below 0.01 mg/L."

Basis for Consideration as a Proven Damage Case: Based on evidence on exceedances of cadmium and nickel, the State pursued an Administrative Action by requiring the removal of the waste, thus qualifying it as a proven damage case.

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[30] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[31] Technical Background Document For the Report to Congress On Remaining Wastes from Fossil Fuel Combustion: Potential Damage Cases, March 15, 1999 (http://www.epa.gov/epaoswer/other/fossil/ffc2_397.pdf)

[32] http://www.epa.gov/epaoswer/other/fossil/volume_2.pdf

5. PEPCO Morgantown Generating Station Faulkner Off-site Disposal Facility, Maryland[33]

History: Landfills at this site manage fly ash, bottom ash, and pyrites from the Morgantown Generating Station starting in 1970. Unlined settling ponds also are used at the site to manage stormwater runoff and leachate from the ash disposal area. In 1991, the State found that water quality was degraded in the underlying aquifer and that ground water contamination had migrated to nearby surface waters (including a stream and a wetland area). The impacts included vegetative damages, orange staining from iron precipitation, and low pH. Because of the ground water migration, the operator was cited for unpermitted discharges to surface water. The low pH impacts are believed to have resulted from pyrite oxidation. The low pH may also have contributed to the migration of other contaminants. Additionally, ground water beneath the facility is shallow. Documentation shows the water table is very close to the bottom of the ash disposal area at the down-gradient end of the facility and well above the base of the settling ponds used to manage stormwater runoff and leachate from the ash disposal area.

Remedial measures at the site included closure and capping of older units, installation of liners in newer units, installation of a slurry wall to prevent ground water migration, and sequestration of pyrites. EPA identified this site as a proven damage case in the March 1999 Report to Congress. It is described in detail in the Report and supporting technical background documents in the rulemaking docket.

Basis for Consideration as a proven Damage Case: EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific - Ground water contamination migrated off-site; and (2) Administrative - The State required remedial action.

6. Virginia Power Yorktown Power Station Chisman Creek Disposal Site, Virginia[34]

History: This site consists of three parcels of land that cover 27 acres. Between 1957 and 1974, abandoned sand and gravel pits at the site received fly ash from the combustion of coal and petroleum coke at the Yorktown Power Station. Disposal at the site ended in 1974 when Virginia Power began burning oil at the Yorktown plant. In 1980, nearby shallow residential wells became contaminated with vanadium and selenium. Water in the wells turned green and contained selenium above the primary MCL and sulfate above the secondary MCL. Investigations in response to the discolored drinking water found heavy metal contamination in the ground water around the fly ash disposal areas, in onsite ponds, and in the sediments of Chisman Creek and its tributaries. Arsenic, beryllium, chromium, copper, molybdenum, nickel, vanadium, and selenium were detected above background levels.

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[33] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[34] Ibid. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

The contamination at the site's vicinity was caused by the combination of several factors: (i) The facility was operated with no dust or erosion controls; (ii) The facility is unlined and located in close proximity to drinking water wells, and ground water at the site was very shallow and possibly in contact with disposed waste.; (iii) A surface water tributary passed through or near the disposal areas.

In September 1983, EPA added the site to the National Priorities List (NPL)[35] under the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA). Cleanup began in late 1986 and was conducted in two parts. The first part addressed the fly ash pits and contaminated ground water and included the following steps:

- Extension of public water to 55 homes with contaminated well water,
- Capping the disposal pits with soil (2 pits) or compacted clay (1 pit) overlain with topsoil and vegetative growth,
- Ground water and leachate collection for treatment and to lower the water table beneath the pits, and
- Post-closure monitoring.

The second part addressed the onsite ponds, a freshwater tributary stream, and the Chisman Creek estuary and included the following steps:

- Relocation of a 600-foot portion of the tributary to minimize contact with the fly ash disposal areas,
- Diversion of surface runoff, and
- Long-term monitoring for the ponds, tributary, and estuary.

Construction of all cleanup components was completed on December 21, 1990. The site has been redeveloped as a public park. Following the completion (in December 2006) of its third five-year review of the site, EPA determined that the remedial action at Operable Unit 1 is protective in the short term because the extent of the vanadium contamination in the shallow ground water aquifer is not presently known. EPA is presently working with Virginia Power to determine the extent of the vanadium contamination and to amend the restriction to make sure it provides the necessary assurance that it will be protective over time.

Basis for Consideration as a Proven Damage Case: EPA identified this site as a proven damage case in the March 1999 Report to Congress. It is described in detail in the Report and supporting technical background documents in the rulemaking docket. EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific – (i) Drinking water wells contained selenium above the (health-based) primary MCL and (ii) There is evidence of surface water and sediment contamination; and (2) Administrative - The site was remediated under CERCLA.

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[35] http://epa.gov/reg3hwmd/npl/VAD980712913.htm

7. Hyco Lake, Roxboro, North Carolina[36]

History: This case was originally identified by a public interest group in a table alleging selenium contamination, and a selenium fish consumption advisory[37].

Hyco Lake was constructed in 1964 as a cooling water source for the CP&L Roxboro Steam Electric Plant. The lake received discharges from the plant's ash-settling ponds containing high levels of selenium. The selenium accumulated in the fish in the lake, affecting reproduction and causing declines in fish populations in the late 1970s and 1980s. The North Carolina Department of Health and Human Services issued a fish consumption advisory in 1988[38].

In 1990, CP&L installed a dry ash handling system to meet new permit limits for selenium. To determine the effectiveness of the new handling system, the Department of Water Quality is requiring long-term monitoring of the lake. Based on the results of fish tissue sampling, the fish consumption advisory has been rescinded in stages starting in 1994[39]. It was completely rescinded in August, 2001[40].

Basis for Consideration as a Proven Damage Case: This case is categorized as a proven ecological damage case for the following reasons: (1) Scientific - declines in fish populations were observed (1970s & 1980s); (2) Administrative - The State concluded that the impacts were attributable to the ash ponds, and issued a fish consumption advisory as a result of the contamination.

8. Georgia Power Company, Plant Bowen, Cartersville, GA[41]

History: This unlined CCW management unit was put in service in 1968. On July 28, 2002, a sinkhole developed in the (coal) ash pond of the Georgia Power Company - Plant Bowen Facility (coal-fired generating facility). The sinkhole ultimately reached four acres and a depth of thirty

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[36] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[37] Letter from the Hoosier Environmental Council to the RCRA Docket Information Center regarding comments on the May 2000 Regulatory Determination, September 19, 2000.

[38] Selenium Posting on Hyco Lake Rescinded, North Carolina Department of Health and Human Services (NCDHHS), August 2001.

[39] Roanoke River Basinwide Water Quality Plan, Section B, Chapter 5: Roanoke River Subbasin 03-02-05, North Carolina Department of Environment and Natural Resources (NCDENR), July 2001. Available at http://h2o.enr.state.nc.us/basinwide/roanoke/2001/2001_Roanoke_wq_management_plan.htm

[40] Selenium Posting on Hyco Lake Rescinded, North Carolina Department of Health and Human Services (NCDHHS), August 2001.

[41] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007. Ecological Assessment of Ash Deposition and Removal, Euharlee Creek, Georgia Power Bowen Plant, available in the docket to the CCW NODA (EPA-HQ-RCRA-2006-0796).

feet. The integrity of the ash pond dikes did not appear to be compromised. The company estimated that 2.25 million gallons of ash/water mixture was released to an unnamed tributary of the Euharlee Creek, containing 281 tons of ash. Georgia's Department of Natural Resources alleges an unpermitted discharge of water containing approximately 80 tons of ash slurry entered Euharlee Creek through a stormwater drainage pipe resulting in a temporary degradation of public waters.

Georgia Department of Natural Resources issued a consent order on November 20, 2002. The order contained the following provisions:

- Fine of $31,250 was imposed;
- Company to perform ecological impact study of the ash discharge into Euharlee Creek and recommend remedial action;
- Company to submit proposed dredging plan if necessitated by impact study;
- Company to submit report on actions taken to fill sinkhole and grout fissures under the dike;
- Company to perform geological engineering assessment of the ash pond stability and recommend corrective actions to address future sinkhole development;
- Company to submit a revised ash water management plan;
- Georgia EPD approved corrective action plans shall be implemented; and
- Company shall submit interim progress report and final schedule for completion of implementation of corrective action plans.

Basis for Consideration as a Proven Damage Case: (1) Scientific - unpermitted discharge of water containing ash slurry into the Euharlee Creek resulting in a temporary degradation of public waters; and (2) Administrative - Georgia Department of Natural Resources issued a consent order requiring, among others, a fine and corrective action.

9. Department of Energy - Oak Ridge Y-12 Plant Chestnut Ridge Operable Unit 2 DOE Oak Ridge Reservation, Oak Ridge, Tennessee[42]

History: This case was originally identified by public commenters in a table that alleged aluminum, arsenic, iron, and selenium contamination, as well as fish deformities and a region of a stream where no fish are found[43].

Chestnut Ridge Operable Unit (OU) 2 consists of Upper McCoy Branch, the Filled Coal Ash Pond (FCAP), and the area surrounding the sluice channel formerly associated with coal ash disposal in the FCAP. Upper McCoy Branch runs from the top of Chestnut Ridge across the FCAP into Rogers Quarry. The FCAP is an 8.5 acre area. The sluice channel area extends approximately 1,000 feet from the crest of Chestnut Ridge to the edge of the FCAP.

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[42] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[43] Letter from HEC et. al., to Dennis Ruddy, February, 2002.

The FCAP is an ash retention impoundment used to dispose of coal ash slurry from the Y-12 steam plant. It was constructed in 1955 by building an earthen dam across a northern tributary of Upper McCoy Branch, and was designed to hold 20 years of ash. By July of 1967, the impoundment was filled to within four feet of the top of the earthen dam. Once the impoundment was no longer able to retain the ash solids, the slurry was released directly into Upper McCoy Branch through direct flow over the earthen dam. In 1967 and 1968, Upper McCoy Branch was diverted into Rogers Quarry. Between 1967 and 1989, the ash slurry flowed directly from the FCAP into Upper McCoy Branch and then into Rogers Quarry. In 1989, a bypass pipe was constructed to carry the slurry directly from the steam plant to Rogers Quarry. Disposal of ash into Rogers Quarry was discontinued in 1990, when a chemical vacuum system and a bottom ash dewatering system were installed at the plant. Both fly ash and bottom ash are now disposed in a landfill. Existing ash deposits were left in place. Erosion of both the spillway and the ash itself has occurred, leading to releases of ash into Upper McCoy Branch[44].

In the mid-1980s, the Y-12 plant began investigation and ground water monitoring at a number of locations within its boundaries, as required under RCRA and by the Tennessee Department of Environmental Conservation (TDEC). The entire Oak Ridge Reservation was placed on the NPL in 1989. CERCLA requires all sites under investigation to complete a remedial investigation to determine the nature and extent of contamination, evaluate the risks to public health and the environment, and determine remedial action goals. The Remedial Investigation for OU conducted in two phases. Phase I was conducted by CH2M Hill in the Upper McCoy Branch zone. Phase II was conducted by CDM Federal in the FCAP and sluice area zones. Both investigations consisted of surface and ground water, soil, and ash sampling. The table below shows a summary of the results of the monitoring programs[45].

Table 3. Oak Ridge Y-12 Plant Chestnut Ridge Operable Unit 2
Surface and Ground Water Monitoring Programs

Monitoring type	Monitoring location	Constituents with exceedances of ambient/ reference/background concentrations	Constituents with exceedance of MCLs or SMCLs
Surface Water	Upper McCoy Branch (Phase I)	Al, Fe, Cu	Al, As, Fe, Mn
	Upper McCoy Branch (Phase II)	Al, As, Ca, Mn, K, Na	Al, As, Mn
	FCAP Pond Water	Al, As, Ba, Ca, Cr, Cu, Fe, Pb, Mg, Mn, K, Na, V, Zn	Al, As, Fe, Mn

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[44] Feasibility Study for the Y-12 Chestnut Ridge Operable Unit 2 Filled Coal Ash Pond, Oak Ridge, Tennessee. DOE/OR/02-1259&D1. August 1994.

[45] Ibid.

Monitoring type	Monitoring location	Constituents with exceedances of ambient/ reference/background concentrations	Constituents with exceedance of MCLs or SMCLs
	Spring Water	Al, As, Ba, Ca, Pb, Mn, Hg, K, V, Zn	Al, As, Fe, Pb, Mn
Ground Water	Upper McCoy Branch (Phase I)	Al, Ba, Ca, Co, Cu, Fe, K, Mg, Mn, Na, Se, Zn	Al, Fe, Mn
	Upper McCoy Branch (Phase II)	information not provided	Mn
	Sluice Channel Area	information not provided	Mn
Soil	Near Upper McCoy Branch (Phase II)	Al, As, Ba, Fe, Mn, K, Na	Not applicable
	Near FCAP	Al, As, K, Na	Not applicable
Ash	Entire Site	No background data	Not applicable

Biological monitoring has also been conducted at the site as part of a RCRA Facility Investigation (RFI) required by the 1984 Hazardous and Solid Waste Amendments to RCRA, and as part of the Phase I Remedial Investigation. The biological monitoring conducted for the RFI included toxicity testing, bioaccumulation studies, fish community assessments, and a benthic macro-invertebrate community assessment. Biological monitoring for the Phase I RI consisted of toxicity testing, a benthic macro-invertebrate assessment, a soil (ash) invertebrate survey, and bioaccumulation studies[46].

The conclusions for the RFI biological monitoring programs were as follows:

- Toxicity testing: The results of the toxicity testing did not show significant evidence for toxic conditions in Upper McCoy Branch.
- Bioaccumulation studies:
    - Concentrations of selenium, arsenic, and possibly thallium were elevated in largemouth bass from Rogers Quarry, relative to bass from another nearby site;
    - Arsenic exceeded screening criteria;
    - Some fish from Rogers Quarry had deformed bony structures (these effects were not described in literature as effects of arsenic or selenium); and
    - Bioaccumulation was not indicated in Upper McCoy Branch discharge

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[46] Ibid.

- Fish community assessment: The results indicate that Upper McCoy Branch is under severe stress:

    - No fish populations were found above Rogers Quarry; and

    - Downstream sunfish populations had high percentages of deformed heads and eroded fins.

- Benthic Macro-invertebrate Community Assessment: The results were indicative of moderate stress. The stress appears to be habitat alteration as a result of ash deposition within the stream channel and possibly leaching of potential toxicants from the ash.

The conclusions for the RI biological monitoring programs were as follows:

- Toxicity testing: The results did not show toxic conditions in Upper McCoy Branch.
- Benthic Macro-invertebrate Assessment: The results exhibited no strong evidence of impact at Upper McCoy Branch. There were some differences in July samples, which could be due to natural variations between the two locations, or could be due to low flow conditions increasing concentrations of contaminants from the ash.
- Soil (ash) Invertebrate Study: No invertebrates were found in samples from the sluice channel area or the FCAP, indicating this is not a possible pathway for contamination of the food chain.

- Bioaccumulation Studies:

    - . Vegetation: The results show that selenium uptake into plants is a possible source of exposure to soil invertebrates and small mammals.
    - Small mammals: The study found higher concentrations of arsenic, selenium and lead in animals from the FCAP than in animals from a reference site.

A remedial action was conducted to stabilize the filled coal ash pond, McCoy Bridge dam holding contaminated pond sediments in place. A wetland, removed during stabilization activities, was re-constructed as part of the remedial action. Physical work was completed in March 1997. The remedial action report was approved in May 1997[47].

Basis for Consideration as a Proven Damage Case: This case has been categorized as a proven ecological damage case based on scientific documentation of impacts to fish and other wildlife on-site. This case has also been categorized as a potential (human health) damage case based on (1) Scientific basis - Exceedances of primary and secondary MCLs were detected in on-site monitoring locations, and (2) Administrative grounds - Federal RCRA and the Tennessee Department of Environmental Conservation (TDEC) requirements, including placement of the entire Oak Ridge Reservation on the NPL.

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[47] http://www.epa.gov/region4/waste/npl/npltn/oakridtn.htm

10. South Carolina Electric & Gas Canadys Plant, South Carolina[48]

History: This facility is a coal-fired power plant located along the Edisto River approximately 10 miles south of St. George, South Carolina. Ash from the power plant is mixed with water and managed in an ash storage pond. The facility operated an unlined, 80-acre ash pond from 1974 to 1989. A new, 95-acre ash pond lined with a bentonite slurry wall began operation in 1989.

Since 1982, arsenic has consistently been found in monitoring wells surrounding the old ash pond at levels above the MCL. Nickel also has occasionally been found above a State standard in a single monitoring well adjacent to the old ash pond. Because of these results, DHEC required the facility to delineate the extent of the contamination surrounding the old ash pond. The contamination was found to extend beyond the original property boundary of the facility, but the operator was allowed to buy neighboring property under State policy at the time. The investigation also showed that the contamination was not reaching the Edisto River and that its vertical extent was limited by a confining geologic unit 15 to 30 feet below the property. The facility is currently deactivating the old ash pond, with ash being removed and sold to a cement company. DHEC concluded that further migration of contaminants was not likely given the ground water conditions and the ongoing deactivation. In 1996, therefore, DHEC approved a mixing zone with ongoing monitoring around the old ash pond. The mixing zone establishes a compliance boundary around the old ash pond. Arsenic concentrations above the MCL are permitted within the mixing zone, but not at or outside of the compliance boundary.

The new ash pond extends beyond the compliance boundary of the old ash pond. Sampling in May 2000 found arsenic above its MCL at, and external to, the compliance boundary in wells that are adjacent to the new ash pond. Resampling in June 2000 confirmed the noncompliance. The facility's engineering contractor and DHEC suspect this arsenic contamination is associated with a separate plume originating from the new ash pond. DHEC suspects improper anchoring or a breach of the slurry wall surrounding the new ash pond. Based on a geophysical investigation, the facility's engineering contractor concluded that the slurry wall appears to have failed in various locations, allowing multiple seeps. The contractor noted that drought-like conditions during the preceding three years have caused a site-wide decrease in the water table. The increase in potentiometric head between the new ash pond and the falling water table may be a contributing factor to the breaches in the slurry wall. The facility has proposed additional monitoring to delineate the extent of the new arsenic plume and an extension of the compliance boundary to encompass the new ash pond. The facility also is evaluating possible corrective action alternatives for repairing or replacing the slurry wall. The extent of the new plume has not yet been fully delineated and DHEC has not yet determined what response may be required of the facility.

This site was initially classified as indeterminate because there was no information on the extent of the contamination (on-site or off-site), quantitative data on whether arsenic levels exceeded State standards, or confirmation that the contamination was attributable to fossil fuel combustion waste. In a follow-up assessment conducted after the Regulatory Determination, a representative

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[48] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

from South Carolina's Department of Health and Environmental Control (DHEC) confirmed that there is arsenic contamination attributable to two coal combustion waste (CCW) management units at this site. According to the DHEC contact, it is unlikely that there are any ground water supply wells or other human exposure points in the vicinity of the facility. Furthermore, ground water supply wells in the region typically are drilled beneath the underlying confining geologic unit.

Basis for Consideration as a Proven Damage Case: Scientific - There are exceedances of the health-based standard for arsenic at this site. While there are no known human exposure points nearby, some recent exceedances have been detected outside an established regulatory boundary.

11. Belews Lake, North Carolina[49]

History: This Lake was impounded in the early 1970s to serve as a cooling reservoir for a large coal-fired power plant. Fly ash produced by the power plant was disposed in a settling basin, which released selenium-laden effluent in return flows to the Lake. Due to the selenium contamination, 16 of the 20 fish species originally present in the reservoir were entirely eliminated, including all the primary sport fish. The pattern of selenium contamination from the plant and fish impacts persisted from 1974 to 1985. In late 1985, under mandates from the State of North Carolina, the power company changed operations for fly ash disposal, and selenium-laden effluent no longer entered the Lake.

A fish advisory was issued for selenium in 1993 which was rescinded December 31, 2000[50].

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven ecological damage case for the following reasons: (1) Scientific evidence of extensive impacts on fish populations due to direct discharge to a surface water body, and (2) Administrative - The State required changes in operating practices to mitigate the contamination.

12. U.S. Department of Energy Savannah River Project, South Carolina[51]

History: The Savannah River Project commenced operations and disposal of ash in 1952. At this site, a coal-fired power plant sluices fly ash to a series of open settling basins. A continuous flow of sluice water exits the basins, overflows, and enters a swamp that in turn discharges to Beaver Dam Creek. Observations of bullfrogs of all developmental stages in the settling basins and swamp suggest that the mixture of pollutants that characterize the site does not prevent

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[49] Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[50] http://134.67.99.49/scripts/esrimap.dll?Name=Listing&Cmd=NameQuery&Left=-178.215026855469&Right=-52.6202812194824&Top=83.1083221435547&Bottom=-14.3755550384521&shp=3&shp=6&idChoice=3&loc=on&NameZoom=NC%20-%20Belews%20Lake

[51] Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

completion of the life cycle. However, bullfrog tadpoles inhabiting the site have oral deformities and impaired swimming and predator avoidance abilities. There also is evidence of metabolic impacts on water snakes inhabiting the site.

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven ecological damage case for the following reasons: (1) Scientific evidence of impacts on several species in a nearby wetland caused by releases from the ash settling ponds.

13. Dairyland Power Cooperative E.J. Stoneman Generating Station Ash Disposal Pond, Wisconsin[52]

History: This facility is an unlined pond that managed ash, demineralizer regenerant, and sand filter backwash from the 1950's until 1987. During the facility's operating life, ground water monitoring of on-site wells around the pond found cadmium and chromium in excess of primary MCLs and sulfate, manganese, iron, and zinc in excess of secondary MCLs. Nearby private drinking water wells showed levels of sulfate and boron elevated from background. As a result, the State concluded that other constituents could reach the drinking water wells in the future.[53] Because of the evidence of ground water contamination and because the facility violated State location standards, the State denied the operator's proposal to continue operation of the pond. The State also required the operator to close the facility and provide alternative drinking water to the affected residences. The history of contamination also led the State to require a new landfill on the site to be constructed with a double liner and leachate collection.

In addition to being unlined, the unconsolidated soils beneath the site consist of highly permeable sand and gravel (estimated permeability of 10^{-2} cm/sec). The pond was located close to the Mississippi River, in violation of the State's requirement for 300 feet of separation from navigable rivers. The proximity to the river caused variable water table levels and periods of ground water mounding, during which the depth of ground water beneath the unit was very shallow (possibly as low as 1 foot). Finally, the pond was located closer to 15 water supply wells than allowed by State standards.

Basis for Consideration as a Proven Damage Case: EPA identified this site as a proven damage case in the March 1999 Report to Congress. It is described in detail in the Report and supporting technical background documents in the rulemaking docket. EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific - Cadmium and chromium exceeded (health-based) primary MCLs, and contamination migrated to nearby, private drinking water wells; and (2) Administrative - The State required closure of the facility.

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[52] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[53] More recent monitoring data confirm this conclusion, with cadmium exceeding the primary MCL and iron and manganese exceeding secondary MCLs in the drinking water wells.

14. WEPCO Highway 59 Landfill, Wisconsin[54]

History: This site is located in an old sand and gravel pit and received fly ash and bottom ash between 1969 and 1978. Ground water monitoring between 1988 and 1998 found sulfate, boron, manganese, chloride, and iron above the State's Enforcement Standards (ES) and arsenic above the State's Preventive Action Level (PAL) in nearby private wells. Other down-gradient monitoring wells showed sulfate, boron, iron, and manganese in excess of the ES and selenium and chloride in excess of PALs. State agency staff considered this site one of the most seriously affected coal ash sites in the State. The State required a continuation of monitoring at this closed facility in 1982 and an investigation into ground water contamination in 1994.

The facility is unlined and the soil underlying the site consists of fine to coarse sands and gravel with minor amounts of silt and clay and is believed to be relatively permeable. The original sand and gravel pit included an area of standing water. The presence of the standing water is attributed to the elevation of the ground water table exceeding the base of the pit in this area. Waste was disposed directly into this area to a depth of 5 to 10 feet below the water table. (Note also that the facility is located in close proximity to a wetland, although there is no documentation of impact to flora in the wetland.)

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven damage case of the following reasons: (1) Scientific - Although the boron standard was not health-based at the time of the exceedances, the boron levels reported for the facility would have exceeded the State's recently promulgated health-based ES for boron; and contamination from the facility appears to have migrated to off-site private wells; and (2) Administrative - As a result of the various PAL and ES exceedances, the State required a ground water investigation.

15. Alliant (formerly Wisconsin Power & Light) Nelson Dewey Ash Disposal Facility, Wisconsin[55]

History: This facility was originally constructed in the early 1960's as a series of settling basins for sluiced ash and permitted by the State in 1979. Waste disposal at the site resulted in exceedances of the State's Preventative Action Levels (PALs) for arsenic, selenium, sulfate, boron, and fluoride. These exceedances occurred within the design management zone of the facility. Waste disposal also has resulted in exceedances of the State's Enforcement Standards (ES) for boron, fluoride, and sulfate outside the design management zone of the facility. As a result of these exceedances, the State required an investigation of ground water contamination in 1993. In 1996, the facility began converting to dry ash management and covering/closing phases of the facility.

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[54] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[55] Ibid.

Soil underlying the site consists of unconsolidated glacial outwash deposits of relatively high permeability (estimated between 10^{-2} and 10^{-5} cm/sec). The facility is not only unlined, but was originally designed to allow sluiced liquids to infiltrate to ground water, with direct discharge to surface water occurring only occasionally. For much of their life, the basins operated with a relatively high hydraulic head. In fact, in 1986, the facility began using direct discharge to reduce the hydraulic head in response to PAL exceedances for sulfate. This combination of conditions resulted in a ground water mound beneath the ash disposal area. While depth to ground water at the site is generally approximately 10 feet, the height of the ground water mound was estimated at 5 to 8 feet, resulting in an estimated effective depth to ground water of only 2 to 5 feet underneath the disposal area.

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific - Although the boron standard was not health-based at the time of the exceedances, the boron levels reported for the facility would have exceeded the State's recently promulgated health-based ES for boron; and (2) Administrative - As a result of the various PAL and ES exceedances, the State required a ground water investigation, and the facility took action to remediate ground water contamination and prevent further contamination.

16. WEPCO Cedar-Sauk Landfill, Wisconsin[56]

History: This facility is an abandoned sand and gravel pit that received coal combustion waste from the WEPCO Port Washington Power Plant from 1969 to 1979. After closure of the facility, ground water monitoring revealed exceedances of the primary MCL for selenium, the State standard for boron, and the secondary MCL for sulfate. Vegetative damage resulting from boron uptake also was observed in a nearby wetland. Presumably, this damage is the result of ground water migration to the wetland. As a result, the State required installation of relief wells to confine and remediate the contamination plume and installation of an upgraded cover at the site. The facility is not only unlined, but was constructed over shallow ground water[57] in highly permeable (10^{-3} to 10^{-2} cm/sec) media. Some time after closure, the water table rose, saturating portions of the ash fill. Furthermore, the original soil cover installed at closure -- less than 2 feet in places -- was found to be insufficient. Finally, the site was located in close proximity to a wetland.

EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants and analyzed it further in the supplemental analysis conducted for its 1993 Regulatory Determination[58]. This case was not counted as a

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[56] Ibid.

[57] Quantitative data on the original depth to ground water are not available, but documentation on the site reports that the water table was near the base of the original pit.

[58] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA., July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

proven damage case in the 1999 Report to Congress, however, because there was no evidence of comanagement of low-volume wastes at the site.

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific - Selenium in ground water exceeded the (health-based) primary MCL, and there was clear evidence of vegetative damage; and (2) Administrative - The State required remedial action.

17. Wisconsin Electric Power Co. (WEPCO) Port Washington Facility, Wisconsin[59]

History: Originally, the commenters identified this Wisconsin site in a table that alleged fly ash contaminated several drinking water wells with boron and selenium. Following a preliminary evaluation by the EPA, this site was initially classified as indeterminate because (i) the commenters did not identify the source of the information, and (ii)
No quantitative data or further information about this site was available.

In the course of reassessment conducted following the Regulatory Determination, a copy of the original Water Well Journal article cited by the commenters was obtained from the National Ground Water Association (NGWA). The article presented instances in which boron and selenium concentrations exceeded standards in a well located down-gradient of the CCW disposal site. Contact was established with Wisconsin Department of Natural Resources (DNR) Waste Management Program. The DNR representative reported that the site affects a residential, private water well supply. He located the well at about 250 feet south of an old quarry that was filled to 40-60 feet in depth with fly ash from the Wisconsin Electric Power Company. The power company placed fly ash in the quarry from 1948-1971, so the ash had been there at least 20 years prior to the contamination described by the article.

In lieu of providing up-gradient well monitoring data, the DNR representative stated with certainty that in his best professional judgment the boron levels reported for the well are not naturally occurring. He also is confident that the contaminants come from the quarry because of the proximity to the monitoring well. He added that boron is characteristic of coal ash and that geologically there is no naturally-occurring source in that area of Wisconsin that would produce boron levels that high. However, he was not aware that a boron standard existed at the time of the exceedances. He reiterated that the selenium concentration exceeds the selenium standard reported in the article. Based on today's standard of 50ug/L, the levels of selenium reported would not be considered a compliance problem.

Based on the information provided by the State, contamination from this facility appears to have migrated to off-site private wells. Documentation to confirm this analysis was received in the form of a laboratory report from the State Laboratory of Hygiene. Samples collected at the John & Dolly Keating Port Washington Sample Tap Pit (an off-site drinking water well) showed very high concentrations of boron. Although the State did not have a health-based standard for boron at the time of the exceedances, the boron levels reported for the facility would have exceeded the State's recently promulgated health-based enforcement standard for boron. Samples collected

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[59] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

also showed elevated selenium concentrations, but the levels detected would not exceed the current primary MCL.

Basis for Consideration as a Proven Damage Case: This case is categorized as a proven damage case based on a scientific observation - The off-site exceedance of a health-based standard for selenium, caused by the fact that the site is an unlined former sand and gravel quarry and is in close proximity to drinking water wells.

18. Lansing Board of Water & Light (LBWL) North Lansing Landfill, Michigan[60]

History: The North Lansing Landfill (NLL), a former gravel quarry pit, was licensed in 1974 for disposal of inert fill materials including soil, concrete, and brick. From 1980 to 1997, the NLL was used for disposal of coal ash from the Lansing Board of Water and Light (LBWL) electric and steam generating plants. The NLL has three disposal areas, two of which were used for coal ash disposal. Filling of Area I ceased in 1988 and a temporary cover was placed over the ash. Area III was the active disposal area from 1988 to January 1997. A temporary cover was placed over Area III in September 1998 and grass was planted on this cover. Area II was not actively used for disposal, although some ash has washed into this area. Since 1992, Area II has usually contained standing water from on- and off-site storm water runoff.

Among the damages that commenters alleged existed at this site were down-gradient selenium and arsenic exceeding their MCLs and down-gradient sulfate greater than "allowable water quality standards." The commenters also stated that an adjacent municipal well field is "threatened."

The site owner claimed that sulfate contamination is due to wastes other than fly ash in the landfill or else is due to off-site sources. The Michigan Department of Environmental Quality (MDEQ) confirmed in writing that ground water contamination had occurred at this historic landfill, which was constructed before current State regulations were in place. The site was eventually closed because the inadequate control of contamination violated current regulatory requirements. According to the letter, the NLL was forced to take remedial action to address the contamination.

This site was initially classified as indeterminate because (i) the documents and quantitative data supporting the alleged damages were not available; (ii) information was needed to positively identify the source of the contamination; and (iii) more information was needed to describe the extent of ground water contamination and to establish whether this contamination extends off-site.

In an effort to reassess this alleged damage case, EPA's contractor contacted MDEQ and found that this site was in the process of a Remedial Investigation (RI) and Feasibility Study (FS). The following information is based on the RI Report, published in May 1999 and revised in December 1999.

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[60] Ibid.

There are two aquifers beneath the NLL. The upper aquifer is highly permeable, but is not used for drinking water. The lower aquifer (the Saginaw), however, supplies the City of Lansing with drinking water. Fill underlying the ash has lower hydraulic conductivity than the underlying aquifer, but does not constitute a liner. The underlying fill has settled in places and the water table has risen, so that lower portions of the ash are now saturated in Areas I and III. The standing water in Area II has merged with ground water, forming a mound in the water table. According to the Lansing Board of Water and Light North Lansing Landfill Remedial Investigation Report (the RI Report), this mounding effect likely extends laterally into the ash, thereby increasing the saturated ash thickness, and consequently the volume of ash subject to leaching in Areas I and III. Because of the rise in the water table, the facility no longer meets the State's requirement for a 4-foot isolation distance between wastes and ground water. Moreover, in mid- to late-1993, abrupt increases were observed in sulfate and selenium concentrations in an on-site monitoring well. As a result, LBWL was required to perform a remedial investigation and feasibility study. The RI Report concluded that the timing of the increase in contamination indicated that leachate released from the saturated fly ash was the source of the contamination.

The objectives of the RI included characterization of site conditions, definition of the nature and extent of ground water impacts, and estimation of future migration. This analysis is complicated by the presence of other known or potential sources of ground water contamination both up-gradient and down-gradient of the NLL site. Therefore, the remedial investigation used statistical comparisons (i.e., tolerance intervals calculated from up-gradient and background monitoring data) to delineate ground water impacts from the NLL. Ground water concentrations were compared to Michigan's Part 201 criteria. The Part 201 standards for ground water identify contaminant concentrations that are safe for long-term, daily consumption. The investigation's statistical analysis, modeling results, and conclusions form the basis for the analysis of the NLL as a damage case.

For a variety of reasons, the RI Report concluded that boron, iron, pH, strontium, selenium, and sulfate are of little concern. The RI Report concluded that the constituents of the most concern are lithium, manganese, and potassium. Based on statistical analysis and consideration of site-specific factors, however, the following cannot be conclusively linked to the NLL: boron, iron, pH, and sulfate. Of the remaining contaminants of concern:

- Lithium appears to be attributable to the NLL and concentrations are above health-based standards off-site;
- Manganese contamination on-site appears to be attributable to the NLL and concentrations are above non-health based-standards. (Note that off-site concentrations of manganese also are above non-health-based standards, but do not appear to be attributable to the NLL);
- Potassium appears to be attributable to the NLL, but has no regulatory standard;
- Selenium appears to be attributable to the NLL and concentrations are above health-based standards on-site, but not off-site;
- Strontium appears, based on statistics, to be attributable to the NLL, but concentrations are below health based standards.

<u>Basis for Consideration as a Proven Damage Case</u>: This site was classified as a proven damage case based on a scientific observation of off-site exceedances of the State's health-based standard

for lithium. The exceedance was caused by the fact that the site is an unlined former gravel quarry with an elevated ground water table leading to ground water contact.

19. Northern Indiana Public Service Corp. (NIPSCO) Yard 520 Landfill Site (Brown's Landfill) Township of Pines, Porter County, IN[61]

History: NIPSCO's Bailly and Michigan City power plants have deposited an estimated 1 million tons of fly ash in the Town of Pines since 1983. Fly ash was buried in the landfill and used as construction fill in the town. The ash is pervasive on site, visible in roads and driveways[62].

Pines is located near the Indiana Dunes National Lakeshore, about 2 miles south of Lake Michigan. This is a region of sand dune ridges which separate low-lying, poorly drained wetland areas. The soil is very sandy, unconsolidated, highly-acidic, and with a high organic content. These sands overlie a less permeable clay-rich unit. The ground water flows in a northerly direction from the Yard 520 landfill toward the town[63].

In April 2000, Indiana DEM received a complaint from a Pines resident that water from her private well tasted foul. IDEM conducted sampling and found residential wells contaminated with elevated levels of benzene, arsenic, manganese, and VOCs including benzene. In 2001, EPA's Superfund program conducted a preliminary assessment and site investigation, and found elevated levels of MTBE, boron, manganese, and molybdenum. In January 2002, IDEM recommended the site for EPA's National Priorities List[64].

Additional site investigations indicate that the Pines Yard 520 Landfill site is the likely source of contamination of residential water wells, caused by leaching of heavy metals (manganese, boron, molybdenum, arsenic, lead) from fly ash that was buried in the landfill and used as construction fill. The presence of elevated levels of contaminants that are not associated with coal ash, such as volatile organic compounds (VOCs) and MTBE, indicate that there are additional sources of contamination that are not related to coal ash[65].

EPA and the responsible parties signed an Administrative Order of Consent effective January 2003 to cover costs of connecting the affected areas to Michigan City's water system (USEPA 2003a). In April 2004, EPA and IDEM negotiated an Administrative Order of Consent with the

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[61] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[62] Tim Drexler, Remedial Project Manager, telephone communications with Bonnie Robinson, USEPA. June 5, 2003.

[63] Final Site Investigation Report on Ground water Contamination, Township of Pines, Porter County, Indiana. December 2002.

[64] EPA Announces Investigation Results at Pines Site (Fact Sheet). January 2003.

[65] Final Site Investigation Report on Ground water Contamination, Township of Pines, Porter County, Indiana. December 2002.

responsible parties for continued work at the site[66]. . In January 2004, the Hoosier Environmental Council, Inc. filed a complaint for declaratory and injunctive relief against NISOURCE, the parent company of NIPSCO (U.S. District Court).

Basis for Consideration as a Proven Damage Case: This site was classified as a proven damage case based on (1) Scientific evidence for boron, molybdenum, arsenic and lead exceeding health-based standards in water wells away from the Pines Yard 520 Landfill site, and (2) Administrative Orders of consent signed between the EPA and IDEM with responsible parties for continued work at the site.

20. Brandy Branch Reservoir, Texas[67]

History: This case was originally identified by a public interest group in a table alleging selenium and chromium contamination, and a selenium fish consumption advisory[68].

The Brandy Branch Reservoir is a power plant cooling reservoir built in 1983 for Southwestern Electric Power Company's Pirkey Power Plant. The cooling reservoir received discharges from ash ponds containing elevated levels of selenium, resulting in increased selenium concentrations in fish from the reservoir. From 1986 to 1989, the Texas Parks and Wildlife Department reported that average selenium concentrations in fish from the Brandy Branch Reservoir increased from 0.81 to 2.29ppm[69]. In 1992, the Texas Department of Health (TDH) issued a fish consumption advisory for the reservoir[70].

The advisory recommended that adults consume no more than eight ounces of fish from the reservoir per week; children seven years and older - no more than four ounces/week; and children under six and pregnant women or women who may become pregnant should not consume any fish from the reservoir. In 1996 and 1997, TDH collected 17 fish from the reservoir. Selenium concentrations in these fish ranged between 0.46 and 1.79ppm, with an average concentration of 0.87ppm (ATSDR 1998).

A total maximum daily load (TMDL) project has been initiated by the Texas Commission on Environmental Quality (TCEQ) to determine the necessary steps to improve water quality in Brandy Branch reservoir. The project involved a fish sampling and analysis program and a

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[66] http://www.epa.gov/region5/sites/pines/

[67] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[68] Letter from the Hoosier Environmental Council to the RCRA Docket Information Center regarding comments on the May 2000 Regulatory Determination, September 19, 2000.

[69] Agency for Toxic Substances and Disease Registry (ATSDR), 1998. Health Consultation: Brandy Branch Reservoir, Marshall, Harrison County, Texas. September 1998. Available at http://www.atsdr.cdc.gov/HAC/PHA/marshall/mar_toc.html.

[70] Texas Bureau of Health (TBH). 1992. Fish Advisory: Brandy Branch Reservoir. May 1992.

human health risk assessment, and was completed in August 2003[71]. Based on its findings, The Texas Commissioner of Health fish advisory was lifted in March 2004[72].
Basis for Consideration as a Proven Damage Case: This case is categorized as a proven ecological damage case for the following reasons: (1) Observations of impacts on fish populations were confirmed by scientific study, based on which the State concluded that the impacts were attributable to the ash ponds; and (2) Administrative - The State issued a fish consumption advisory as a result of the contamination.

21. Southwestern Electric Power Company Welsh Reservoir, Texas[73]

History: This Lake was constructed in 1976 to serve as a cooling reservoir for a power plant and receives discharges from an open ash settling pond system. The Texas Parks and Wildlife Department's (TPWDs) monitoring program documents elevated levels of selenium and other metals in fish. In 1992 the Texas Commissioner of Health issued a fish consumption advisory for selenium similar to the one issued for the Brandy Branch Reservoir described above[74]. The TPWD's report concludes that "discharges from the open ash settling ponds may be a source for the elevated levels of selenium in fish." The Texas Commissioner of Health fish advisory was lifted in March 2004[75].

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven ecological damage case for the following reasons: (1) the State concluded that, based on scientific evidence, selenium accumulation in fish may be attributable to the ash settling ponds; and (2) Administrative - The State has issued a fish consumption advisory as a result of the contamination.

22. Texas Utilities Electric Martin Lake Reservoir, Texas[76]

History: This Lake was constructed in 1974 to serve as a cooling reservoir for a power plant and was the site of a series of major fish kills in 1978 and 1979. Investigations determined that unpermitted discharges from ash settling ponds resulted in elevated levels of selenium in the

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[71] Texas Commission on Environmental Quality (TCEQ). 2003. Improving Water Quality in Brandy Branch Reservoir; One TMDL for Selenium. February 2003.

[72] Assessing the Fish Consumption Use, Water Quality in Brandy Branch Reservoir, TCEQ, March 2004.

[73] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[74] http://www.tceq.state.tx.us/implementation/water/tmdl/14-welshreservoir.html

[75] Assessing the Fish Consumption Use, Water Quality in Welsh Reservoir, TCEQ, March 2004.

[76] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

water and fish. The State's monitoring program continues to document elevated levels of selenium and other metals in fish at the Lake. The Texas Commissioner of Health issued a fish consumption advisory for this Lake similar to the one issued for the Brandy Branch Reservoir described above in 1992[77]. There also is evidence of elevated selenium concentrations in birds nesting near the Lake. The Texas Commissioner of Health fish advisory was lifted October 14, 2004[78].

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven ecological damage case for the following reasons: (1) Scientifically based evidence of adverse effects on wildlife - impacts on fish populations were observed, and the State concluded that the impacts were attributable to the ash setting ponds; and (2) Administrative - The State has issued a fish consumption advisory as a result of the contamination.

23. Basin Electric Power Cooperative W.J. Neal Station Surface Impoundment, North Dakota[79]

History: This site was an unlined, 44-acre surface impoundment that received fly ash and scrubber sludge from a coal-fired power plant, along with other wastes (including ash from the combustion of sunflower seed hulls), from the 1950's until the late 1980's. Sampling in 1982 found chromium at 8.15 parts per million in the pond sediment and in excess of the primary MCL in down-gradient ground water. The State issued a special use disposal permit to allow disposal to continue, but required a continuation of monitoring and began negotiations for closure of the site. The facility was closed between 1989 and 1990, when the impoundment sediments were consolidated to a 22-acre area and capped. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the site underwent a preliminary assessment (PA) in 1990 and a site inspection (SI) in 1995. The PA found sediments in a marshy area adjacent to the closed facility with antimony, arsenic, chromium, manganese, selenium, and sodium elevated above background. The PA also found arsenic in excess of the primary MCL and aluminum in excess of the secondary MCL in down-gradient ground water. The SI found arsenic elevated above background in the marsh sediments and in surface water passing through the wetland. The SI also found cadmium and lead in excess of primary MCLs and zinc in excess of the secondary MCL in a public water supply well. The SI concluded that releases had occurred from the surface impoundment to ground water and surface water.

Soils underlying the facility are characterized by one source as relatively permeable (10^{-4} cm/sec). Regionally, the surficial aquifer varies in depth from 3 to 25 feet below the surface. While a precise mapping of the water table at the site is not available, the SI characterizes ground water beneath the closed, unlined impoundment as "very shallow." Other information in the literature confirms this and possibly suggests ground water may directly contact the disposed material, specifically:

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[77] http://www.tceq.state.tx.us/implementation/water/tmdl/12-martincreekreservoir.html

[78] Assessing the Fish Consumption Use, Water Quality in Martin Creek Reservoir, TCEQ, March 2004.

[79] Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

- Depth to water in the monitoring wells surrounding the facility ranges from 5.5 to 16 feet, while the depth of the ash fill is estimated at approximately 10 feet.
- According to the PA, regionally, "many lakes and potholes represent "windows" into the water table ..." and an on-site pond located directly up-gradient and adjacent to the disposal area may be "a surface expression of the ground water onsite."

Additionally, the site was operated without any control of surface waters from the impoundment. A tributary to the marsh and a nearby creek formerly flowed through the ash disposal areas. Even as late as 1989, surface water ran directly off the site from the surface impoundment dike into the marsh. This direct discharge was not documented as being permitted under State or Federal regulations.

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific investigation - Several constituents have exceeded their (health-based) primary MCLs in down-gradient ground water, and the site inspection found documentation of releases to ground water and surface water from the site; and (2) Administrative - The State required closure of the facility.

24. Cooperative Power Association/United Power Coal Creek Station Surface Impoundments, North Dakota[80]

History: This site includes a number of evaporation ponds and ash storage/disposal ponds that were constructed in 1978 and 1979. The ponds were originally lined but developed severe leaks in the late 1970's. The ponds are operated as a zero discharge facility. While quantitative data on the depth to ground water are not available, documentation from the State agency indicates that the ponds were constructed "directly over and adjacent to" the Weller Slough Aquifer, suggesting the presence of shallow ground water. Ground water monitoring at the site showed arsenic in excess of the primary MCL in 1987 and selenium in excess of the primary MCL in 1992 and 1993. Down-gradient monitoring data also have shown sulfate and chloride above secondary MCLs and elevated levels of boron. In the facility's 1990 permit application, the State required relining of the ponds with a composite liner.

Basis for Consideration as a Proven Damage Case: EPA has categorized this case as a proven damage case for the following reasons: (1) Scientific evidence - Arsenic and selenium exceeded (health-based) primary MCLs, and (2) Administrative - The State required remedial action.

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[80] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

Potential Coal Combustion Waste Damage Cases

III. Potential Damage Cases

According to 65 FR 32224, "Potential damage cases were those with documented MCL exceedences that were measured in ground water beneath or close to the waste source. In these cases, the documented exceedences had not been demonstrated at a sufficient distance from the waste management unit to indicate that waste constituents had migrated to the extent that they could cause human health concerns. State regulations typically use a compliance procedure that relies on measurement at a receptor site or in ground water at a point beyond the waste boundary (e.g., 150 meters)." In addition, groundwater contamination would be considered as a potential damage case also where there are documented exceedances of secondary MCLs or other non-health based standards on-site or off-site.

25. K.R. Rezendes South Main Street Ash Landfill, Freetown, Massachusetts[81]

History: This case was originally identified through contacts with State regulators.

This site consists of an ash monofill located in a former sand and gravel quarry located in Freetown, Massachusetts. The landfill began operation in 1976 and has an area of approximately 35 acres. It was originally approved as a 14-acre monofill by the Freetown Board of Health and by permit from the MADEP. The Board of Health granted approval for the remaining 21 acres in 1990, and approved a request for expansion to within 250 feet of Assonet Bay in 1993. The final permit for the site was issued by MADEP in 1994.

The site accepted ash from PG&E's Salem Harbor (approximately 250,000 tons/year) and Brayton Point Plants (approximately 140,000 tons/year). According to PG&E estimates, a total of 2,500,000 tons of ash have been disposed at the K.R. Rezendes South Main Street Ash Landfill.

Ground water monitoring at the site has detected levels of selenium above the primary MCL. Elevated levels of sulfates, total dissolved solids, manganese, iron, and aluminum have also been detected at the site, although levels are below the relevant secondary MCLs. All of the monitoring wells at the site are located on-site. There are no down-gradient drinking water sources, because the landfill is adjacent to a down-gradient water body (Assonet Bay), which is not used as a drinking water source due to its brackish water.

In early 2001, MADEP required modifications to the ground water monitoring program, including:

- Increase in sampling from annual to semi-annual;
- Semi-annual surface water sampling;
- Evaluation of wells to ensure the wells yield representative samples;
- Installation of additional monitoring wells; and

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[81] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

- Evaluation of ground water discharge to the adjacent Assonet Bay.

Operations at the landfill ended in 2001 as the result of a bylaw passed by the Town of Freetown. The bylaw bans the disposal of coal combustion wastes within the town. It was appealed by the landfill operator and PG&E, but upheld by the State Attorney General.

Basis for Consideration as a Potential Damage Case: This case has been categorized as a potential damage case for the following reasons: (1) Scientific - Selenium exceeded its primary MCL in on-site monitoring wells; and (2) Administrative - The State required modification to the site's ground water monitoring program.

26. New England Power, Brayton Point, Massachusetts[82]

History: Associated with the largest coal- and oil- powered generating station in New England, this is one of nine sites managing oil combustion wastes that have ground water contamination identified for the 1999 Report to Congress. Seven of the nine, including this site, were documented in EPRI's oil ash report; the two other sites were found in the 1993 Regulatory Determination and in RCRA Corrective Action records. Most of the nine sites evaluated were solid settling basins, while one site had a landfill and a second site had a solids disposal pond. At each of the nine sites, the waste management unit was found to negatively impact ground water in one of the following ways: (1) at least one constituent was found in down-gradient ground water monitoring wells above its MCL, but was not present in up-gradient wells above its MCL, or (2) a constituent exceeded its MCL both up-gradient and down-gradient, but the down-gradient concentrations were noticeably higher than the up-gradient concentrations. These constituents most often include manganese and nickel. Other parameters (including arsenic, cadmium, chromium, selenium, silver, and zinc) exceeded their MCL in down-gradient wells at only one of the sites. Although vanadium does not have an MCL, the parameter was found in ground water down-gradient of waste management units.

At several of the sites reviewed, EPA found that the waste management unit very likely contributes to the contamination of constituents, such as manganese, nickel, and vanadium, into ground water. Many of these sites are located next to the ocean or other large bodies of water where such releases can be diluted and no drinking water wells would be located between the management unit and the surface water. EPA did not find any cases of drinking water contamination or other environmental damages resulting from these releases. Additionally, most or all unlined units are operated under state permit allowing exceedances of ground water standards close to the management unit, but which must be met outside the zone of discharge.

Basis for Consideration as a Potential Damage Case: This case has been categorized as a potential damage case for the following reasons: exceedance of one or more MCL standards

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[82] Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Potential Damage Cases, March 15, 1999 (http://www.epa.gov/epaoswer/other/fossil/ffc2_397.pdf). Status of Alleged Damage Cases Submitted by HEC, et. al., to Dennis Ruddy, February, 2002. Brayton Point Administrative Consent Order (ACO-BO-00-2002, undated), Brayton Point Administrative Consent Order Timetable, August 22, 2006.

down flow from the plant's unlined wastewater treatment basins that does not impact drinking water wells offsite.

27. AES Creative Resources Weber Ash Disposal Site, New York[83]

History: Monitoring data at this site from between 1991 and 1998 show levels of sulfate, total dissolved solids, manganese, iron, aluminum, and pH in down-gradient wells in excess of their secondary MCLs. There is no information available on the location of these wells relative to the waste management units.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site: sulfate, total dissolved solids, manganese, iron, aluminum, and pH, are of non-health-based standards. Therefore, this case is a potential damage case.

28. Central Hudson Gas and Electric Corporation Danskammer Waste Management Facility, New York[84]

History: There were exceedances of State non-health-based standards for sulfate, sulfide, total dissolved solids, turbidity, iron, magnesium, manganese, sodium, boron, and pH attributable to CCW at the site. It is unclear whether the exceedances of health-based standards were attributable to CCW.

Basis for Consideration as a Potential Damage Case: The contamination at the site: sulfate, sulfide, total dissolved solids, turbidity, iron, magnesium, manganese, sodium, boron, and pH did not appear likely to threaten human health or the environment. Therefore, this case was determined to be a potential damage case.

29. C. R. Huntley Flyash Landfill, New York[85]

History: There were exceedances of State health-based standards for arsenic and non-health-based standards for iron, manganese, sulfate, and total dissolved solids at this site's down-gradient wells. While there also were exceedances in up-gradient wells, there was statistical evidence of significant increases over up-gradient concentrations for several of these constituents. In addition, the State regulatory agency and the site contractor identified some of these constituents as potential indicators of leachate.

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[83] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[84] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[85] Ibid.

Basis for Consideration as a Potential Damage Case: All of the exceedances were in wells located on-site, close to the waste management unit. Therefore, this case was determined to be a potential damage case.

30. Elrama Plant, Pennsylvania[86]

History: EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants. It is described in detail in that document. In the 1988 Report, EPA found concentrations of cadmium in down-gradient wells above the primary MCL; the highest concentrations were found in the well closest to the landfill. EPA concluded that coal combustion wastes have been a source of contamination at the site, but also concluded that exceedances for many contaminants were probably due to concurrent contamination from acid mine drainage.

Basis for Consideration as a Potential Damage Case: While levels of cadmium exceed the primary MCL, the contamination appears to be at least partially attributable to sources other than coal combustion wastes. Therefore, this case is a potential damage case.

31. Tennessee Valley Authority - Bull Run Steam Plant, Oak Ridge, Tennessee[87]

Basis for Consideration as a Potential Damage Case: This case was categorized as a potential damage case for the following reasons: (1) exceedances of the secondary MCLs for aluminum, calcium, iron, and sulfate were detected in on-site surface water; (2) a toxicity study indicates the potential for ecological impacts; and (3) these impacts appear to be directly attributable to CCW management.

32. Tennessee Valley Authority Widows Creek Fossil Fuel Plant, Alabama[88]

History: Monitoring data at this site show lead in excess of the primary MCL Action Level. This exceedance, however, occurred in an on-site well that appears to be opposite the direction of ground water flow. Still, in a 1993 memorandum, the Alabama Department of Environmental Management (ADEM) expressed concern with this exceedance and elevated levels of cadmium and chromium (which did not exceed their primary MCLs) in this well and recommended that corrective action measures be established.

Basis for Consideration as a Potential Damage Case: While the ADEM has expressed concern with on-site contamination and recommended that corrective action measures be established,

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[86] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[87] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[88] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

there is no evidence available of off-site migration of contaminants. Therefore, this case is a potential damage case.

33. Tennessee Valley Authority Colbert Fossil Fuel Plant, Alabama[89]

History: Only limited information on this site was available from the commenters. The commenters' summary of monitoring data shows no exceedances of primary MCLs in ground water at the site. The only primary MCL exceedances (for sulfate, chromium and selenium) reported by the commenters are found in a well installed within the saturated ash of the surface impoundment. A 1998 letter from the facility owner to the ADEM, however, does indicate some exceedances of primary MCLs in on-site wells that the owner proposes to eliminate from its sampling program. The only constituent identified in this letter is cadmium. The commenters report that ADEM believes ground water contamination has resulted from the disposal of coal combustion wastes at this facility. An ADEM geologist also reported to the commenters that the disposal area has been subject to collapse into a karst sinkhole.

Basis for Consideration as a Potential Damage Case: While some primary MCL exceedances (for sulfate, chromium and selenium) appear to have occurred in on-site wells, there is no evidence available of off-site migration of contaminants. Therefore, this case is a potential damage case.

34. Duke Power Allen Steam Generating Plant, North Carolina[90]

History: The Allen Plant of Duke Power Company was included in a study of waste disposal at coal-fired power plants conducted by Arthur D. Little, Inc (ADL) in 1985. ADL conducted ground water sampling in 18 monitoring wells installed on-site, detecting exceedances of manganese and iron, both secondary water quality standards.

Contact was made with North Carolina Department of Environment and Natural Resources (DENR). According to those contacted, the State has only surface water discharge information for this facility. There is no record of ground water monitoring at the facility, and no indication that violations or enforcement actions occurred at the facility. A permit check determined that ground water monitoring at the site is not required by the facility permit. There is no indication that any ground water samples have been tested since the 1985 study.

Basis for Consideration as a Potential Damage Case: According to the 1985 data, there were documented exceedances of manganese and iron, non-health-based standards, in wells downstream from the waste management unit. Therefore, this site is categorized as a potential damage case.

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[89] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. TVA Colbert ground water data, undated.

[90] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

35. Cinergy East Bend Scrubber Sludge Landfill, Kentucky[91]

History: Commenters identified this site in a table that alleged an estimated 300 tons of sulfate per year is leaking into the Ohio River from this site. This site was initially classified as indeterminate because the commenters did not identify the source of the information and no quantitative data or further information about this site was available.

Subsequently, additional information was obtained through the Kentucky Department of Environmental Protection (DEP). According to the DEP, there were on-site exceedances of non-health-based standards for total dissolved solids, iron, and sulfate at this site. The State has taken regulatory action based on these exceedances.

Basis for Consideration as a Potential Damage Case: Based on the on-site exceedances of non-health-based standards for total dissolved solids, iron, and sulfate at this site, and subsequent State regulatory action based on these exceedances, this case is a potential damage case.

36. Florida Power and Light Lansing Smith Plant, Florida[92]

History: EPA initially identified this site in the supplemental analysis conducted for its 1993 Regulatory Determination[93]. As a result of this analysis, EPA rejected this site as a damage case because there was no evidence that coal combustion wastes were comanaged with low-volume wastes at this site. A subsequent evaluation of the information for this site indicates that there were documented exceedances of primary drinking water standards for cadmium, chromium and fluoride and secondary drinking water standards for sulfate, chloride, manganese and iron in on-site ground water attributable to CCW.

Basis for Consideration as a Potential Damage Case: This site has been reclassified as a potential damage case Based on documented exceedances of primary drinking water standards for cadmium, chromium and fluoride and secondary drinking water standards for sulfate, chloride, manganese and iron in on-site ground water attributable to CCW.

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[91] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[92] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Status of Alleged Damage Cases Submitted by HEC, et. al., to Dennis Ruddy, February, 2002. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[93] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA. July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

37. Florida Power and Light Port Everglades Plant, Florida[94]

History: This is one of nine sites managing oil combustion wastes that have ground water contamination identified for the 1999 Report to Congress. Seven of the nine, including this site, were documented in EPRI's oil ash report; the two other sites were found in the 1993 Regulatory Determination and in RCRA Corrective Action records. Most of the nine sites evaluated were solid settling basins, while one site had a landfill and a second site had a solids disposal pond. At each of the nine sites, the waste management unit was found to negatively impact ground water in one of the following ways: (1) at least one constituent was found in down-gradient ground water monitoring wells above its MCL, but was not present in up-gradient wells above its MCL, or (2) a constituent exceeded its MCL both up-gradient and down-gradient, but the down-gradient concentrations were noticeably higher than the up-gradient concentrations. These constituents most often include manganese and nickel. Other parameters (including arsenic, cadmium, chromium, selenium, silver, and zinc) exceeded their MCL in down-gradient wells at only one of the sites. Although vanadium does not have an MCL, the parameter was found in ground water down-gradient of waste management units.

At several of the sites reviewed, EPA found that the waste management unit very likely contributes to the contamination of constituents, such as manganese, nickel, and vanadium, into ground water. Many of these sites are located next to the ocean or other large bodies of water where such releases can be diluted and no drinking water wells would be located between the management unit and the surface water. EPA did not find any cases of drinking water contamination or other environmental damages resulting from these releases. Additionally, most or all unlined units are operated under state permit allowing exceedances of ground water standards close to the management unit, but which must be met outside the zone of discharge.

Basis for Consideration as a Potential Damage Case: This case has been categorized as a potential damage case for the following reasons: exceedance of one or more MCL standards down flow from the plant's disposal facility that does not impact drinking water wells offsite.

38. Florida Power and Light Riviera Plant[95]

See the preceding description for the Port Everglades Plant.

39. Florida Power and Light P.L. Bartow Plant[96]

See the preceding description for the Port Everglades Plant.

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[94] Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Potential Damage Cases, March 15, 1999 (http://www.epa.gov/epaoswer/other/fossil/ffc2_397.pdf).

[95] Ibid.

[96] Ibid.

40. Commonwealth Edison Powerton Plant - Mahoney Landfill, Pekin, Tazewell County, Illinois[97]

History: This case was originally identified during the review of candidate damage cases for the 1988 Report to Congress on Wastes from the Combustion of Coal by Electric Utility Power Plants. Although it was rejected as a proven damage case in EPA's 1993 Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste (EPA 1993), this case was re-examined in light of EPA's subsequently developed criteria for categorizing cases as "potential" damage cases.

There were exceedances of primary MCLs for cadmium, lead, and nitrate and secondary MCLs for iron, manganese, and sulfate in ground water and surface water at the site. The exceedances of secondary MCLs in ground water appear attributable to management of CCW.

Basis for Consideration as a Potential Damage Case: All the reported exceedances that are attributable to management of CCW are for constituents with non-health-based standards and are located in on-site wells. Therefore, this case was categorized as a potential damage case.

41. Xcel Energy/Southern Minnesota Municipal Power Agency - Sherburne County (Sherco) Generating Plant Becker, Minnesota[98]

History: This case was originally identified during the review of candidate damage cases for the 1988 Report to Congress on Wastes from the Combustion of Coal by Electric Utility Power Plants. Although it was rejected as a proven damage case in EPA's 1993 Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste (EPA 1993), this case was re-examined in light of EPA's subsequently developed criteria for categorizing cases as "potential" damage cases.

There were exceedances of primary MCLs for arsenic, cadmium, chromium, fluoride, lead, and nitrate and secondary MCLs for chloride, copper, iron, manganese, sulfate, and zinc at the site, at least some of which appear attributable to management of CCW. While a scientific study indicated the potential for future increases in contamination, more recent data were not available.

Basis for Consideration as a Potential Damage Case: The reported exceedances of both primary and secondary MCLs were located in on-site wells and the potential for off-site migration of contamination may be limited. Therefore, this case was categorized as a potential damage case.

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[97] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[98] Ibid.

42. Alliant Rock River Ash Disposal Facility, Wisconsin[99]

History: Monitoring data at this site show down-gradient levels of arsenic and mercury that would exceed the Wisconsin Department of Natural Resources (WDNRs) drinking water enforcement standard (ES) levels (equivalent to primary MCLs). The data also show down-gradient levels of sulfate and iron that would exceed their ES levels (equivalent to secondary MCLs for these constituents). According to information provided by WDNR, however, the site has no down-gradient ES points of standards application due to its proximity to the Rock River (i.e., all wells are within the design management zone of the landfill). Thus, the State considers the preventive action limit (PAL) exceedances, not ES exceedances. The preventive action limit represents a lesser concentration of the substance than the enforcement standard[100]. In 1996, as a result of the PAL exceedances for sulfate and iron, WDNR required the company to begin submitting biennial ground water reports evaluating causes and trends relating to the continued PAL exceedances. Ongoing monitoring at the site includes indicator parameters and iron.

Basis for Consideration as a Potential Damage Case: Whereas the levels of arsenic and mercury in down-gradient wells exceed health-based enforcement standards, these exceedances are within the design management zone of the landfill and there is no evidence available of off-site migration of contaminants. Therefore, this case was determined to be a potential damage case.

43. Michigan City Site, Michigan City, Indiana[101]

History: EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants. It is described in detail in that document. In the 1988 Report, EPA concluded that ash ponds at the site are responsible for arsenic concentrations above the primary Maximum Contaminant Limit (MCL). EPA also concluded, however, that effects on ground water appeared to be limited to areas within the facility boundaries.

Basis for Consideration as a Potential Damage Case: While levels of arsenic found on-site exceed the primary MCL, there was no evidence available of off-site migration of contaminants. Therefore, this case is a potential damage case.

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[99] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[100] The PAL is either 10%, 20%, or 50% of the enforcement standard as specified by statute based on the health-related characteristics of the particular substance. Ten percent is used for cancer-causing substances, 20% for substances with other health effects and 50% for substances having aesthetic or other public-welfare concerns.

[101] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

44. Bailly Generating Station, Indiana[102]

History: EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants. The site is identified as the "Bailly Site, Dune Acres, Indiana" and described in detail in that document. In the 1988 Report, EPA concluded that leachate from ash disposal ponds was the most probable contributor to concentrations of arsenic and lead that were found above the primary MCL and primary MCL Action Level, respectively, in on-site, down-gradient wells. EPA also observed, however, that cadmium was the only constituent whose down-gradient off-site concentration exceeded the primary MCL. Elevated cadmium concentrations also were found in samples taken from the background well, leading EPA to conclude that the elevated down-gradient concentrations of cadmium may not have been caused by leachate from the coal ash.

Basis for Consideration as a Potential Damage Case: While levels of arsenic and lead found on-site exceed health-based standards, the only off-site exceedances of health-based standards (for cadmium) are not shown to be attributable to coal combustion waste. Therefore, this case is a potential damage case.

45. Alliant Edgewater 1-4 Ash Disposal Site, Wisconsin[103]

History: Monitoring data at the site show down-gradient levels of boron that exceed WDNR's health-based ES level[104]. Additional data shows that private water supply wells have shown ES exceedances for sulfate and iron (equivalent to secondary MCLs for these contaminants) and PAL exceedances for chloride. As a result of these exceedances, WDNR required a series of investigations from 1988 to 1997. The investigations found that cessation of ash sluicing and capping of the landfill had effectively controlled the contamination of ground water and no additional remedial actions were required. Ongoing monitoring at the site (including monitoring of the private wells) includes boron, sulfate, and arsenic. Previous monitoring included selenium, iron, fluoride, and chloride.

Basis for Consideration as a Potential Damage Case: The level of boron found down-gradient exceeds a health-based standard. It is unclear, however, whether this exceedance is in an off-site monitoring location. The exceedances found in off-site private wells are for constituents without health-based standards. Therefore, this case is a potential damage case.

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[102] Ibid.

[103] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[104] As of January 1, 2000, Wisconsin elevated boron to the status of a human health-related parameter.

46. Wisconsin Power Supply Co. (WPSC) Pulliam Ash Disposal Site, Wisconsin[105]

History: Monitoring data at this site showed down-gradient levels of sulfate and manganese that would exceed WDNR's ES levels (equivalent to secondary MCLs for these constituents) and levels of iron that exceed WDNR's PAL. According to information provided, however, the site had no down-gradient ES points of standards application (i.e., all wells are within the design management zone of the landfill). Thus, the State would consider the sulfate and manganese exceedances to be PAL, not ES, exceedances. Further review by WDNR found an inadequate monitoring network at the facility. Therefore, in 1994, WDNR required an investigation of the ground water contamination and an upgrade of the monitoring network. Ongoing monitoring at the site includes indicator parameters plus boron, selenium, manganese, and iron.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, manganese and iron, are within the design management zone of the landfill and are for constituents without health-based standards. Therefore, this case is a potential damage case.

47. Central Illinois Light Co. Duck Creek Station, Illinois[106]

History: Monitoring data at this site from April 1999 showed levels of sulfate, total dissolved solids, chloride, manganese, and iron in excess of their secondary MCLs. There is no clear indication of down-gradient wells or whether these wells are on-site or off-site.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids, chloride, manganese and iron, are of non-health-based standards. Therefore, this case is a potential damage case.

48. Illinois Power Co. Hennepin Power Station, Illinois[107]

History: Monitoring data at this site from between 1997 and 1999 showed levels of sulfate and total dissolved solids in down-gradient wells in excess of their secondary MCLs. There is no information available on the location of these wells relative to the waste management units. There is no monitoring data for metals at this site.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate and total dissolved solids, are of non-health-based standards. Therefore, this case is a potential damage case.

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[105] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[106] Ibid.

[107] Ibid.

49. Illinois Power Co. Havanna Power Plant, Illinois[108]

History: Monitoring data at this site between 1997 and 1999 showed levels of manganese down-gradient of the south ash impoundment in excess of the secondary MCL. The data also show levels of sulfate down-gradient of the east ash impoundment greater than up-gradient levels, but within the secondary MCL. There is no information available on the location of the monitoring wells relative to the waste management units.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, manganese and sulfate, are of non-health-based standards. Therefore, this case is a potential damage case.

50. Dairyland Power Alma On-site Fly Ash Landfill, Wisconsin[109]

History: EPA initially identified this site in the supplemental analysis conducted for its 1993 Regulatory Determination[110]. This analysis, along with additional information submitted by commenters, shows down-gradient levels of sulfate and manganese that would exceed WDNR's ES levels (equivalent to secondary MCLs for these constituents). According to information provided by WDNR, however, there are no ES points of standards application at the site (i.e., all wells are within the design management zone of the landfill). Thus, the State considers these exceedances PAL, not ES exceedances. In 1975, WDNR issued an administrative order as a result of an inspection that disclosed a number of operational and locational problems at the facility. Among other things, the order required submission of a closure plan and an in-field conditions report. The closure plan was approved in 1981 and included ground water monitoring. In 1986, the Department required the company to install additional monitoring wells and to monitor seven private water supply wells for two rounds of monitoring. Ongoing monitoring at the site includes indicator parameters plus manganese and boron.

Basis for Consideration as a Potential Damage Case: While the State has taken regulatory action at this site, the action appears to be based on operational and locational problems, not evidence of contamination. The exceedances found at the site, sulfate and manganese, are of non-health-based standards. Therefore, this case is a potential damage case.

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[108] Ibid.

[109] Ibid.

[110] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA. July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

51. Dairyland Power Alma Off-site Fly Ash Landfill, Wisconsin[111]

History: EPA initially identified this site in the supplemental analysis conducted for its 1993 Regulatory Determination[112]. This analysis, along with additional information submitted by commenters, shows down-gradient levels of sulfate and manganese that would be in excess of WDNR's ES levels (equivalent to secondary MCLs for these constituents). The monitoring data also show levels of boron that exceed WDNR's PAL. According to information provided by WDNR, however, the sulfate and manganese exceedances were not found at ES points of application; they were found in an on-site well within the design management zone of the landfill. Thus, the State considers the exceedances PAL, not ES, exceedances. None of the ES wells for the site have shown exceedances. Because of the PAL exceedances and a proposal by the owner to expand the ash disposal area, WDNR required an analysis of the performance of the existing landfill along with an upgraded liner system and other design improvements for the new facility on the site. Ongoing monitoring at the site includes indicator parameters plus iron and boron, although the company has monitored some wells for a list of metals as part of the siting for the expansion.

Basis for Consideration as a Potential Damage Case: While the State has taken regulatory action at the site, the exceedances found at this site, sulfate and manganese, are within the design management zone of the landfill and are for constituents without health-based standards. Therefore, this case is a potential damage case.

52. Illinois Power Vermillion Power Station, Illinois[113]

History: Monitoring data at this site showed levels of sulfate and total dissolved solids in down-gradient wells in excess of their secondary MCLs. No monitoring data for metals, trace elements, or organics were available.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate and total dissolved solids, are of non-health-based standards. Therefore, this case is a potential damage case.

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[111] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[112] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA. July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

[113] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

53. Central Illinois Public Service Company Hutsonville Power Station, Illinois[114]

History: Monitoring data at this site showed levels of sulfate, total dissolved solids, and manganese in excess of their secondary MCLs. These exceedances were in wells that were presumed by the commenters to be down-gradient. There is no clear indication of down-gradient wells or whether these wells are on-site or off-site. No monitoring data for metals, trace elements, or organics were available.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids and manganese, are of non-health-based standards. Therefore, this case is a potential damage case.

54. Illinois Power Company Wood River Power Station, Illinois[115]

History: Monitoring data at this site showed levels of sulfate, total dissolved solids, chloride, manganese, and iron in excess of their secondary MCLs. It is unclear from the information provided whether these exceedances were observed in wells close to the waste management unit boundaries or in more distant wells. All of the monitoring wells, however, appear to be within the property boundary. There is insufficient information to designate wells at this site as up-gradient or down-gradient.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids, chloride, manganese and iron, are of non-health-based standards. Therefore, this case is a potential damage case.

55. R.M. Schahfer Generating Station, IN[116]

History: EPA initially identified this site in the supplemental analysis conducted for its 1993 Regulatory Determination[117]. This analysis, along with additional information submitted by commenters, showed down-gradient levels of sulfate in excess of its secondary MCL. EPA concluded in the supplemental analysis that other pollutant exceedances at the site appeared to be outliers or were for up-gradient wells only.

Basis for Consideration as a Potential Damage Case: The sulfate exceedances found at this site are of non-health-based standards. Therefore, this case is a potential damage case.

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[114] Ibid.

[115] Ibid.

[116] Ibid.

[117] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA. July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

56. Coffeen/White & Brewer Trucking Fly Ash Landfill, Illinois[118]

History: Monitoring data at this site showed levels of sulfate, total dissolved solids, and manganese in down-gradient wells in excess of their secondary MCLs. Two of the three wells for which the commenters provided data appear to be located directly underneath the landfill area. A May 18, 1995 memorandum from the Illinois Environmental Protection Agency (IEPA) documents areas of dead or distressed grass on-site, apparently due to ground water seepage.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids and manganese, are of non-health-based standards. Therefore, this case is a potential damage case.

57. Southern Indiana Gas and Electric Company (SIGECO) A.B Brown Generating Station, Indiana[119]

History: EPA initially identified this site in the supplemental analysis conducted for its 1993 Regulatory Determination[120]. This analysis, along with additional information submitted by commenters, shows down-gradient levels of sulfate, total dissolved solids, chloride, and pH in excess of their secondary MCLs.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids, chloride and pH, are of non-health-based standards. Therefore, this case is a potential damage case.

58. Cincinnati Gas & Electric Co. Miamiview Landfill, Ohio[121]

History: Monitoring data at this site from 1994 show levels of sulfate in excess of its secondary MCL. This exceedance was identified in a well near the boundary of the landfill. An investigation of the site estimates that the sulfate plume extends to an area approximately 400 feet south of the site[122]. No data are available for other constituents for the site.

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[118] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[119] Ibid.

[120] Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste. U.S. EPA. July 30, 1993. Available from the docket for the 1993 Regulatory Determination for Fossil Fuel Combustion (Part 1), EPA-HQ-RCRA-1993-0042-1642.

[121] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[122] Report: Sulfate Investigation, Miamiview Landfill, Hamilton County, Ohio. Prepared for the Cincinnati Gas & Electric Company by Dames & Moore. December 13, 1994. Available in the docket titled Availability of Report to Congress on Fossil Fuel Combustion; Request for Comments and Announcement of Public Hearing, EPA-HQ-RCRA-1999-0022-0632.

Basis for Consideration as a Potential Damage Case: The sulfate exceedances found at this site are of non-health-based standards. Therefore, this case is a potential damage case.

59. Indiana Power & Light Petersburg Generating Station, Indiana[123]

History: Monitoring data at this site showed levels of sulfate and total dissolved solids in down-gradient wells in excess of their secondary MCLs. There is no information available on the location of these wells relative to the waste management units.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate and total dissolved solids, are of non-health-based standards. Therefore, this case is a potential damage case.

60. Hoosier Energy Mermon Generating Station Coal Combustion Waste Landfill, Indiana[124]

History: The historical exceedances of health-based standards (primary MCLs for barium, chromium, cadmium, and lead and secondary MCLs for sulfate and chloride) at this site are correlated with up-gradient exceedances and occur in on-site wells.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, primary MCLs for barium, chromium, cadmium, and lead and secondary MCLs for sulfate and chloride, are all confined to on-site wells.. Therefore, this case is a potential damage case.

61. Cinergy W.C. Beckjord Station, Ohio[125]

History: There were exceedances of non-health-based standards (secondary MCL for sulfate) and a single exceedance of a health-based standard (primary MCL for selenium) at this site. There was no evidence available of off-site migration. A public water supply well within the property boundary was shut down and can no longer be used as a drinking water supply as a direct or indirect result of the contamination due to exceedance of sulfate.

Basis for Consideration as a Potential Damage Case: While a public water supply well within the property boundary was shut down, the contaminant of concern (sulfate) in the water supply well does not have a health-based standard. Therefore, this case is a potential damage case.

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[123] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[124] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[125] Ibid.

62. Lemberger Landfill, Wisconsin[126]

History: The 21-acre Lemberger Landfill, Inc. site is located in Manitowoc County. The Township of Franklin used the site, an old gravel pit, as an open dump from 1940 to 1970. Lemberger Landfill, Inc. operated the site as a sanitary landfill under a license from the Wisconsin Department of Natural Resources (WDNR) from 1969 to 1976. From 1976 to 1977, the Wettencamp and Brunner Excavating Company transported fly ash from Manitowoc Public Utilities to the Lemberger facility. An estimated 1,750 to 2,500 cubic yards of fly ash were disposed of monthly. Past WDNR inspections showed that Lemberger used fly ash and bottom ash as cover, instead of burying them along with the refuse.

Damages at the site include the seepage of landfill leachate onto adjacent property. Ground water at the site is contaminated with volatile organic compound (VOC) and inorganic constituents including arsenic, barium, chromium, cadmium, and lead. VOCs were present in residential wells in the vicinity of the site, according to monitoring conducted by the State in 1984 and 1985; and a river near the site also is impacted by VOCs, cadmium and lead. A group of potentially responsible parties (PRPs) entered into a consent decree (CD) with U.S. EPA in 1992 to perform design and remedy implementation activities. Construction was completed in September 1996. The five-year review of September 2000 identified that the groundwater extraction system was not capturing the entire contaminant plume. In order to correct this problem, modifications to the groundwater extraction system were constructed in winter 2001.

On June 15, 2006, U.S. EPA and WDNR approved the PRP's workplan for the monitored natural attenuation pilot study and gave approval to shut down the groundwater pump and treat system. The pump and treat system was shut down on August 1, 2006[127].

Basis for Consideration as a Potential Damage Case: Because the available documentation does not clearly implicate, or rule out, coal combustion waste as a source of the contamination, this case is a potential damage case.

63. Conesville Fixed FGD Sludge Landfill, Ohio[128]

History: EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants. Ground water monitoring data are described in detail in the report.

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[126] Memorandum from SAIC to Dennis Ruddy regarding Additional Information Regarding Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[127] http://www.epa.gov/R5Super/npl/wisconsin/WID980901243.htm

[128] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

Thirty-four monitoring wells were installed (two up-gradient) to monitor the effectiveness of a Poz-O-Tec fixation process (fluidized gas desulfurization (FGD) sludge mixed with fly ash and lime) to stabilize and thus immobilize potential contaminants. The stabilized FGD sludge was deposited next to the fly ash pond.

Two sets of samples were collected, one between February 27 and April 12, 1979 and the other between December 4, 1979 and July 10, 1980. Samples from the first set of data contained lead concentrations which exceeded the primary drinking water standard (PDWS) in two on-site wells and three off-site wells. Samples from on-site wells in the first set of data also showed increases above background levels in the secondary drinking water standards (SDWS) of calcium, magnesium, total dissolved solids (TDS), sulfate and iron.

In the second set of data, samples from on-site wells showed increases in calcium, magnesium, TDS and sulfate relative to the first set of data. Exceedances of the PDWS for arsenic, cadmium, chromium and selenium were found in on-site wells and exceedances of the PDWS for chromium were found in off-site wells. Lead was not detected in any of the second set of samples.

Elevated levels of selenium were detected in up-gradient wells in both the first and second sets of samples suggesting that selenium is originating from indigenous sediments rather than coal combustion wastes. The only constituents that appeared to be migrating off-site were lead in the first set of sampling and chromium in the second set of sampling.

Based on data collected, there appeared to be a temporal change in ground water quality at this site, and potential adverse impacts from constituents migrating off-site appeared to be limited. While the data indicated that lead and chromium appeared to be migrating off-site, EPA rejected this site as a damage case due to apparent limited potential adverse impacts. Subsequent to the March 2000 Regulatory Determination, this site was reevaluated and rejected as a damage case because there was no evidence that coal combustion wastes were comanaged with low-volume wastes at this site so the site was not covered by that Regulatory Determination[129]. Since then, the Agency has learned that the site receives various types of coal combustion wastes, including fly ash, and is covered by the March 2000 Regulatory Determination.

<u>Basis for Consideration as a Potential Damage Case:</u> Based on the on-site ground water contamination of the cited secondary drinking water standards (calcium, magnesium, total dissolved solids, sulfate and iron), and of primary drinking water standards (arsenic, cadmium, chromium and selenium) and the limited potential for the off-site migration of contaminants, this site has been reclassified as a potential damage case.

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[129] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

64. Muscatine County Landfill, Iowa[130]

History: It is not clear, based on the available data, if the currently active facility was constructed on the same site as the older, closed landfill. However, the issue of whether or not the sites are the same does not affect the analysis here, because the available data for the active site do not cover the constituents of concern (sulfate and selenium) for the older site. Further research is unlikely to find any additional information about the old facility. Therefore, conclusions about this site are based on the limited historical data.

Basis for Consideration as a Potential Damage Case: The exceedances of non-health-based standards (secondary MCL for sulfate) and possibly a single health-based standard (primary MCL for selenium) at this site are in wells located on-site, close to the waste management unit. Therefore, this case is a potential damage case.

65. Dave Johnston Power Plant, Wyoming[131]

History: Exceedances of the primary MCL for cadmium and the secondary MCLs for manganese and sulfate were observed in ground water up-gradient and down-gradient of the site. Interpretations of sampling results were difficult to make because other potential sources of contamination exist, such as other waste disposal areas at the site; contaminants naturally occurring in the soil which is highly mineralized around the Johnston site; and uncertainties with regard to what degree leachate from the two landfills had reached the down-gradient wells.

Basis for Consideration as a Potential Damage Case: Whereas exceedances of the primary MCL (cadmium) and the secondary MCLs (manganese and sulfate) were observed in ground water down-gradient of the site, the natural occurrence of mineralization products in the local soils and possible and other potential sources of contamination Therefore, this case is a potential damage case.

66. Montana-Dakota Utilities R.M. Heskett Station, North Dakota[132]

History: Monitoring data at this site from 1998 show levels of sulfate and boron immediately down-gradient of an old ash pile in excess of the secondary MCL. According to the NDDOH, the State required the company "... to install ground water monitoring wells and implement a closure plan. Since that time, the site has been effectively closed and is currently revegetated

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[130] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[131] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[132] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

with a good stand of growth. The ground water monitoring data indicate that impact to ground water has been reduced since closure of the site[133]."

Basis for Consideration as a Potential Damage Case: While the State has taken regulatory action at this site, the sulfate and boron exceedances found are of non-health-based standards. Therefore, this case is a potential damage case.

67. Arizona Public Service Co. Cholla Steam Electric Generating Station, Arizona[134]

History: Monitoring data at this site show levels of sulfate, total dissolved solids, chloride, and fluoride in excess of their secondary MCLs. These exceedances are found in a well located directly at the foot of the fly ash pond. The affected aquifer has "naturally poor water quality," but no background or up-gradient data are available. The commenters use a comparison to distant alluvial ground water to implicate pond leachate as a source of contamination. The commenters also allege that construction of the waste management units has caused naturally poor quality water from upper aquifers to contaminate the pristine lower aquifer, regardless of leachate contamination.

Basis for Consideration as a Potential Damage Case: The exceedances found at this site, sulfate, total dissolved solids, chloride and fluoride, are of non-health-based standards and are in a well directly at the foot of a waste management unit. Therefore, this case is a potential damage case.

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[133] Attachment B to the letter from the Hoosier Environmental Council to Dennis Ruddy regarding damage case sites, November 11, 1999, Document ID # EPA-HQ-RCRA-1999-0022-1235 in the docket titled Comments In Response To The April 28, 1999 Federal Register: Availability Of Report To Congress On Fossil Fuel Combustion: Request For Comments And Announcement Of Public Hearing, Attachment B: Report On R.M. Heskett Station. The Report On R.M. Heskett Station is accessible at: http://www.hecweb.org/ProgramsandInitatives/CCW/heskett.pdf

[134] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

Rejected Coal Combustion Waste Damage Cases (Excluding Minefills)

IV. Rejected Damage Cases

The following alleged damage cases were rejected due to either (1) lack of any evidence of damage or (2) lack of evidence that damages were uniquely associated with CCW.

68. American Coal Corporation #5 Landfill[135]

No information available

69. Cardinal PFBC Monofill[136]

According to Ohio EPA representatives, the Cardinal PFBC Monofill is used for the disposal of bed ash from the Ohio Power Cardinal Power Plant. The monofill was constructed on top of the closed Fly Ash Reservoir I Impoundment. The State has ground water monitoring data for the site, but the representatives could not confirm the presence of any suspected impacts. The data do not show any exceedences of primary or secondary MCLs. Furthermore, according to the State's hydrogeologists, interpretation of the data is occluded by mining impacts in the area. There are no exceedences of primary or secondary MCLs at this site. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

70. Cardinal Fly Ash Reservoir II Impoundment[137]

According to Ohio EPA representatives, the Cardinal Fly Ash Reservoir II Impoundment is used for the disposal of fly ash from the Ohio Power Cardinal Power Plant. The State has ground water monitoring data for the site, but the representatives could not confirm the presence of any suspected impacts. The data do not show any exceedences of primary or secondary MCLs. Furthermore, according to the State's hydrogeologists, interpretation of the data is occluded by mining impacts in the area. There are no exceedences of primary or secondary MCLs at this site. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

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[135] Memorandum from SAIC to Dennis Ruddy regarding Revised Identification of New Candidate Damage Cases, December 7, 2001.

[136] Ibid.

[137] Ibid.

71. Clinch River, Virginia[138]

EPA identified this site in its original 1988 Report to Congress on Wastes from the Combustion of Fossil Fuels by Electric Utility Power Plants. It is described in detail in that document. EPA concluded that this site represented a proven damage case for purposes of the 1993 Regulatory Determination. In conducting its analysis for the 1999 Report to Congress, however, EPA concluded that there was no evidence of comanagement at this site. EPA therefore rejected this site as a damage case for purposes of the 1999 Report to Congress.[139]

72. Copicut Road[140]

Monitoring results do not document any exceedances of federal or state standards (Ruddy 2001), except for pH. The ground water pH was below (more acidic than) its minimum secondary MCL both prior to and during placement (PG&E undated). Because acidic ground water was present prior to ash placement, this exceedance cannot be attributed to ash placement. Monitoring data for the site reveal no exceedances of primary or secondary MCLs attributable to coal combustion waste placement at the site. Therefore, this case is categorized as a case without documented evidence of proven or potential damage to human health or the environment.[141]

73. Dixie Caverns County Landfill, Virginia[142]

Dixie Caverns Landfill was operated by Roanoke County, Virginia, as a disposal site for municipal refuse, solvents, and fly ash. When the landfill was closed in 1976, it was not capped and an intermittent stream on the site flowed through a large drum pile and the fly ash pile and emptied into the Roanoke River, approximately two miles southeast of the landfill. There was also a sludge disposal pit on site. The contaminants identified on site include lead, cadmium, zinc, silver, iron, benzene, substituted benzene, chlorinated ethane, and polynuclear aromatic hydrocarbons (PAHs). Based on review of the materials provided by the commenters, it is apparent that the fly ash disposed at the site is emission control dust from an electric arc furnace,

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[138] Letter from the Hoosier Environmental Council to the RCRA Docket Information Center regarding the CCW RTC, June 11, 1999, Letter from the Hoosier Environmental Council and the Citizens Coal Council to the RCRA Docket Information Center regarding the CCW RTC, June 14, 1999 and Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

[139] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000. Memorandum from SAIC to Dennis Ruddy regarding Review of Causative Factors for Coal Combustion Waste Damage Cases, November 29, 2000.

[140] Letter from HEC, et. al., to Dennis Ruddy, February, 2002.

[141] Compendium of nineteen alleged coal combustion wastes damage cases, May 3, 2007.

[142] Letter from the Hoosier Environmental Council and the Citizens Coal Council to the RCRA Docket Information Center regarding the CCW RTC, June 14, 1999 and Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

not fossil fuel combustion waste. This site did not receive fossil fuel combustion waste and therefore is not applicable.[143]

74. Gavin Impoundments[144]

According to Ohio EPA representatives, the Gavin Plant ash ponds are used for the disposal of ash from the Ohio Power Gavin Plant. The fly ash pond is no longer receiving ash, but has not yet been closed. The facility has not conducted ground water monitoring, but has submitted a ground water monitoring plan and will be required to monitor as part of their closure activities for the fly ash pond. The bottom ash pond is still receiving wastes. There is no ground water monitoring for the bottom ash pond. The representatives could not confirm the presence of any suspected impacts and the State has not undertaken any regulatory action at the site. There is no evidence of damage at this site. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

75. Kyger Creek Power Plant Impoundments[145]

According to Ohio EPA representatives, the Kyger Creek Plant surface impoundments are used for the disposal of ash from the Ohio Valley Electric Kyger Creek Power Plant. Bottom ash is disposed of in the bottom ash pond, although most of the facility's bottom ash is used by Black Beauty, an on-site company which sells products containing bottom ash. While there is no ground water monitoring around the bottom ash pond, Ohio EPA staff are unaware of any issues related to this pond.

76. Lake Erie, Ohio[146]

Commenters provided a study of trace element concentrations in sediments, surface water, and biota in proximity to an ash disposal basin along the shore of Lake Erie. The study noted that sediment concentrations in the proximity of the basin had the potential for adverse effects on benthos (*oligochatetes*) and fish in early life stages. In addition, the study observed changes in fish behavior (e.g., possibly due to avoidance) near the basins. The study findings, however, do not conclusively implicate coal combustion waste as the source of the observed behavioral changes. There is insufficient evidence to confirm that fossil fuel combustion wastes are the source of contamination in this case.

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[143] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[144] Memorandum from SAIC to Dennis Ruddy regarding Revised Identification of New Candidate Damage Cases, December 7, 2001.

[145] Ibid.

[146] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

77. Muskingum River Power Plant Impoundments[147]

According to Ohio EPA representatives, the Ohio Power Muskingum River Power Plant disposes of bottom ash in ponds located next to the plant. The representatives confirmed that there are no monitoring wells at the site. They indicated, however, that elevated levels of iron and manganese have been detected in facility production wells. These observations have led the State's hydrogeologists to suspect that there might be some impacts from the bottom ash ponds. The representatives, however, stated that the levels of iron and manganese detected are below the relevant secondary MCLs. Because there are no exceedances of primary or secondary MCLs at this site, the evidence is not sufficient to categorize this case as a proven or potential damage case under EPA's definitions. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

The fly ash pond originally consisted of two ponds in series. One of the ponds has recently been closed and capped, while the other continues to accept waste. At the time that the fly ash pond was closed, the facility installed ground water monitoring wells around the perimeter of the entire fly ash disposal area and five years of monitoring data now are available. According to the Ohio EPA representatives, monitoring has detected some statistically "out of range" values for iron, manganese, and TDS. These observations have led the State's hydrogeologists to suspect that there might be some impacts from the fly ash ponds. The representatives, however, stated that the levels detected are below the relevant secondary MCLs. Because there are no exceedances of primary or secondary MCLs at this site, the evidence is not sufficient to categorize this case as a proven or potential damage case under EPA's definitions. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

78. Muskogee Environmental Fly Ash Disposal Site, Oklahoma[148]

Commenters provided a printout from the Superfund Archive identifying this site as a Superfund site. The information provided, however, does not identify the constituents of concern, the reason for inclusion of this site in the Superfund database, or otherwise indicate that any contamination at this site is associated with fossil fuel combustion wastes. There is insufficient information available to identify the extent and nature of damages present and attribute them to fossil fuel combustion wastes.[149]

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[147] Ibid.

[148] Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

[149] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

79. Public Service Co Fly Ash Disposal Site, Oklahoma[150]

Commenters provided a printout from the Superfund Archive identifying this site as a Superfund site. The information provided, however, does not identify the constituents of concern, the reason for inclusion of this site in the Superfund database, or otherwise indicate that any contamination at this site is associated with fossil fuel combustion wastes. There is insufficient information available to identify the extent and nature of damages present and attribute them to fossil fuel combustion wastes.[151]

80. Star Coal Company #6 Landfill[152]

No information available

81. Star Coal Company #14 Landfill[153]

No information available

82. Stuart Station Impoundments[154]

According to Ohio EPA representatives, the Stuart Station ash ponds are used for the disposal of ash from the Dayton Power & Light Stuart Station. The State has ground water monitoring data for wells near the ash ponds and older data from facility production wells. According to the State's hydrogeologists, the facility relocated their production wellfield due to ground water quality impacts of "undetermined origin." The monitoring data also show a statistical increase over background concentrations. The specific constituents showing increases were not identified, but there are no exceedances of primary or secondary MCLs at the site, according to the Ohio EPA representatives. The State's hydrogeologists also indicated that the impacts observed may be either from the ash ponds or from coal piles located in the area. Because there are no exceedances of primary or secondary MCLs at this site, the evidence is not sufficient to categorize this case as a proven or potential damage case under EPA's definitions. Therefore, this site is categorized as a case without documented evidence of proven or potential damage to human health or the environment.

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[150] Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999. .

[151] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[152] Memorandum from SAIC to Dennis Ruddy regarding Revised Identification of New Candidate Damage Cases, December 7, 2001.

[153] Ibid.

[154] Ibid.

83. Thompson Landfill, Michigan[155]

This site is an abandoned landfill. Commenters cited a MDEQ study that allegedly shows arsenic greater than Michigan "cleanup criteria" attributable to the landfill. This document and quantitative data supporting the alleged damages were not available. Recent information from the MDEQ, however, confirms that ground water contamination is present and that the site is being remediated. There is no information on whether wastes other than coal combustion wastes might be present that could contribute to the contamination. There is no information on whether the alleged contamination extends off-site. There is insufficient information available to identify the extent of ground water contamination, or to positively identify the source of the contamination.[156]

84. Turris Coal Company Elkhart Mine, Illinois[157]

This site is an underground mine that disposes of coal processing waste and coal combustion waste in a diked surface lagoon. Commenters provided monitoring data showing exceedances of the secondary MCLs for sulfate, chloride, and total dissolved solids in a single well at the site. The data for this well also show an increase in these concentrations since the placement of coal combustion waste began. The other wells at the site do not show similar exceedances or trends. There is no quantitative data on the presence of other constituents at the site. There is insufficient data on hydrogeology at the site, the location of coal combustion waste placement at the site, or on activities other than coal combustion waste placement at the site to conclude that the impacts identified are due to coal combustion waste placement. Although there is some quantitative evidence of contamination, the available data are limited to a small number of constituents. There also is insufficient information to identify the extent of the contamination or confirm the source of the contamination.[158]

85. Western Farmers Electrical Fly Ash Site, Oklahoma[159]

Commenters provided a printout from the Superfund Archive identifying this site as a Superfund site. The information provided, however, does not identify the constituents of concern, the reason for inclusion of this site in the Superfund database, or otherwise indicate that any

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[155] Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

[156] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[157] Memorandum from SAIC to Dennis Ruddy regarding Rationale and Conclusions Regarding Commenter-Identified Fossil Fuel Combustion Waste Damage Cases, April 20, 2000.

[158] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

[159] Letter from the Hoosier Environmental Council, et. al., to Dennis Ruddy regarding the CCW RTC, September 24, 1999.

contamination at this site is associated with fossil fuel combustion wastes. There is insufficient information available to identify the extent and nature of damages present and attribute them to fossil fuel combustion wastes.[160]

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[160] Memorandum from SAIC to Dennis Ruddy regarding Final Revised Report on Resolution of 18 Previously Indeterminate Candidate Damage Cases, March 5, 2003.

Hart Exhibit 8
Docket No. E-2, Sub 1219

SUBCHAPTER 2L - GROUNDWATER CLASSIFICATION AND STANDARDS

SECTION .0100 - GENERAL CONSIDERATIONS

15A NCAC 02L .0101 AUTHORIZATION

(a) N.C. General Statute 143-214.1 directs that the Commission develop and adopt after proper study a series of classifications and standards which will be appropriate for the purpose of classifying each of the waters of the state in such a way as to promote the policy and purposes of the act. Pursuant to this statute, the rules in this Subchapter establish a series of classifications and water quality standards applicable to the groundwaters of the state.

(b) These rules are applicable to all activities or actions, intentional or accidental, which contribute to the degradation of groundwater quality, regardless of any permit issued by a governmental agency authorizing such action or activity except an innocent landowner who is a bona fide purchaser of property which contains a source of groundwater contamination, who purchased such property without knowledge or a reasonable basis for knowing that groundwater contamination had occurred, or a person whose interest or ownership in the property is based or derived from a security interest in the property, shall not be considered a responsible party.

History Note: Authority G.S. 143-214.1; 143-214.2; 143-215.3(a)(1); 143B-282;
Eff. June 10, 1979;
Amended Eff. August 1, 1989; July 1, 1988; September 1, 1984; December 30, 1983.

15A NCAC 02L .0102 DEFINITIONS

The definition of any word or phrase used in these Rules shall be the same as given in G.S. 143-212 and G.S. 143-213 except that the following words and phrases shall have the following meanings:

(1) "Bedrock" means any consolidated rock encountered in the place in which it was formed or deposited and which cannot be readily excavated without the use of explosives or power equipment.
(2) "Commission" means the Environmental Management Commission as organized under G.S. 143B.
(3) "Compliance boundary" means a boundary around a disposal system at and beyond which groundwater quality standards may not be exceeded and only applies to facilities which have received a permit issued under the authority of G.S. 143-215.1 or G.S. 130A.
(4) "Contaminant" means any substance occurring in groundwater in concentrations which exceed the groundwater quality standards specified in Rule .0202 of this Subchapter.
(5) "Corrective action plan" means a plan for eliminating sources of groundwater contamination or for achieving groundwater quality restoration or both.
(6) "Director" means Director of the Division of Environmental Management.
(7) "Division" means the Division of Environmental Management.
(8) "Exposure pathway" means a course taken by a contaminant by way of a transport medium after its release to the environment.
(9) "Free product" means a non-aqueous phase liquid which may be present within the saturated zone or in surface water.
(10) "Fresh groundwaters" means those groundwaters having a chloride concentration equal to or less than 250 milligrams per liter.
(11) "Groundwaters" means those waters occurring in the subsurface under saturated conditions.
(12) "Hazardous substance" means any substance as defined by Section 101(14) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA).
(13) "Licensed geologist" means a person who has been duly licensed as a geologist in accordance with the requirements of G.S. 89E.
(14) "Natural remediation" means those natural processes acting to restore groundwater quality, including dilution, filtration, sorption, ion-exchange, chemical transformation and biodegradation.
(15) "Practical Quantitation Limit" means the lowest concentration of a given material that can be reliably achieved among laboratories within specified limits of precision and accuracy by a given analytical method during routine laboratory analysis.
(16) "Natural conditions" means the physical, biological, chemical and radiological conditions which occur naturally.
(17) "Potable waters" means those waters suitable for drinking by humans.

(18) "Professional Engineer" means a person who has been duly registered and licensed as a professional engineer in accordance with the requirements of G.S. 89C.

(19) "Receptor" means any human, plant, animal, or structure which is, or has the potential to be, adversely effected by the release or migration of contaminants. Any well constructed for the purpose of monitoring groundwater and contaminant concentrations shall not be considered a receptor.

(20) "Review boundary" means a boundary around a permitted disposal facility, midway between a waste boundary and a compliance boundary at which groundwater monitoring is required.

(21) "Saline groundwaters" means those groundwaters having a chloride concentration of more than 250 mg/l.

(22) "Saturated zone" means that part of the subsurface below the water table in which all the interconnected voids are filled with water under pressure at or greater than atmospheric. It does not include the capillary fringe.

(23) "Standards" means groundwater quality standards as specified in Rule .0202 of this Subchapter.

(24) "Suitable for drinking" means a quality of water which does not contain substances in concentrations which, either singularly or in combination if ingested into the human body, may cause death, disease, behavioral abnormalities, congenital defects, genetic mutations, or result in an incremental lifetime cancer risk in excess of 1x10-6, or render the water unacceptable due to aesthetic qualities, including taste, odor or appearance.

(25) "Time of travel" means the time required for contaminants in groundwater to move a unit distance.

(26) "Waste boundary" means the perimeter of the permitted waste disposal area.

(27) "Water table" means the surface of the saturated zone below which all interconnected voids are filled with water and at which the pressure is atmospheric.

History Note: *Authority G.S. 143-214.1; 143-215; 143B-282;*
Eff. June 10, 1979.
Amended Eff. October 1, 1993; August 1, 1989; July 1, 1988; March 1, 1985.

15A NCAC 02L .0103 POLICY

(a) The rules established in this Subchapter are intended to maintain and preserve the quality of the groundwaters, prevent and abate pollution and contamination of the waters of the state, protect public health, and permit management of the groundwaters for their best usage by the citizens of North Carolina. It is the policy of the Commission that the best usage of the groundwaters of the state is as a source of drinking water. These groundwaters generally are a potable source of drinking water without the necessity of significant treatment. It is the intent of these Rules to protect the overall high quality of North Carolina's groundwaters to the level established by the standards and to enhance and restore the quality of degraded groundwaters where feasible and necessary to protect human health and the environment, or to ensure their suitability as a future source of drinking water.

(b) It is the intention of the Commission to protect all groundwaters to a level of quality at least as high as that required under the standards established in Rule .0202 of this Subchapter. In keeping with the policy of the Commission to protect, maintain, and enhance groundwater quality within the State of North Carolina, the Commission will not approve any disposal system subject to the provisions of G.S. 143-215.1 which would result in:

(1) the significant degradation of groundwaters which have existing quality that is better than the assigned standard, unless such degradation is found to be in the best interests of the citizens of North Carolina based upon the projected economic benefits of the facility and a determination that public health will be protected, or

(2) a violation of a groundwater quality standard beyond a designated compliance boundary, or

(3) the impairment of existing groundwater uses or increased risk to the health or safety of the public due to the operation of a waste disposal system.

(c) Violations of standards resulting from groundwater withdrawals which are in compliance with water use permits issued pursuant to G.S. 143-215.15, shall not be subject to the corrective action requirements of Rule .0106 of this Subchapter.

(d) No person shall conduct or cause to be conducted, any activity which causes the concentration of any substance to exceed that specified in Rule .0202 of this Subchapter, except as authorized by the rules of this Subchapter.

(e) Work that is within the scope of the practice of geology and engineering, performed pursuant to the requirements of this Subchapter, which involves site assessment, the interpretation of subsurface geologic conditions, preparation of conceptual corrective action plans or any work requiring detailed technical knowledge of site conditions which is submitted to the Director, shall be performed by persons, firms or professional corporations who are duly licensed to offer geological or engineering services by the appropriate occupational licensing board or are exempted from such licensing by G.S. 89E-6.

Work which involves design of remedial systems or specialized construction techniques shall be performed by persons, firms or professional corporations who are duly licensed to offer engineering services. Corporations that are authorized by law to perform engineering or geological services and are exempt from the Professional Corporation Act, G.S. 55B, may perform these services.

History Note: *Authority G.S. 143-214; 143-214.1; 143-214.2; 143-215.3(e); 143-215.3(a)(1); 143B-282;*
Eff. June 10, 1979;
Amended Eff. August 1, 1989; July 1, 1988; September 1, 1984; December 30, 1983;
RRC Objection Eff. September 17, 1993, due to lack of necessity for Paragraph (e);
Amended Eff. November 4, 1993.

15A NCAC 02L .0104 RESTRICTED DESIGNATION (RS)

(a) The RS designation serves as a warning that groundwater so designated may not be suitable for use as a drinking water supply without treatment. The designation is temporary and will be removed by the Director upon a determination that the quality of the groundwater so designated has been restored to the level of the applicable standards or when the groundwaters have been reclassified by the Commission. The Director is authorized to designate GA or GSA groundwaters as RS under any of the following circumstances:

- (1) Where, as a result of man's activities, groundwaters have been contaminated and the Director has approved a corrective action plan, or termination of corrective action, that will not result in the immediate restoration of such groundwaters to the standards established under this Subchapter.
- (2) Where a statutory variance has been granted as provided in Rule .0113 of this Subchapter.

(b) Groundwaters occurring within an area defined by a compliance boundary in a waste disposal permit are deemed to be designated RS.

(c) The boundary of a designated RS area may be approximated in the absence of analytical data sufficient to define the dimension of the area. The boundary shall be located at least 250 feet away from the predicted edge of the contaminant plume, and shall include any areas into which the contamination is expected to migrate.

(d) In areas designated RS, the person responsible for groundwater contamination shall establish and implement a groundwater monitoring system sufficient to detect changes in groundwater quality within the RS designated area. Monitoring shall be quarterly for the first year and may be reduced to semi-annually thereafter until the applicable standards have been achieved. If during the monitoring period, contaminant concentrations increase, additional remedial action or monitoring pursuant to these Rules may be required.

(e) The applicant for an RS designation shall also provide written verification that all property owners within and adjacent to the proposed RS area have been notified of the requested RS designation.

(f) The Division shall provide public notice of the intent to designate any groundwater RS in accordance with the following requirements:

- (1) Notice shall be published at least 30 days prior to any proposed final action in accordance with G.S. 143-215.4. In addition, notice shall be provided to all property owners identified pursuant to Paragraph (e) of this Rule and to the local County Health Director and the chief administrative officer of the political jurisdiction(s) in which the contamination occurs.
- (2) The notice shall contain the following information:
  - (A) name, address, and phone number of the agency issuing the public notice;
  - (B) the location and extent of the designated area;
  - (C) the county title number, county tax identification number, or the property tax book and page identifiers;
  - (D) a brief description of the action or actions which resulted in the degradation of groundwater in the area;
  - (E) actions or intended actions taken to restore groundwater quality;
  - (F) the significance of the RS designation;
  - (G) conditions applicable to removal of the RS designation;
  - (H) address and phone number of a Division contact from whom interested parties may obtain further information.
- (3) The Director shall consider all requests for a public hearing, and if he determines that there is significant public interest he shall issue public notice and hold a public hearing in accordance with G.S 143-215.4(b) and Rule .0113(e) of this Section.

(4) These requirements shall not apply to groundwaters defined in Paragraph (b) of this Rule.

History Note: Authority G.S. 143-214.1; 143-215.3(a)(1); 143B-282(2);
Eff. June 10, 1979;
Amended Eff. October 1, 1993; December 1, 1989; August 1, 1989; December 30, 1983.

15A NCAC 02L .0105 ADOPTION BY REFERENCE

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Repealed Eff. August 1, 1989.

15A NCAC 02L .0106 CORRECTIVE ACTION

(a) Where groundwater quality has been degraded, the goal of any required corrective action shall be restoration to the level of the standards, or as closely thereto as is economically and technologically feasible as determined by the Department in accordance with this Rule. In all cases involving requests to the Secretary, as defined in 15A NCAC 02C .0102, for approval of corrective action plans, or termination of corrective action, the responsibility for providing all information required by this Rule lies with the person(s) making the request.

(b) Any person conducting or controlling an activity that results in the discharge of a waste or hazardous substance or oil to the groundwaters of the State, or in proximity thereto, shall take action upon discovery to terminate and control the discharge, mitigate any hazards resulting from exposure to the pollutants and notify the Department, as defined in 15A NCAC 02C .0102, of the discharge.

(c) Any person conducting or controlling an activity that has not been permitted by the Department and that results in an increase in the concentration of a substance in excess of the standard, other than agricultural operations, shall:

(1) within 24 hours of discovery of the violation, notify the Department of the activity that has resulted in the increase and the contaminant concentration levels;
(2) respond in accordance with Paragraph (f) of this Rule;
(3) submit a report to the Secretary assessing the cause, significance, and extent of the violation; and
(4) implement an approved corrective action plan for restoration of groundwater quality in accordance with a schedule established by the Secretary. In establishing a schedule, the Secretary shall consider a schedule proposed by the person submitting the plan. A report shall be made to the Health Director of the county or counties in which the contamination occurs in accordance with the requirements of Rule .0114(a) in this Section.

Any activity not permitted pursuant to G.S. 143-215.1 or G.S. 130A-294 shall, for the purpose of this Rule, be deemed not permitted by the Department and subject to the provisions of this Paragraph.

(d) Any person conducting or controlling an activity that is conducted under the authority of a permit initially issued by the Department on or after December 30, 1983 pursuant to G.S. 143-215.1 or G.S. 130A-294 and that results in an increase in concentration of a substance in excess of the standards:

(1) at or beyond a review boundary: the person shall demonstrate, through predictive calculations or modeling, that natural site conditions, facility design and operational controls will prevent a violation of standards at the compliance boundary. Alternately, the person may submit a plan for alteration of existing site conditions, facility design, or operational controls that will prevent a violation at the compliance boundary, and implement that plan upon its approval by the Secretary.
(2) at or beyond a compliance boundary: the person shall respond in accordance with Paragraph (f) of this Rule, assess the cause, significance and extent of the violation of standards and submit the results of the investigation, and a plan and proposed schedule for corrective action to the Secretary. The permittee shall implement the plan as approved by and in accordance with a schedule established by the Secretary. In establishing a schedule the Secretary shall consider any schedule proposed by the permittee, the scope of the project, the extent of contamination, and the corrective action being proposed.

(e) Any person conducting or controlling an activity that is conducted under the authority of a permit initially issued by the Department prior to December 30, 1983 pursuant to G.S. 143-215.1 or G.S. 130A-294, and that results in an increase in concentration of a substance in excess of the standards at or beyond the compliance boundary specified in the permit, shall:

(1) within 24 hours of discovery of the violation, notify the Department of the activity that has resulted in the increase and the contaminant concentration levels;
(2) respond in accordance with Paragraph (f) of this Rule;

(3) submit a report to the Secretary assessing the cause, significance and extent of the violation; and
(4) implement an approved corrective action plan for restoration of groundwater quality at or beyond the compliance boundary, in accordance with a schedule established by the Secretary. In establishing a schedule the Secretary shall consider any schedule proposed by the person submitting the plan. A report shall be made to the Health Director of the county or counties where the contamination occurs in accordance with the requirements of Rule .0114(a) in this Section.

(f) Initial response required to be conducted prior to or concurrent with the assessment required in Paragraphs (c), (d), or (e) of this Rule shall include:
(1) Prevention of fire, explosion, or the spread of noxious fumes;
(2) Abatement, containment, or control of the migration of contaminants;
(3) Removal, treatment, or control of any primary pollution source such as buried waste, waste stockpiles, or surficial accumulations of free products;
(4) Removal, treatment, or control of secondary pollution sources that would be potential continuing sources of pollutants to the groundwaters, such as contaminated soils and non-aqueous phase liquids. Contaminated soils that threaten the quality of groundwaters shall be treated, contained, or disposed of in accordance with rules in this Chapter and in 15A NCAC 13 applicable to such activities. The treatment or disposal of contaminated soils shall be conducted in a manner that will not result in a violation of standards or North Carolina Hazardous Waste Management rules.

(g) The site assessment conducted pursuant to the requirements of Paragraphs (c), (d), or (e) of this Rule, shall include:
(1) The source and cause of contamination;
(2) Any imminent hazards to public health and safety, as defined in G.S. 130A-2, and any actions taken to mitigate them in accordance with Paragraph (f) of this Rule;
(3) All receptors and significant exposure pathways;
(4) The horizontal and vertical extent of soil and groundwater contamination and all significant factors affecting contaminant transport; and
(5) Geological and hydrogeological features influencing the movement, chemical, and physical character of the contaminants.

Reports of site assessments shall be submitted to the Department as soon as practicable or in accordance with a schedule established by the Secretary. In establishing a schedule the Secretary shall consider a proposal by the person submitting the report.

(h) Corrective action plans for restoration of groundwater quality, submitted pursuant to Paragraphs (c), (d), and (e) of this Rule shall include:
(1) A description of the proposed corrective action and reasons for its selection;
(2) Specific plans, including engineering details where applicable, for restoring groundwater quality;
(3) A schedule for the implementation and operation of the proposed plan; and
(4) A monitoring plan for evaluating the effectiveness of the proposed corrective action and the movement of the contaminant plume.

(i) In the evaluation of corrective action plans, the Secretary shall consider the extent of any violations, the extent of any threat to human health or safety, the extent of damage or potential adverse impact to the environment, technology available to accomplish restoration, the potential for degradation of the contaminants in the environment, the time and costs estimated to achieve groundwater quality restoration, and the public and economic benefits to be derived from groundwater quality restoration.

(j) A corrective action plan prepared pursuant to Paragraphs (c), (d), or (e) of this Rule shall be implemented using a remedial technology demonstrated to provide the most effective means, taking into consideration geological and hydrogeological conditions at the contaminated site, for restoration of groundwater quality to the level of the standards. Corrective action plans prepared pursuant to Paragraphs (c) or (e) of this Rule may request an exception as provided in Paragraphs (k), (l), (m), (r), and (s) of this Rule.

(k) Any person required to implement an approved corrective action plan for a site subject to Paragraphs (c) or (e) of this Rule may request that the Secretary approve such a plan without requiring groundwater remediation to the standards. A request submitted to the Secretary under this Paragraph shall include a description of site-specific conditions, including information on the availability of public water supplies for the affected area; the technical basis for the request; and any other information requested by the Secretary to evaluate the request in accordance with Subparagraphs (1) through (7) of this Paragraph. The person making the request shall demonstrate:
(1) that all sources of contamination and free product have been removed or controlled pursuant to Paragraph (f) of this Rule;

- (2) that the time and direction of contaminant travel can be predicted with reasonable certainty;
- (3) that contaminants have not and will not migrate onto adjacent properties, or that:
    - (A) such properties are served by an existing public water supply system dependent on surface waters or hydraulically isolated groundwater; or
    - (B) the owners of such properties have consented in writing to the request;
- (4) that the standards specified in Rule .0202 of this Subchapter will be met at a location no closer than one year time of travel upgradient of an existing or foreseeable receptor, based on travel time and the natural attenuation capacity of subsurface materials or on a physical barrier to groundwater migration that exists or will be installed by the person making the request;
- (5) that, if the contaminant plume is expected to intercept surface waters, the groundwater discharge will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 02B .0200;
- (6) that public notice of the request has been provided in accordance with Rule .0114(b) of this Section; and
- (7) that the proposed corrective action plan would be consistent with all other environmental laws.

(l) Any person required to implement an approved corrective action plan for a site subject to Paragraphs (c) or (e) of this Rule may request that the Secretary approve such a plan based upon natural processes of degradation and attenuation of contaminants. A request submitted to the Secretary under this Paragraph shall include a description of site-specific conditions, including written documentation of projected groundwater use in the contaminated area based on current state or local government planning efforts; the technical basis for the request; and any other information requested by the Secretary to evaluate the request in accordance with Subparagraphs (1) through (10) of this Paragraph. The person making the request shall demonstrate:

- (1) that all sources of contamination and free product have been removed or controlled pursuant to Paragraph (f) of this Rule;
- (2) that the contaminant has the capacity to degrade or attenuate under the site-specific conditions;
- (3) that the time and direction of contaminant travel can be predicted based on subsurface conditions and the contaminant's physical and chemical properties;
- (4) that contaminant migration will not result in any violation of applicable groundwater standards at any existing or foreseeable receptor;
- (5) that contaminants have not and will not migrate onto adjacent properties, or that:
    - (A) such properties are served by an existing public water supply system dependent on surface waters or hydraulically isolated groundwater; or
    - (B) the owners of such properties have consented in writing to the request;
- (6) that, if the contaminant plume is expected to intercept surface waters, the groundwater discharge will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 02B .0200;
- (7) that the person making the request will put in place a groundwater monitoring program that, based on subsurface conditions and the physical and chemical properties of the contaminant, will accurately track the degradation and attenuation of contaminants and contaminant by-products within and down gradient of the plume and to detect contaminants and contaminant by-products prior to their reaching any existing or foreseeable receptor at least one year's time of travel upgradient of the receptor and no greater than the distance the groundwater at the contaminated site is predicted to travel in five years;
- (8) that all necessary access agreements needed to monitor groundwater quality pursuant to Subparagraph (7) of this Paragraph have been or can be obtained;
- (9) that public notice of the request has been provided in accordance with Rule .0114(b) of this Section; and
- (10) that the proposed corrective action plan would be consistent with all other environmental laws.

(m) The Department or any person required to implement an approved corrective action plan for a site subject to Paragraphs (c) or (e) of this Rule may request that the Secretary approve termination of corrective action.

- (1) A request submitted to the Secretary under this Paragraph shall include:
    - (A) a discussion of the duration of the corrective action, the total project cost, projected annual cost for continuance and evaluation of the success of the corrective action;
    - (B) an evaluation of alternate treatment technologies that could result in further reduction of contaminant levels, projected capital, and annual operating costs for each technology; and
    - (C) the effects, including health and safety impacts, on groundwater users if contaminant levels remain at levels existing at the time corrective action is terminated.
- (2) In addition, the person making the request shall demonstrate:

(A) that continuation of corrective action would not result in a significant reduction in the concentration of contaminants. This demonstration shall show the duration and degree of success of existing remedial efforts to attain standards. For the purpose of this Part, a "significant reduction" is demonstrated by showing that the asymptotic slope of the contaminants curve of decontamination is less than a ratio of 1:40 over a term of one year based on quarterly sampling;

(B) that contaminants have not and will not migrate onto adjacent properties, or that:

(i) such properties are served by an existing public water supply system dependent on surface waters or hydraulically isolated groundwater; or

(ii) the owners of such properties have consented in writing to the request;

(C) that, if the contaminant plumes are expected to intercept surface waters, the groundwater discharge will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 02B .0200;

(D) that public notice of the request has been provided in accordance with Rule .0114(b) of this Section; and

(E) that the proposed termination would be consistent with all other environmental laws.

(3) The Secretary shall not authorize termination of corrective action for any area that, at the time the request is made, has been identified by a state or local groundwater use planning process for resource development.

(4) The Secretary may authorize the termination of corrective action, or amend the corrective action plan after considering all the information in the request. In making the authorization, the Secretary shall consider health and safety impacts on all existing and foreseeable receptors and the impacts the contaminated plume may have if it reaches them. Upon termination of corrective action, the Secretary shall require implementation of a groundwater monitoring program that, based on subsurface conditions and the physical and chemical properties of the contaminants, will accurately track the degradation and attenuation of contaminants at a location of no less than one year's predicted time of travel upgradient of any existing or foreseeable receptor. The monitoring program shall remain in effect until there is sufficient evidence that the contaminant concentrations have been reduced to the level of the standards. For the purpose of this Part, "sufficient evidence" means that sampling and analyses demonstrate that contaminant concentrations have been reduced to the level of the standards on multiple sampling events.

(n) Upon a determination by the Secretary that continued corrective action would result in no significant reduction in contaminant concentrations, and the contaminated groundwaters can be rendered potable by treatment using technologies that are in use in other applications and shown to be effective for removal of contaminants, the Secretary may designate the remaining area of degraded groundwater RS. Where the remaining degraded groundwaters cannot be made potable by such treatment, the Secretary may consider a request for reclassification of the groundwater to a GC classification as outlined in Rule .0201 of this Subchapter.

(o) If at any time the Secretary determines that a new technology is available that would remediate the contaminated groundwater to the standards specified in Rule .0202 of this Subchapter, the Secretary may require the responsible party to evaluate the economic and technological feasibility of implementing the new technology in an active groundwater corrective action plan in accordance with a schedule established by the Secretary. The Secretary's determination to utilize new technology at any site or for any particular constituent shall include a consideration of the factors in Paragraph (h) of this Rule.

(p) Where standards are exceeded as a result of the application of pesticides or other agricultural chemicals, the Secretary shall request the Pesticide Board or the Department of Agriculture and Consumer Services to assist the Department in determining the cause of the violation. If the violation is determined to have resulted from the use of pesticides, the Secretary shall request the Pesticide Board to take appropriate regulatory action to control the use of the chemical or chemicals responsible for, or contributing to, such violations, or to discontinue their use.

(q) The approval pursuant to this Rule of any corrective action plan, or modification or termination thereof, that permits the migration of a contaminant onto adjacent property, shall not affect any private right of action by any party that may be affected by that contamination.

(r) If a discharge or release is not governed by the rules in Section .0400 of this Subchapter and the increase in the concentration of a substance in excess of the standard resulted in whole or in part from a release from a commercial or noncommercial underground storage tank as defined in G.S. 143-215.94A, any person required to implement an approved corrective action plan pursuant to this Rule and seeking reimbursement for the Commercial or Noncommercial Leaking Petroleum Underground Storage Tank Cleanup Funds shall implement a corrective action plan meeting the requirements of Paragraph (k) or (l) of this Rule unless the person demonstrates to the Secretary that:

(1) contamination resulting from the discharge cannot qualify for approval of a plan based on the requirements of the Paragraphs; or

(2) the cost of making such a demonstration would exceed the cost of implementing a corrective action plan submitted pursuant to Paragraph (c) of this Rule.

(s) If a discharge or release is not governed by the rules in Section .0400 of this Subchapter and the increase in the concentration of a substance in excess of the standard resulted in whole or in part from a release from a commercial or noncommercial underground storage tank as defined in G.S. 143-215.94A, the Secretary may require any person implementing or operating a previously approved corrective action plan pursuant to this Rule to:

(1) develop and implement a corrective action plan meeting the requirements of Paragraphs (k) and (l) of this Rule; or

(2) seek discontinuance of corrective action pursuant to Paragraph (m) of this Rule.

History Note: *Authority G.S. 143-215.1; 143-215.3; 143-215.94A; 143-215.94T; 143-215.94V; 143B-282;*
1995 (Reg. Sess. 1996) c. 648, s. 1;
Eff. August 1, 1989;
Amended Eff. October 1, 1993; September 1, 1992;
Temporary Amendment Eff. January 2, 1998; January 2, 1996;
Amended Eff. July 1, 2016; October 29, 1998.

15A NCAC 02L .0107 COMPLIANCE BOUNDARY

(a) For disposal systems individually permitted prior to December 30, 1983, the compliance boundary is established at a horizontal distance of 500 feet from the waste boundary or at the property boundary, whichever is closer to the source.

(b) For disposal systems individually permitted on or after December 30, 1983, a compliance boundary shall be established 250 feet from the waste boundary, or 50 feet within the property boundary, whichever point is closer to the source.

(c) The boundary shall be established by the Director, or his designee at the time of permit issuance. Any sale or transfer of property which affects a compliance boundary shall be reported immediately to the Director, or his designee. For disposal systems which are not governed by Paragraphs (e) or (f) of this Rule, the compliance boundary affected by the sale or transfer of property will be re-established consistent with Paragraphs (a) or (b) of this Rule, whichever is applicable.

(d) Except as provided in Paragraph (g) of this Rule, no water supply wells shall be constructed or operated within the compliance boundary of a disposal system individually permitted or repermitted after January 1, 1993.

(e) Except as provided in Paragraph (g) of this Rule, a permittee shall not transfer land within an established compliance boundary of a disposal system permitted or repermitted after January 1, 1993 unless:

(1) the land transferred is serviced by a community water system as defined in 15A NCAC 18C, the source of which is located outside the compliance boundary; and

(2) the deed transferring the property:

  (A) contains notice of the permit, including the permit number, a description of the type of permit, and the name, address and telephone number of the permitting agency; and

  (B) contains a restrictive covenant running with the land and in favor of the permittee and the State, as a third party beneficiary, which prohibits the construction and operation of water supply wells within the compliance boundary; and

  (C) contains a restrictive covenant running with the land and in favor of the permittee and the State, as a third party beneficiary, which grants the right to the permittee and the State to enter on such property within the compliance boundary for groundwater monitoring and remediation purposes.

(f) Except as provided in Paragraph (g) of this Rule, if at the time a permit is issued or reissued after January 1, 1993, the permittee is not the owner of the land within the compliance boundary, it shall be a condition of the permit issued or renewed that the landowner of the land within the compliance boundary, if other than the permittee, execute and file in the Register of Deeds in the county in which the land is located, an easement running with the land which:

(1) contains:

  (A) either a notice of the permit, including the permit number, a description of the type of permit, and the name, address and telephone number of the permitting agency; or

  (B) a reference to a notice of the permit with book and page number of its recordation if such notice is required to be filed by statute;

(2) prohibits the construction and operation of water supply wells within the compliance boundary; and

(3) reserves the right to the permittee and the State to enter on such property within the compliance boundary for groundwater monitoring and remediation purposes. The easement may be terminated by the Director

when its purpose has been fulfilled or the need for the easement no longer exists. Under those conditions the Director shall, upon request by the landowner, file a document terminating the easement with the appropriate Register of Deeds.

(g) The requirements of Paragraphs (d), (e) and (f) of this Rule are not applicable to ground adsorption treatment systems serving four or fewer single family dwellings or multiunit dwellings of four or fewer units.

(h) The boundary shall form a vertical plane extending from the water table to the maximum depth of saturation.

(i) For ground absorption sewage treatment and disposal systems which are permitted under 15A NCAC 18A .1900, the compliance boundary shall be established at the property boundary.

(j) Penalties authorized pursuant to G.S. 143-215.6A(a)(1) will not be assessed for violations of standards within a compliance boundary unless the violations are the result of violations of permit conditions or negligence in the management of the facility.

(k) The Director shall require:

- (1) that permits for all activities governed by G.S. 143-215.1 be written to protect the quality of groundwater established by applicable standards, at the compliance boundary;
- (2) that necessary groundwater quality monitoring shall be conducted within the compliance boundary; and
- (3) that a violation of standards within the compliance boundary resulting from activities conducted by the permitted facility be remedied through clean-up, recovery, containment, or other response when any of the following conditions occur:
  - (A) a violation of any standard in adjoining classified groundwaters occurs or can be reasonably predicted to occur considering hydrogeologic conditions, modeling, or other available evidence;
  - (B) an imminent hazard or threat to the public health or safety exists; or
  - (C) a violation of any standard in groundwater occurring in the bedrock other than limestones found in the Coastal Plain sediments, unless it can be demonstrated that the violation will not adversely affect, or have the potential to adversely affect a water supply well.

History Note: *Authority G.S. 143-215.1(b); 143-215.3(a)(1); 143B-282;*
Eff. August 1, 1989;
Amended Eff. October 1, 1993; November 2, 1992.

15A NCAC 02L .0108 REVIEW BOUNDARY

A review boundary is established around any disposal system midway between the compliance boundary and the waste boundary. When the concentration of any substance equals or exceeds the standard at the review boundary as determined by monitoring, the permittee shall take action in accordance with the provisions of Rule .0106(c)(2)(A) of this Subchapter.

History Note: *Authority G.S. 143-215.1(b); 143-215.3(a)(1); 143B-282;*
Eff. August 1, 1989.

15A NCAC 02L .0109 DELEGATION

(a) The Director is delegated the authority to enter into consent special orders under G.S. 143-215.2 for violations of the standards except when a public meeting is required as provided in 15A NCAC 2H .1203.

(b) The Director is delegated the authority to prepare a proposed special order to be issued by the Commission without the consent of the person affected and to notify the affected person of that proposed order and of the procedure set out in G.S. 150B-23 to contest the proposed special order.

(c) The Director, or his designee shall give public notice of proposed consent special orders as specified in 15A NCAC 2H .1203.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.3(a)(4);*
Eff. August 1, 1989;
Amended Eff. October 1, 1993; October 1, 1990.

15A NCAC 02L .0110 MONITORING

(a) Except where exempted by statute or this Subchapter, any person who causes, permits or has control over any discharge of waste, or groundwater cleanup program, shall install and implement a monitoring system, at such locations, and in such detail, as the Director, or his designee may require to evaluate the effects of the discharge upon the waters of the state, including the effect of any actions taken to restore groundwater quality, as well as the efficiency of any treatment facility. The monitoring plan shall be prepared under the responsible charge of a Professional Engineer or Licensed Geologist and bear the seal of the same.

(b) Monitoring systems shall be constructed in a manner that will not result in the contamination of adjacent groundwaters of a higher quality.

(c) Monitoring shall be conducted and results reported in a manner and at a frequency specified by the Director, or his designee.

History Note: *Authority G.S. 143-215.1(b); 143-215.3(a)(1); 143-215.65; 143-215.66; 143B-282;*
Eff. August 1, 1989;
Amended Eff. October 1, 1993.

15A NCAC 02L .0111 REPORTS

(a) Any person subject to the requirements for corrective action specified in Rule .0106 of this Section shall submit to the Director, in such detail as the Director may require, a written report that describes:

- (1) the results of the investigation specified in Paragraphs (c) and (d) of Rule .0106 of this Section, including but not limited to:
    - (A) a description of the sampling procedures followed and methods of chemical analyses used; and
    - (B) all technical data utilized in support of any conclusions drawn or determinations made.
- (2) the results of the predictive calculations or modeling, including a copy of the calculations or model runs and all supporting technical data, used in the demonstration required in Paragraph (d) of Rule .0106 of this Section; and
- (3) the proposed methodology and timetable associated with the corrective action for those situations identified in Paragraphs (c) and (d) of Rule .0106 of this Section.

(b) The report shall be prepared under the responsible charge of a Professional Engineer or Licensed Geologist and bear the seal of the same as specified in Rule .0106(d) of this Section.

History Note: *Authority G.S. 143-215.1(b); 143-215.3(a)(1); 143-215.65; 143B-282;*
Eff. August 1, 1989;
Amended Eff. October 1, 1993.

15A NCAC 02L .0112 ANALYTICAL PROCEDURES

Tests or analytical procedures to determine compliance or noncompliance with the standards established in Rule .0202 of this Subchapter will be in accordance with:

- (1) The most sensitive of the following methods or procedures for substances where the standard is at or above the method detection limit value:
    - (a) The most recent version of Standard Methods for the Examination of Water and Wastewater, published jointly by American Public Health Association, American Water Works Association and Water Pollution Control Federation;
    - (b) Methods for Chemical Analysis of Water and Waste, 1979, U.S. Environmental Protection Agency publication number EPA-600/4-79-020, as revised March 1983;
    - (c) Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 3rd Edition, 1986, U.S. Environmental Protection Agency publication number SW-846;
    - (d) Test Procedures for the Analysis of Pollutants Under the Clean Water Act, Federal Register Vol. 49, No. 209, 40 CFR Part 136, October 26, 1984;
    - (e) Methods or procedures approved by letter from the Director upon application by the regulated source; or
- (2) A method or procedure approved by the Director for substances where the standard is less than the method detection limit value.

History Note: *Authority G.S. 143-215.3(a)(1); 143B-282;*
Eff. August 1, 1989;
Amended Eff. October 1, 1993.

15A NCAC 02L .0113 VARIANCE

(a) The Commission, on its own initiative or pursuant to a request under G.S. 143-215.3(e), may grant variances to the rules of this Subchapter.

(b) Requests for variances are filed by letter from the applicant to the Environmental Management Commission. The application shall be mailed to the chairman of the Commission in care of the Director, Division of Environmental Management, Post Office Box 29535, Raleigh, N.C. 27626-0535.

(c) The application shall contain the following information:

- (1) Applications filed by counties or municipalities must include a resolution of the County Board of Commissioners or the governing board of the municipality requesting the variance.
- (2) A description of the past, existing or proposed activities or operations that have or would result in a discharge of contaminants to the groundwaters.
- (3) Description of the proposed area for which a variance is requested. A detailed location map, showing the orientation of the facility, potential for groundwater contaminant migration, as well as the area covered by the variance request, with reference to at least two geographic references (numbered roads, named streams/rivers, etc.) must be included.
- (4) Supporting information to establish that the variance will not endanger the public health and safety, including health and environmental effects from exposure to groundwater contaminants. (Location of wells and other water supply sources including details of well construction within 1/2 mile of site must be shown on a map).
- (5) Supporting information to establish that requirements of this Rule cannot be achieved by providing the best available technology economically reasonable. This information must identify specific technology considered, and the costs of implementing the technology and the impact of the costs on the applicant.
- (6) Supporting information to establish that compliance would produce serious financial hardship on the applicant.
- (7) Supporting information that compliance would produce serious financial hardship without equal or greater public benefit.
- (8) A copy of any Special Order that was issued in connection with contaminants in the proposed area and supporting information that applicant has complied with the Special Order.
- (9) A list of the names and addresses of any property owners within the proposed area of the variance as well as any property owners adjacent to the site covered by the variance.

(d) Upon receipt of the application, the Director will review it for completeness and request additional information if necessary. When the application is complete, the Director shall give public notice of the application and schedule the matter for a public hearing in accordance with G.S. 143-215.4(b) and the procedures set out in Paragraph (e) of this Rule.

(e) Notice of Public Hearing:

- (1) Notice of public hearing on any variance application shall be circulated in the geographical areas of the proposed variance by the Director at least 30 days prior to the date of the hearing:
  - (A) by publishing the notice one time in a newspaper having general circulation in said county;
  - (B) by mailing to the North Carolina Department of Environment, Health, and Natural Resources, Division of Environmental Health and appropriate local health agency;
  - (C) by mailing to any other federal, state or local agency upon request;
  - (D) by mailing to the local governmental unit or units having jurisdiction over the geographic area covered by the variance;
  - (E) by mailing to any property owner within the proposed area of the variance, as well as any property owners adjacent to the site covered by the variance; and
  - (F) by mailing to any person or group upon request.
- (2) The contents of public notice of any hearing shall include at least the following:
  - (A) name, address, and phone number of agency holding the public hearing;
  - (B) name and address of each applicant whose application will be considered at the meeting;
  - (C) brief summary of the variance request;
  - (D) geographic description of a proposed area for which a variance is requested;
  - (E) brief description of activities or operations which have or will result in the discharge of contaminants to the groundwaters described in the variance application;
  - (F) a brief reference to the public notice issued for each variance application;
  - (G) information regarding the time and location for the hearing;
  - (H) the purpose of the hearing;

(I) address and phone number of premises at which interested persons may obtain further information, request a copy of each application, and inspect and copy forms and related documents; and

(J) a brief description of the nature of the hearing including the rules and procedures to be followed. The notice shall also state that additional information is on file with the Director and may be inspected at any time during normal working hours. Copies of the information on file will be made available upon request and payment of cost or reproduction.

(f) All comments received within 30 days following the date of the public hearing shall be made part of the application file and shall be considered by the Commission prior to taking final action on the application.

(g) In determining whether to grant a variance, the Commission shall consider whether the applicant has complied with any Special Order, or Special Order by Consent issued under G.S. 143-215.2.

(h) If the Commission's final decision is unacceptable, the applicant may file a petition for a contested case in accordance with Chapter 150B of the General Statutes. If the petition is not filed within 60 days, the decision on the variance shall be final and binding.

(i) A variance shall not operate as a defense to an action at law based upon a public or private nuisance theory or any other cause of action.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.3(a)(3); 143-215.3(a)(4); 143-215.3(e); 143-215.4;*
Eff. August 1, 1989;
Amended Eff. October 1, 1993.

15A NCAC 02L .0114 NOTIFICATION REQUIREMENTS

(a) Any person subject to the requirements of Rule .0106(c) of this Section shall submit to the local Health Director, and the chief administrative officer of the political jurisdictions in which the groundwater contamination has occurred, a report that describes:

(1) The area extent of the contaminant plume;
(2) The chemical constituents in the groundwater which exceed the standards described in Rule .0202 of this Subchapter;
(3) Actions taken and intended to mitigate threats to human health;
(4) The location of any wells installed for the purpose of monitoring the contaminant plume and the frequency of sampling.

The report described in this Rule shall be submitted no later than five working days after submittal of the completed report assessing the cause, significance and extent of the violation as required by Rule .0106(c).

(b) Any person who submits a request under Rule .0106(k), (l), or (m) of this Section shall notify the local Health Director and the chief administrative officer of the political jurisdictions in which the contaminant plume occurs, and all property owners and occupants within or contiguous to the area underlain by the contaminant plume, and under the areas where it is expected to migrate, of the nature of the request and reasons supporting it. Notification shall be made by certified mail concurrent with the submittal of the request to the Director. A final decision by the Director shall be postponed for a period of 30 days following receipt of the request so that the Director may consider comments submitted by individuals interested in the request.

(c) Any person whose request under Rule .0106(k), (l), or (m) of this Section is granted by the Director shall notify parties specified in Paragraph (b) of this Rule of the Director's decision. Notification shall be made by certified mail within 30 days of receipt of the Director's decision.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1); 143B-282(2)b;*
Eff. October 1, 1993.

15A NCAC 02L .0115 RISK-BASED ASSESSMENT AND CORRECTIVE ACTION FOR PETROLEUM UNDERGROUND STORAGE TANKS

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Temporary Adoption Eff. January 2, 1998;
Eff. October 29, 1998;
Recodified to 15A NCAC 02L .0400 Eff. December 1, 2005.

SECTION .0200 - CLASSIFICATIONS AND GROUNDWATER QUALITY STANDARDS

15A NCAC 02L .0201 GROUNDWATER CLASSIFICATIONS

The classifications which may be assigned to the groundwaters will be those specified in the following series of classifications:

(1) Class GA groundwaters; usage and occurrence:
  (a) Best Usage. Existing or potential source of drinking water supply for humans.
  (b) Conditions Related to Best Usage. This class is intended for those groundwaters in which chloride concentrations are equal to or less than 250 mg/l, and which are considered suitable for drinking in their natural state, but which may require treatment to improve quality related to natural conditions.
  (c) Occurrence. In the saturated zone.

(2) Class GSA groundwaters; usage and occurrence:
  (a) Best Usage. Existing or potential source of water supply for potable mineral water and conversion to fresh waters.
  (b) Conditions Related to Best Usage. This class is intended for those groundwaters in which the chloride concentrations due to natural conditions is in excess of 250 mg/l, but which otherwise may be considered suitable for use as potable water after treatment to reduce concentrations of naturally occurring substances.
  (c) Occurrence. In the saturated zone.

(3) Class GC groundwaters: usage and occurrence:
  (a) Best Usage. The best usage of GC groundwaters is as a source of water supply for purposes other than drinking, including other domestic uses by humans.
  (b) Conditions Related to Best Usage. This class includes those groundwaters that do not meet the quality criteria for GA or GSA groundwaters and for which efforts to improve groundwater quality would not be technologically feasible, or not in the best interest of the public. Continued consumption of waters of this class by humans could result in adverse health affects.
  (c) Occurrence. Groundwaters of this class may be defined by the Commission pursuant to Section .0300 of this Subchapter on a case by case basis.

History Note: *Authority G.S. 143-214.1; 143B-282(2);*
Eff. June 10, 1979;
Amended Eff. October 1, 1993; August 1, 1989; September 1, 1984; December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0202 GROUNDWATER QUALITY STANDARDS

(a) The groundwater quality standards for the protection of the groundwaters of the state are those specified in this Rule. They are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for its intended best usage.

(b) The groundwater quality standards for contaminants specified in Paragraphs (h) and (i) of this Rule are as listed, except that:

(1) Where the standard for a substance is less than the practical quantitation limit, the detection of that substance at or above the practical quantitation limit constitutes a violation of the standard.

(2) Where two or more substances exist in combination, the Director shall consider the effects of chemical interactions as determined by the Division of Public Health and may establish maximum concentrations at values less than those established in accordance with Paragraphs (c), (h), or (i) of this Rule. In the absence of information to the contrary, in accordance with Paragraph (d) of this Rule, the carcinogenic risks associated with carcinogens present shall be considered additive and the toxic effects associated with non-carcinogens present shall also be considered additive.

(3) Where naturally occurring substances exceed the established standard, the standard shall be the naturally occurring concentration as determined by the Director.

(4) Where the groundwater standard for a substance is greater than the Maximum Contaminant Level (MCL), the Director shall apply the MCL as the groundwater standard at any private drinking water well or public water system well that may be impacted.

(c) Except for tracers used in concentrations which have been determined by the Division of Public Health to be protective of human health, and the use of which has been permitted by the Division, substances which are not naturally occurring and for which no standard is specified shall not be permitted in concentrations at or above the practical quantitation limit in Class GA or Class GSA groundwaters. Any person may petition the Director to establish an interim maximum allowable concentration for a substance for which a standard has not been established under this Rule. The petitioner shall submit relevant toxicological and epidemiological data, study results, and calculations necessary to establish a standard in accordance with Paragraph (d) of this Rule. Within three months after the establishment of an interim maximum allowable concentration for a substance by the Director, the Director shall initiate action to consider adoption of a standard for that substance.

(d) Except as provided in Paragraph (f) of this Rule, groundwater quality standards for substances in Class GA and Class GSA groundwaters are established as the least of:

(1) Systemic threshold concentration calculated as follows: [Reference Dose (mg/kg/day) x 70 kg (adult body weight) x Relative Source Contribution (.10 for inorganics; .20 for organics)] / [2 liters/day (avg. water consumption)];
(2) Concentration which corresponds to an incremental lifetime cancer risk of 1x10-6;
(3) Taste threshold limit value;
(4) Odor threshold limit value;
(5) Maximum contaminant level; or
(6) National secondary drinking water standard.

(e) The following references, in order of preference, shall be used in establishing concentrations of substances which correspond to levels described in Paragraph (d) of this Rule.

(1) Integrated Risk Information System (U.S. EPA).
(2) Health Advisories (U.S. EPA Office of Drinking Water).
(3) Other health risk assessment data published by the U.S. EPA.
(4) Other relevant, published health risk assessment data, and scientifically valid peer-reviewed published toxicological data.

(f) The Commission may establish groundwater standards less stringent than existing maximum contaminant levels or national secondary drinking water standards if it finds, after public notice and opportunity for hearing, that:

(1) more recent data published in the EPA health references listed in Paragraph (e) of this Rule results in a standard which is protective of public health, taste threshold, or odor threshold;
(2) the standard will not endanger the public health and safety, including health and environmental effects from exposure to groundwater contaminants; and
(3) compliance with a standard based on the maximum contaminant level or national secondary drinking water standard would produce serious hardship without equal or greater public benefit.

(g) Groundwater quality standards specified in Paragraphs (h) and (i) of this Rule and interim maximum allowable concentrations established pursuant to Paragraph (c) of this Rule shall be reviewed by the Director on a triennial basis. Appropriate modifications to established standards shall be made in accordance with the procedure prescribed in Paragraph (d) of this Rule where modifications are considered appropriate based on data published subsequent to the previous review.

(h) Class GA Standards. Unless otherwise indicated, the standard refers to the total concentration in micrograms per liter of any constituent in a dissolved, colloidal or particulate form which is mobile in groundwater. This does not apply to sediment or other particulate matter which is preserved in a groundwater sample as a result of well construction or sampling procedures. The Class GA standards are:

(1) Acenaphthene: 80;
(2) Acenaphthylene: 200;
(3) Acetone: 6 mg/L;
(4) Acrylamide: 0.008;
(5) Anthracene: 2 mg/L;
(6) Arsenic: 10;
(7) Atrazine and chlorotriazine metabolites: 3;
(8) Barium: 700;
(9) Benzene: 1;
(10) Benzo(a)anthracene (benz(a)anthracene): 0.05;
(11) Benzo(b)fluoranthene: 0.05;

(12) Benzo(k)fluoranthene: 0.5;
(13) Benzoic acid: 30 mg/L;
(14) Benzo(g,h,i,)perylene: 200;
(15) Benzo(a)pyrene: 0.005;
(16) Bis(chloroethyl)ether: 0.03;
(17) Bis(2-ethylhexyl) phthalate (di(2-ethylhexyl) phthalate): 3;
(18) Boron: 700;
(19) Bromodichloromethane: 0.6;
(20) Bromoform (tribromomethane): 4;
(21) n-Butylbenzene: 70;
(22) sec-Butylbenzene: 70;
(23) tert-Butylbenzene: 70;
(24) Butylbenzyl phthalate: 1 mg/L;
(25) Cadmium: 2;
(26) Caprolactam: 4 mg/L;
(27) Carbofuran: 40;
(28) Carbon disulfide: 700;
(29) Carbon tetrachloride: 0.3;
(30) Chlordane: 0.1;
(31) Chloride: 250 mg/L;
(32) Chlorobenzene: 50;
(33) Chloroethane: 3,000;
(34) Chloroform (trichloromethane): 70;
(35) Chloromethane (methyl chloride): 3;
(36) 2-Chlorophenol: 0.4;
(37) 2-Chlorotoluene (o-chlorotoluene): 100;
(38) Chromium: 10;
(39) Chrysene: 5;
(40) Coliform organisms (total): 1 per 100 mL;
(41) Color: 15 color units;
(42) Copper: 1 mg/L;
(43) Cyanide (free cyanide): 70;
(44) 2, 4-D (2,4-dichlorophenoxy acetic acid): 70;
(45) DDD: 0.1;
(46) DDT: 0.1;
(47) Dibenz(a,h)anthracene: 0.005;
(48) Dibromochloromethane: 0.4;
(49) 1,2-Dibromo-3-chloropropane: 0.04;
(50) Dibutyl (or di-n-butyl) phthalate: 700;
(51) 1,2-Dichlorobenzene (orthodichlorobenzene): 20;
(52) 1,3-Dichlorobenzene (metadichlorobenzene): 200;
(53) 1,4-Dichlorobenzene (paradichlorobenzene): 6;
(54) Dichlorodifluoromethane (Freon-12; Halon): 1 mg/L;
(55) 1,1-Dichloroethane: 6;
(56) 1,2-Dichloroethane (ethylene dichloride): 0.4;
(57) 1,2-Dichloroethene (cis): 70;
(58) 1,2-Dichloroethene (trans): 100;
(59) 1,1-Dichloroethylene (vinylidene chloride): 350;
(60) 1,2-Dichloropropane: 0.6;
(61) 1,3-Dichloropropene (cis and trans isomers): 0.4;
(62) Dieldrin: 0.002;
(63) Diethylphthalate: 6 mg/L;
(64) 2,4-Dimethylphenol (m-xylenol): 100;
(65) Di-n-octyl phthalate: 100;
(66) 1,4-Dioxane (p-dioxane): 3;

(67) Dioxin (2,3,7,8-TCDD): 0.0002 ng/L;
(68) 1,1– Diphenyl (1,1,-biphenyl): 400;
(69) Dissolved solids (total): 500 mg/L;
(70) Disulfoton: 0.3;
(71) Diundecyl phthalate (Santicizer 711): 100;
(72) Endosulfan: 40;
(73) Endrin, total (includes endrin, endrin aldehyde and endrin ketone): 2;
(74) Epichlorohydrin: 4;
(75) Ethyl acetate: 3 mg/L;
(76) Ethylbenzene: 600;
(77) Ethylene dibromide (1,2-dibromoethane): 0.02;
(78) Ethylene glycol: 10 mg/L;
(79) Fluoranthene: 300;
(80) Fluorene: 300;
(81) Fluoride: 2 mg/L;
(82) Foaming agents: 500;
(83) Formaldehyde: 600;
(84) Gross alpha (adjusted) particle activity (excluding radium-226 and uranium): 15 pCi/L;
(85) Heptachlor: 0.008;
(86) Heptachlor epoxide: 0.004;
(87) Heptane: 400;
(88) Hexachlorobenzene (perchlorobenzene): 0.02;
(89) Hexachlorobutadiene: 0.4;
(90) Hexachlorocyclohexane isomers (technical grade): 0.02;
(91) n-Hexane: 400;
(92) Indeno(1,2,3-cd)pyrene: 0.05;
(93) Iron: 300;
(94) Isophorone: 40;
(95) Isopropylbenzene: 70;
(96) Isopropyl ether: 70;
(97) Lead: 15;
(98) Lindane (gamma hexachlorocyclohexane): 0.03;
(99) Manganese: 50;
(100) Mercury: 1;
(101) Methanol: 4 mg/L;
(102) Methoxychlor: 40;
(103) Methylene chloride (dichloromethane): 5;
(104) Methyl ethyl ketone (2-butanone): 4 mg/L;
(105) 2-Methylnaphthalene: 30;
(106) 3-Methylphenol (m-cresol): 400;
(107) 4-Methylphenol (p-cresol): 40;
(108) Methyl tert-butyl ether (MTBE): 20;
(109) Naphthalene: 6;
(110) Nickel: 100;
(111) Nitrate (as N): 10 mg/L;
(112) Nitrite (as N): 1 mg/L;
(113) N-nitrosodimethylamine: 0.0007;
(114) Oxamyl: 200;
(115) Pentachlorophenol: 0.3;
(116) Petroleum aliphatic carbon fraction class (C5 - C8): 400;
(117) Petroleum aliphatic carbon fraction class (C9 - C18): 700;
(118) Petroleum aliphatic carbon fraction class (C19 - C36): 10 mg/L;
(119) Petroleum aromatics carbon fraction class (C9 - C22): 200;
(120) pH: 6.5 - 8.5;
(121) Phenanthrene: 200;

(122) Phenol: 30;
(123) Phorate: 1;
(124) n-Propylbenzene: 70;
(125) Pyrene: 200;
(126) Selenium: 20;
(127) Silver: 20;
(128) Simazine: 4;
(129) Styrene: 70;
(130) Sulfate: 250 mg/L;
(131) 1,1,2,2-Tetrachloroethane: 0.2;
(132) Tetrachloroethylene (perchloroethylene; PCE): 0.7;
(133) 2,3,4,6-Tetrachlorophenol: 200;
(134) Toluene: 600;
(135) Toxaphene: 0.03;
(136) 2,4,5-TP (Silvex): 50;
(137) 1,2,4-Trichlorobenzene: 70;
(138) 1,1,1-Trichloroethane: 200;
(139) Trichloroethylene (TCE): 3;
(140) Trichlorofluoromethane: 2 mg/L;
(141) 1,2,3-Trichloropropane: 0.005;
(142) 1,2,4-Trimethylbenzene: 400;
(143) 1,3,5-Trimethylbenzene: 400;
(144) 1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113): 200 mg/L;
(145) Vinyl chloride: 0.03;
(146) Xylenes (o-, m-, and p-): 500; and
(147) Zinc: 1 mg/L.

(i) Class GSA Standards. The standards for this class are the same as those for Class GA except as follows:

(1) chloride: allowable increase not to exceed 100 percent of the natural quality concentration; and
(2) dissolved solids (total): 1000 mg/L.

(j) Class GC Standards.

(1) The concentrations of substances that, at the time of classification, exceed the standards applicable to Class GA or GSA groundwaters shall not be caused to increase, nor shall the concentrations of other substances be caused to exceed the GA or GSA standards as a result of further disposal of contaminants to or beneath the surface of the land within the boundary of the area classified GC.
(2) The concentrations of substances that, at the time of classification, exceed the standards applicable to GA or GSA groundwaters shall not be caused to migrate as a result of activities within the boundary of the GC classification, so as to violate the groundwater or surface water quality standards in adjoining waters of a different class.
(3) Concentrations of specific substances, that exceed the established standard at the time of classification, are listed in Section .0300 of this Subchapter.

History Note: *Authority G.S. 143-214.1; 143B-282(a)(2);*
Eff. June 10, 1979;
Amended Eff. November 1, 1994; October 1, 1993; September 1, 1992; August 1, 1989;
Temporary Amendment Eff. June 30, 2002;
Amended Eff. August 1, 2002;
Temporary Amendment Expired February 9, 2003;
Amended Eff. April 1, 2013; January 1, 2010; April 1, 2005;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

SECTION .0300 - ASSIGNMENT OF UNDERGROUND WATER CLASSIFICATIONS

15A NCAC 02L .0301 CLASSIFICATIONS: GENERAL

(a) Schedule of Classifications. The classifications are based on the quality, occurrence and existing or contemplated best usage of the groundwaters as established in Section .0200 of this Subchapter and are assigned statewide except where supplemented or supplanted by specific classification assignments by major river basins.
(b) Classifications and Water Quality Standards. The classifications and standards assigned to the groundwaters are denoted by the letters GA, GSA, or GC. These classifications refer to the classifications and standards established by Rule .0201 of this Subchapter.

History Note: Authority G.S. 143-214.1; 143B-282(2);
Eff. December 30, 1983;
Amended Eff. August 1, 1989;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0302 STATEWIDE

The classifications assigned to the groundwaters located within the boundaries or under the extraterritorial jurisdiction of the State of North Carolina are:

(1) Class GA Waters. Those groundwaters in the state naturally containing 250 mg/l or less of chloride are classified GA.
(2) Class GSA Waters. Those groundwaters in the state naturally containing greater than 250 mg/l chloride are classified GSA.
(3) Class GC Waters. Those groundwaters assigned the classification GC in Rules .0303 - .0318 of this Section.

History Note: Authority G.S. 143-214.1; 143B-282(2);
Eff. December 30, 1983;
Amended Eff. August 1, 1989;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0303 BROAD RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0304 CAPE FEAR RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0305 CATAWBA RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0306 CHOWAN RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0307 FRENCH BROAD RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0308 HIWASSEE RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0309 LITTLE TENNESSEE RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0310 SAVANNAH RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0311 LUMBER RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0312 NEUSE RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0313 NEW-WATAUGA RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0314 PASQUOTANK RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: Authority G.S. 143-214.1;
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0315 ROANOKE RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: *Authority G.S. 143-214.1;*
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0316 TAR PAMLICO RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: *Authority G.S. 143-214.1;*
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0317 WHITE OAK RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: *Authority G.S. 143-214.1;*
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0318 YADKIN-PEE DEE RIVER BASIN

No classification assignments other than those specified in Rule .0302 are made for the river basin.

History Note: *Authority G.S. 143-214.1;*
Eff. December 30, 1983;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

15A NCAC 02L .0319 RECLASSIFICATION

The groundwater classifications as assigned may be revised by the Commission following public notice and subsequent public hearing. Changes may be to a higher or lower classification. Reclassification requests may be submitted to the Director.

History Note: *Authority G.S. 143-214.1; 143-215.3(e); 143B-282(2);*
Eff. December 30, 1983;
Amended Eff. August 1, 1989;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018.

SECTION .0400 - RISK-BASED ASSESSMENT AND CORRECTIVE ACTION FOR PETROLEUM UNDERGROUND STORAGE TANKS

15A NCAC 02L .0401 PURPOSE

(a) The purpose of this Section is to establish procedures for risk-based assessment and corrective action sufficient to:
- (1) protect human health and the environment;
- (2) abate and control contamination of the waters of the State as deemed necessary to protect human health and the environment;
- (3) permit management of the State's groundwaters to protect their designated current usage and potential future uses;
- (4) provide for anticipated future uses of the State's groundwater;
- (5) recognize the diversity of contaminants, the State's geology and the characteristics of each individual site; and
- (6) accomplish these goals in a cost-efficient manner to assure the best use of the limited resources available to address groundwater pollution within the State.

(b) Section .0100 of this Subchapter shall apply to this Section unless specifically excluded.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(a);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0402 DEFINITIONS

The definitions as set out in Rule .0102 of this Subchapter shall apply to this Section.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0403 RULE APPLICATION

This Section shall apply to any discharge or release from a "commercial underground storage tank" or a "noncommercial underground storage tank," as those terms are defined in G.S. 143-215.94A, that is reported on or after January 2, 1998. The requirements of this Section shall apply to the owner and operator of the underground storage tank from which the discharge or release occurred, a landowner seeking reimbursement from the Commercial Leaking Underground Storage Tank Fund or the Noncommercial Leaking Underground Storage Tank Fund under G.S. 143-215.94E, and any other person responsible for the assessment or cleanup of a discharge or release from an underground storage tank, including any person who has conducted or controlled an activity that results in the discharge or release of petroleum or petroleum products as defined in G.S. 143-215.94A(10) to the groundwaters of the State or in proximity thereto; these persons shall be collectively referred to for purposes of this Section as the "responsible party." This Section shall be applied in a manner consistent with the rules found in 15A NCAC 02N in order to assure that the State's requirements regarding assessment and cleanup from underground storage tanks are no less stringent than Federal requirements.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(b);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0404 REQUIRED INITIAL ABATEMENT ACTIONS BY RESPONSIBLE PARTY

(a) Upon a discharge or release of petroleum from a commercial underground storage tank the responsible party shall:

(1) take action to prevent all further discharge or release of petroleum from the underground storage tank; identify and mitigate all fire, explosion, and vapor hazards; remove any free product; and comply with the requirements of 15A NCAC 02N .0601 through .0604, .0701 through .0703, and .0705 within 24 hours of discovery;

(2) incorporate the requirements of 15A NCAC 02N .0704 into the submittal required under Subparagraph (3) of this Paragraph or the limited site assessment report required under Rule .0405 of this Section, whichever is applicable. The submittals shall constitute compliance with the reporting requirements of 15A NCAC 02N .0704(b); and

(3) submit within 90 days of the discovery of the discharge or release a soil contamination report containing information sufficient to show that remaining unsaturated soil in the side walls and at the base of the excavation does not contain contaminant levels that exceed either the "soil-to-groundwater" or the residential maximum soil contaminant concentrations established by the Department pursuant to Rule .0411 of this Section, whichever is lower. If the showing is made, the discharge or release shall be classified as low risk by the Department as defined in Rules .0406 and .0407 of this Section.

(b) Upon a discharge or release of petroleum from a noncommercial underground storage tank the responsible party shall:

(1) take necessary actions to protect public health, safety, and welfare and the environment, including actions to prevent all further discharge or release of petroleum from the noncommercial underground storage tank; identify and mitigate all fire, explosion, and vapor hazards; and report the release within 24 hours of discovery, in compliance with G.S. 143-215.83(a), G.S. 143-215.84(a), G.S. 143-215.85(b), and G.S. 143-215.94E; and

(2) provide or otherwise make available any information required by the Department to determine the site risk as described in Rules .0405, .0406, and .0407 of this Section.

(c) The Department shall notify the responsible party for a discharge or release of petroleum from a noncommercial underground storage tank that no cleanup, no further cleanup, or no further action shall be required without additional soil remediation pursuant to Rule .0408 of this Section if the site is determined by the Department to be low risk. This classification is based on information provided to the Department that:

(1) describes the source and type of the petroleum release, site-specific risk factors, and risk factors present in the surrounding area as defined in Rules .0406 and .0407 of this Section;

(2) demonstrates that no remaining risk factors are present that are likely to be affected per G.S. 143-215.94V(b); or

(3) documents that soils remaining onsite do not contain contaminant levels that exceed either the "soil-to-groundwater" or the residential maximum soil contaminant concentrations established by the Department pursuant to Rule .0411 of this Section, whichever is lower.

The Department shall reclassify the site as high risk, as defined in Rule .0406(1) of this Section, upon receipt of new information related to site conditions indicating that the discharge or release from a noncommercial underground storage tank poses an unacceptable risk or a potentially unacceptable risk to human health or the environment, as described in Rule .0407 of this Section.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(c)(1)-(3);
Amended Eff. December 1, 2005;
Temporary Amendment Eff. September 29, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0405 REQUIREMENTS FOR LIMITED SITE ASSESSMENT

(a) If the required showing for a commercial underground storage tank cannot be made or if the Department determines that a release from a noncommercial underground storage tank represents an unacceptable risk under Rule .0404 of this Section, the responsible party shall submit within 120 days of the discovery of the discharge or release, a report containing information needed by the Department to classify the level of risk to human health and the environment posed by a discharge or release under Rule .0406 of this Section.

(b) The responsible party may submit a written request for an extension to the 120 day deadline set forth in Paragraph (a) of this Rule to the Department for the Department's consideration prior to the deadline. The request for deadline extension by the responsible party shall demonstrate that the extension, if granted by the Department, would not increase the risk posed by the release. When considering a request from a responsible party for additional time to submit the report, the Department shall consider the following:

(1) the extent to which the request for additional time is due to factors outside of the control of the responsible party;

(2) the previous history of the person submitting the report in complying with deadlines established under the Commission's rules;

(3) the technical complications associated with assessing the extent of contamination at the site or identifying potential receptors; and

(4) the necessity for action to eliminate an imminent threat to public health or the environment.

(c) The report shall include:

(1) a location map, based on a USGS topographic map, showing the radius of 1500 feet from the source area of a confirmed release or discharge and depicting all water supply wells, surface waters, and designated wellhead protection areas as defined in 42 U.S.C. 300h-7(e) within the 1500-foot radius. 42 U.S.C. 300h-7(e), is incorporated by reference including subsequent amendments and editions. Copies may be obtained at no cost from the U.S. Government Bookstore's website at http://www.gpo.gov/fdsys/pkg/USCODE-2010-title42/html/USCODE-2010-title42-chap6A-subchapXII-partC-sec300h-7.htm. The material is available for inspection at the Department of Environmental Quality, UST Section, 217 West Jones Street, Raleigh, NC 27603. For purposes of this Section, "source area" means the point of release or discharge from the underground storage tank system;

(2) a determination of whether the source area of the discharge or release is within a designated wellhead protection area as defined in 42 U.S.C. 300h-7(e);

(3) if the discharge or release is in the Coastal Plain physiographic region as designated on a map entitled "Geology of North Carolina" published by the Department in 1985, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the Department's website at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/1985-geologic-map-of-nc, a determination of whether the source area of the discharge or release is located in an area in which there is recharge to an unconfined or semi-confined deeper aquifer that is being used or may be used as a source of drinking water;

(4) a determination of whether vapors from the discharge or release pose a threat of explosion due to the accumulation of vapors in a confined space or pose any other serious threat to public health, public safety, or the environment;

(5) scaled site maps showing the location of the following that are on or adjacent to the property where the source is located:
    (A) site boundaries;
    (B) roads;
    (C) buildings;
    (D) basements;
    (E) floor and storm drains;
    (F) subsurface utilities;
    (G) septic tanks and leach fields;
    (H) underground and aboveground storage tank systems;
    (I) monitoring wells;
    (J) water supply wells;
    (K) surface water bodies and other drainage features;
    (L) borings; and
    (M) the sampling points;

(6) the results from a limited site assessment that shall include:
    (A) the analytical results from soil samples collected during the construction of a monitoring well installed in the source area of each confirmed discharge or release from a noncommercial or commercial underground storage tank and either the analytical results of a groundwater sample collected from the well or, if free product is present in the well, the amount of free product in the well. The soil samples shall be collected every five feet in the unsaturated zone unless a water table is encountered at or greater than a depth of 25 feet from land surface in which case soil samples shall be collected every 10 feet in the unsaturated zone. The soil samples shall be collected from suspected worst-case locations exhibiting visible contamination or elevated levels of volatile organic compounds in the borehole;
    (B) if any constituent in the groundwater sample from the source area monitoring well installed in accordance with Part (A) of this Subparagraph, for a site meeting the high risk classification in Rule .0406(1) of this Section, exceeds the standards or interim standards established in Rule .0202 of this Subchapter by a factor of 10 and is a discharge or release from a commercial underground storage tank, the analytical results from a groundwater sample collected from each of three additional monitoring wells or, if free product is present in any of the wells, the amount of free product in such well. The three additional monitoring wells shall be installed as follows: one upgradient of the source of contamination and two downgradient of the source of contamination. The monitoring wells installed upgradient and downgradient of the source of contamination shall be located such that groundwater flow direction can be determined; and
    (C) potentiometric data from all required wells;

(7) the availability of public water supplies and the identification of properties served by the public water supplies within 1500 feet of the source area of a confirmed discharge or release;

(8) the land use, including zoning if applicable, within 1500 feet of the source area of a confirmed discharge or release;

(9) a discussion of site-specific conditions or possible actions that could result in lowering the risk classification assigned to the release. The discussion shall be based on information known or required to be obtained under this Paragraph; and

(10) names and current addresses of all owners and operators of the underground storage tank systems for which a discharge or release is confirmed, the owners of the land upon which such systems are located, and all potentially affected real property owners.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(c)(4);
Amended Eff. December 1, 2005;
Temporary Amendment Eff. September 29, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0406 DISCHARGE OR RELEASE CLASSIFICATIONS

The Department shall classify the risk of each known discharge or release as high, intermediate, or low risk unless the discharge or release has been classified under Rule .0404(a)(3) or (c) of this Section. For purposes of this Section:

(1) "High risk" means that:
  (a) a water supply well, including one used for non-drinking purposes, has been contaminated by a release or discharge;
  (b) a water supply well used for drinking water is located within 1000 feet of the source area of a confirmed discharge or release from a commercial underground storage tank or a noncommercial underground storage tank of 1100 gallons or less in capacity used for storing motor fuel for noncommercial purposes;
  (c) a water supply well not used for drinking water is located within 250 feet of the source area of a confirmed discharge or release from a commercial underground storage tank or a noncommercial underground storage tank of 1100 gallons or less in capacity used for storing motor fuel for noncommercial purposes;
  (d) the groundwater within 500 feet of the source area of a confirmed discharge or release from a commercial underground storage tank or a noncommercial underground storage tank of 1100 gallons or less in capacity used for storing motor fuel for noncommercial purposes has the potential for future use in that there is no source of water supply other than the groundwater;
  (e) a water supply well, including one used for non-drinking purposes, is located within 150 feet of the source area of a confirmed discharge or release from a noncommercial underground storage tank storing heating oil for consumptive use on the premises;
  (f) the vapors from a discharge or release pose a serious threat of explosion due to accumulation of the vapors in a confined space; or
  (g) a discharge or release poses an imminent danger to public health, public safety, or the environment.

(2) "Intermediate risk" means that:
  (a) surface water is located within 500 feet of the source area of a confirmed discharge or release from a commercial underground storage tank and the maximum groundwater contaminant concentration exceeds the applicable surface water quality standards and criteria found in 15A NCAC 02B .0200 by a factor of 10;
  (b) in the Coastal Plain physiographic region as designated on a map entitled "Geology of North Carolina" published by the Department in 1985, the source area of a confirmed discharge or release from a commercial underground storage tank is located in an area in which there is recharge to an unconfined or semi-confined deeper aquifer that the Department determines is being used or may be used as a source of drinking water;
  (c) the source area of a confirmed discharge or release from a commercial underground storage tank is within a designated wellhead protection area, as defined in 42 U.S.C. 300h-7(e);
  (d) the levels of groundwater contamination associated with a confirmed discharge or release from a commercial underground storage tank for any contaminant except ethylene dibromide, benzene, and alkane and aromatic carbon fraction classes exceed 50 percent of the solubility of the contaminant at 25 degrees Celsius or 1,000 times the groundwater standard or interim standard established in Rule .0202 of this Subchapter, whichever is lower; or
  (e) the levels of groundwater contamination associated with a confirmed discharge or release from a commercial underground storage tank for ethylene dibromide and benzene exceed 1,000 times the

federal drinking water standard set out in 40 CFR 141. 40 CFR 141 is incorporated by reference including subsequent amendments and editions. Copies may be obtained at no cost from the U.S. Government Bookstore's website at https://www.gpo.gov/fdsys/pkg/CFR-2015-title40-vol23/pdf/CFR-2015-title40-vol23-part141.pdf. The material is available for inspection at the Department of Environmental Quality, UST Section, 217 West Jones Street, Raleigh, NC 27603.

(3) "Low risk" means that:

(a) the risk posed does not fall within the high risk category for any underground storage tank, or within the intermediate risk category for a commercial underground storage tank; or

(b) based on review of site-specific information, limited assessment, or interim corrective actions, the discharge or release poses no significant risk to human health or the environment.

If the criteria for more than one risk category applies, the discharge or release shall be classified at the highest risk level identified in Rule .0407 of this Section.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(d);
Amended Eff. December 1, 2005;
Temporary Amendment Eff. September 29, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0407 RECLASSIFICATION OF RISK LEVELS

(a) Each responsible party shall have the continuing obligation to notify the Department of any changes that may affect the level of risk assigned to a discharge or release by the Department if the change is known or should be known by the responsible party, including changes in zoning of real property, use of real property, or the use of groundwater that has been contaminated or is expected to be contaminated by the discharge or release.

(b) The Department shall reclassify the risk posed by a release if warranted by further information concerning the potential exposure of receptors to the discharge or release or upon receipt of new information concerning changed conditions at the site. After initial classification of the discharge or release, the Department may require limited assessment, interim corrective action, or other actions that the Department believes will result in a lower risk classification.

(c) If the risk posed by a discharge or release is determined by the Department to be high risk, the responsible party shall comply with the assessment and cleanup requirements of Rule .0106(c), (g), and (h) of this Subchapter and 15A NCAC 02N .0706 and .0707. The goal of a required corrective action for groundwater contamination shall be restoration to the level of the groundwater standards set forth in Rule .0202 of this Subchapter, or as closely thereto as is economically and technologically feasible. In a corrective action plan submitted pursuant to this Paragraph, natural attenuation shall be used to the maximum extent possible, when the benefits of its use do not increase the risk to the environment and human health. If the responsible party demonstrates that natural attenuation prevents the further migration of the plume, the Department may approve a groundwater monitoring plan.

(d) If the risk posed by a discharge or release is determined by the Department to be an intermediate risk, the responsible party shall comply with the assessment requirements of Rule .0106(c) and (g) of this Subchapter and 15A NCAC 02N .0706. As part of the comprehensive site assessment, the responsible party shall evaluate, based on site-specific conditions, whether the release poses a significant risk to human health or the environment. If the Department determines, based on the site-specific conditions, that the discharge or release does not pose a significant threat to human health or the environment, the site shall be reclassified as a low risk site. If the site is not reclassified, the responsible party shall, at the direction of the Department, submit a groundwater monitoring plan or a corrective action plan, or a combination thereof, meeting the cleanup standards of this Paragraph and containing the information required in Rule .0106(h) of this Subchapter and 15A NCAC 02N .0707. Discharges or releases that are classified as intermediate risk shall be remediated, at a minimum, to a cleanup level of 50 percent of the solubility of the contaminant at 25 degrees Celsius or 1,000 times the groundwater standard or interim standard established in Rule .0202 of this Subchapter, whichever is lower, for any groundwater contaminant except ethylene dibromide, benzene and alkane and aromatic carbon fraction classes. Ethylene dibromide and benzene shall be remediated to a cleanup level of 1,000 times the federal drinking water standard as referenced in 15A NCAC 18C .1518 incorporated by reference including subsequent amendments and editions, and available free of charge at http://reports.oah.state.nc.us/ncac/title 15a - environmental quality/chapter 18 - environmental health/subchapter c/15a ncac 18c .1518.pdf. Additionally, if a corrective action plan or groundwater monitoring plan is required under this Paragraph, the responsible party shall demonstrate that the groundwater cleanup levels are sufficient to prevent a violation of:

(1) the rules contained in 15A NCAC 02B;

(2) the standards contained in Rule .0202 of this Subchapter in a deep aquifer as described in Rule .0406(2)(b) of this Section; and

(3) the standards contained in Rule .0202 of this Subchapter at a location no closer than one year time of travel upgradient of a well within a designated wellhead protection area, based on travel time and the natural attenuation capacity of the subsurface materials or on a physical barrier to groundwater migration that exists or will be installed by the person making the request.

In any corrective action plan submitted pursuant to this Paragraph, natural attenuation shall be used to the maximum extent possible, if the benefits of its use do not increase the risk to the environment and human health.

(e) If the risk posed by a discharge or release is determined to be a low risk, the Department shall notify the responsible party that no cleanup, no further cleanup, or no further action is required by the Department unless the Department later determines that the discharge or release poses an unacceptable risk or a potentially unacceptable risk to human health or the environment. No notification shall be issued pursuant to this Paragraph, however, until the responsible party has:

(1) completed soil remediation pursuant to Rule .0408 of this Section or as closely thereto as economically or technologically feasible;

(2) submitted proof of public notification, if required pursuant to Rule .0409(b) of this Section; and

(3) recorded all required land-use restrictions pursuant to G.S. 143B-279.9 and 143B-279.11.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(e)-(h);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0408 ASSESSMENT AND REMEDIATION PROCEDURES

Assessment and remediation of soil contamination shall be addressed as follows:

(1) At the time that the Department determines the risk posed by the discharge or release, the Department shall also determine, based on site-specific information, whether the site is "residential" or "industrial/commercial." For the purposes of this Section, a site is presumed residential, but may be classified as industrial/commercial if the Department determines based on site-specific information that exposure to the soil contamination is limited in time due to the use of the site and does not involve exposure to children. For the purposes of this Paragraph, "site" means both the property upon which the discharge or release occurred and any property upon which soil has been affected by the discharge or release.

(2) For a discharge or release from a commercial underground storage tank, or for a discharge or release from a noncommercial underground storage tank classified by the Department as high risk, the responsible party shall submit a report to the Department assessing the vertical and horizontal extent of soil contamination in excess of the lower of:

    (a) the residential or industrial/commercial maximum soil contaminant concentration, whichever is applicable, that has been established by the Department pursuant to Rule .0411 of this Section; or

    (b) the "soil-to-groundwater" maximum soil contaminant concentration that has been established by the Department pursuant to Rule .0411 of this Section.

(3) For a discharge or release from a commercial underground storage tank classified by the Department as low risk, the responsible party shall submit a report demonstrating that soil contamination has been remediated to either the residential or industrial/commercial maximum soil contaminant concentration established by the Department pursuant to Rule .0411 of this Section, whichever is applicable.

(4) For a discharge or release classified by the Department as high or intermediate risk, the responsible party shall submit a report demonstrating that soil contamination has been remediated to the lower of:

    (a) the residential or industrial/commercial maximum soil contaminant concentration, whichever is applicable, that has been established by the Department pursuant to Rule .0411 of this Section; or

    (b) the "soil-to-groundwater" maximum soil contaminant concentration that has been established by the Department pursuant to Rule .0411 of this Section.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(i);

Amended Eff. December 1, 2005;
Temporary Amendment Eff. September 29, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0409 NOTIFICATION REQUIREMENTS

(a) A responsible party who submits a corrective action plan that proposes natural attenuation, to cleanup groundwater contamination to a standard other than a standard as set forth in Rule .0202 of this Subchapter, or to cleanup soil other than to the standard for residential use or soil-to-groundwater contaminant concentration established pursuant to this Section, whichever is lowest, shall give notice to:

(1) the local Health Director and the chief administrative officer of each political jurisdiction in which the contamination occurs;
(2) all property owners and occupants within or contiguous to the area containing the contamination; and
(3) all property owners and occupants within or contiguous to the area where the contamination is expected to migrate.

The notice shall describe the nature of the plan and the reasons supporting it. Notification shall be made by certified mail concurrent with the submittal of the corrective action plan. Approval of the corrective action plan by the Department shall be postponed for a period of 60 days following receipt of the request so that the Department may receive and consider comments. The responsible party shall, within 30 days, provide the Department with a copy of the notice and proof of receipt of each required notice or of refusal by the addressee to accept delivery of a required notice. If notice by certified mail to occupants under this Paragraph is impractical, the responsible party shall give notice as provided in G.S. 1A-1, Rule 4(j) or 4(j1). If notice is made to occupants by posting, the responsible party shall provide the Department with a copy of the posted notice and a description of the manner in which such posted notice was given.

(b) A responsible party who receives a notice from the Department pursuant to Rule .0404(c) or .0407(e) of this Section for a discharge or release that has not been remediated to the groundwater standards or interim standards established in Rule .0202 of this Subchapter or to the lower of the residential or soil-to-groundwater contaminant concentrations established under Rule .0411 of this Section, shall, within 30 days of the receipt of such notice, provide a copy of the notice to:

(1) the local Health Director and the chief administrative officer of each political jurisdiction in which the contamination occurs;
(2) all property owners and occupants within or contiguous to the area containing the contamination; and
(3) all property owners and occupants within or contiguous to the area where the contamination is expected to migrate.

Notification shall be made by certified mail. The responsible party shall, within 60 days of receipt of the original notice from the Department, provide the Department with proof of receipt of the copy of the notice or of refusal by the addressee to accept delivery of the copy of the notice. If notice by certified mail to occupants under this Paragraph is impractical, the responsible party shall give notice as provided in G.S. 1A-1, Rule 4(j) or 4(j1). If notice is made to occupants by posting, the responsible party shall provide the Department with a description of the manner in which the posted notice was given.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(j) and (k);
Amended Eff. December 1, 2005;
Temporary Amendment Eff. September 29, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0410 DEPARTMENTAL LISTING OF DISCHARGES OR RELEASES

The Department shall maintain in each of the Department's regional offices a list of all petroleum underground storage tank discharges or releases discovered and reported to the Department within the region on or after the effective date of this Section and all petroleum underground storage tank discharges or releases for which notification was issued under Rule .0407(e) of this Section by the Department on or after the effective date of this Section.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(l);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0411 ESTABLISHING MAXIMUM SOIL CONTAMINATION CONCENTRATIONS

The Department shall publish on the Department website and annually revise maximum soil contaminant concentrations to be used as soil cleanup levels for contamination from petroleum underground storage tank systems. The Department shall establish maximum soil contaminant concentrations for residential, industrial/commercial, and soil-to-groundwater exposures as follows:

(1) The following equations and references shall be used in establishing residential maximum soil contaminant concentrations. Equation 1 shall be used for each contaminant with an EPA carcinogenic classification of A, B1, B2, C, D or E. Equation 2 shall be used for each contaminant with an EPA carcinogenic classification of A, B1, B2 or C. The maximum soil contaminant concentration shall be the lower of the concentrations derived from Equations 1 and 2.

(a) Equation 1: Non-cancer Risk-based Residential Ingestion Concentration
Soil mg/kg =[0.2 x oral chronic reference dose x body weight, age 1 to 6 x averaging time noncarcinogens] / [exposure frequency x exposure duration, age 1 to 6 x (soil ingestion rate, age 1 to 6 / 10^6 mg/kg)].

(b) Equation 2: Cancer Risk-based Residential Ingestion Concentration
Soil mg/kg =[target cancer risk of 10^{-6} x averaging time carcinogens] / [exposure frequency x (soil ingestion factor, age adjusted / 10^6mg/kg) x oral cancer slope factor]. The age adjusted soil ingestion factor shall be calculated by: [(exposure duration, age 1 to 6 x soil ingestion rate, age 1 to 6) /(body weight, age 1 to 6)] + [((exposure duration, total - exposure duration, age 1 to 6) x soil ingestion, adult) / (body weight, adult)].

(c) The exposure factors selected in calculating the residential maximum soil contaminant concentrations shall be within the recommended ranges specified in the following references or the most recent version of these references:

(i) EPA, 2011. Exposure Factors Handbook, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252;

(ii) EPA, 1991. Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals), incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-b;

(iii) EPA. Regional Screening Level Generic Tables (RSL) and User's Guide, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/risk/regional-screening-levels-rsls; and

(iv) EPA, 2018. Region 4 Human Health Risk Assessment Supplemental Guidance, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/sites/production/files/2018-03/documents/hhra_regional_supplemental_guidance_report-march-2018_update.pdf.

(d) The following references or the most recent version of these references, in order of preference, shall be used to obtain oral chronic reference doses and oral cancer slope factors:

(i) EPA. Integrated Risk Information System (IRIS) Computer Database, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/iris;

(ii) EPA. Health Effects Assessment Summary Tables (HEAST), incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://epa-heast.ornl.gov;

(iii) EPA. Regional Screening Level Generic Tables (RSL) and User's Guide;

(iv) EPA, 2018. Region 4 Human Health Risk Assessment Supplemental Guidance; and

        (v) Other scientifically valid peer-reviewed published health risk assessment data, and scientifically valid peer-reviewed published toxicological data.

(2) The following equations and references shall be used in establishing industrial/commercial maximum soil contaminant concentrations. Equation 1 shall be used for each contaminant with an EPA carcinogenic classification of A, B1, B2, C, D or E. Equation 2 shall be used for each contaminant with an EPA carcinogenic classification of A, B1, B2 or C. The maximum soil contaminant concentration shall be the lower of the concentrations derived from Equations 1 and 2.

    (a) Equation 1: Non-cancer Risk-based Industrial/Commercial Ingestion Concentration
    Soil mg/kg =[0.2 x oral chronic reference dose x body weight, adult x averaging time noncarcinogens] / [exposure frequency x exposure duration, adult x (soil ingestion rate, adult / 10^6 mg/kg) x fraction of contaminated soil ingested].

    (b) Equation 2: Cancer Risk-based Industrial/Commercial Ingestion Concentration
    Soil mg/kg =[target cancer risk of 10^{-6} x body weight, adult x averaging time carcinogens] / [exposure frequency x exposure duration, adult x (soil ingestion rate, adult / 10^6 mg/kg) x fraction of contaminated soil ingested x oral cancer slope factor].

    (c) The exposure factors selected in calculating the industrial/commercial maximum soil contaminant concentrations shall be within the recommended ranges specified in the following references or the most recent version of these references:

        (i) EPA, 2011. Exposure Factors Handbook;
        (ii) EPA, 1991. Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals);
        (iii) EPA. Regional Screening Level Generic Tables (RSL) and User's Guide; and
        (iv) EPA, 2018. Region 4 Human Health Risk Assessment Supplemental Guidance.

    (d) The following references or the most recent version of these references, in order of preference, shall be used to obtain oral chronic reference doses and oral cancer slope factors:

        (i) EPA. Integrated Risk Information System (IRIS) Computer Database;
        (ii) EPA. Health Effects Assessment Summary Tables (HEAST);
        (iii) EPA. Regional Screening Level Generic Tables (RSL) and User's Guide;
        (iv) EPA, 2018. Region 4 Human Health Risk Assessment Supplemental Guidance; and
        (v) Other scientifically valid peer-reviewed published health risk assessment data, and scientifically valid peer-reviewed published toxicological data.

(3) The following equations and references shall be used in establishing the soil-to-groundwater maximum contaminant concentrations:

    (a) Organic Constituents:
    Soil mg/kg = groundwater standard or interim standard x [(.02 x soil organic carbon-water partition coefficient) + 4 + (1.733 x 41 x Henry's Law Constant (atm.-m3/mole))].

        (i) If no groundwater standard or interim standard has been established under Rule .0202 of this Subchapter, the practical quantitation limit shall be used in lieu of a standard to calculate the soil-to-groundwater maximum contaminant concentrations.
        (ii) The following references or the most recent version of these references, in order of preference, shall be used to obtain soil organic carbon-water partition coefficients and Henry's Law Constants:

            (A) EPA. Superfund Chemical Data Matrix (SCDM), incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/superfund/superfund-chemical-data-matrix-scdm;
            (B) EPA, 1991. Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part A), incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part/; it is Volume I of the three-volume set called Risk Assessment Guidance for Superfund;

(C) Agency for Toxic Substances and Disease Registry, "Toxicological Profile for [individual chemical]," incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Agency for Toxic substances and Disease Registry website at https://www.atsdr.cdc.gov/substances/index.asp;
(D) Montgomery, J.H., 2007. Groundwater Chemicals Desk Reference. CRC Press. This document is incorporated by reference including subsequent amendments and editions, and may be obtained for a charge of two hundred ninety six dollars ($296.00) at https://www.crcpress.com/Groundwater-Chemicals-Desk-Reference/Montgomery/p/book/9780849392764/ or a copy may be reviewed at the Division of Waste Management, Underground Storage Tank Section office at 217 West Jones Street, Raleigh, N.C. 27603; and
(E) Other scientifically valid peer-reviewed published data.

(b) Inorganic Constituents:
Soil mg/kg = groundwater standard or interim standard x [(20 x soil-water partition coefficient for pH of 5.5) + 4 + (1.733 x 41 x Henry's Law Constant (atm.-m3/mole))].
(i) If no groundwater standard or interim standard has been established under Rule .0202 of this Subchapter, the practical quantitation limit shall be used in lieu of a standard to calculate the soil-to-groundwater maximum contaminant concentrations.
(ii) The following references or the most recent version of these references, in order of preference, shall be used to obtain soil-water partition coefficients and Henry's Law Constants:
(A) EPA. Superfund Chemical Data Matrix (SCDM);
(B) Baes, C.F., III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor, 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture. Oak Ridge National Laboratory, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the United States Nuclear Regulatory Commission website at https://www.nrc.gov;
(C) Agency for Toxic Substances and Disease Registry, "Toxicological Profile for [individual chemical];" and
(D) Other scientifically valid peer-reviewed published data.

History Note: Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;
Recodified from 15A NCAC 02L .0115(m);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0412 ANALYTICAL PROCEDURES FOR SOIL SAMPLES

(a) Analytical procedures for soil samples required under this Section shall be methods accepted by the US EPA as suitable for determining the presence and concentration of petroleum hydrocarbons for the type of petroleum released.

(b) Soil samples collected, including the most contaminated sample, shall be analyzed as follows in order to determine the risks of the constituents of contamination:
(1) soil samples collected from a discharge or release of low boiling point fuels, including gasoline, aviation gasoline, and gasohol, shall be analyzed for volatile organic compounds and additives, including isopropyl ether and methyl tertiary butyl ether, using EPA Method 8260;
(2) soil samples collected from a discharge or release of high boiling point fuels, including kerosene, diesel, varsol, mineral spirits, naphtha, jet fuels, and fuel oil no. 2, shall be analyzed for volatile organic compounds using EPA Method 8260 and semivolatile organic compounds using EPA Method 8270;
(3) soil samples collected from a discharge or release of heavy fuels shall be analyzed for semivolatile organic compounds using EPA Method 8270;
(4) soil samples collected from a discharge or release of used and waste oil shall be analyzed for volatile organic compounds using EPA Method 8260, semivolatile organic compounds using EPA Method 8270,

polychlorinated biphenyls using EPA Method 8080, and chromium and lead using procedures specified in Subparagraph (6) of this Paragraph;

(5) soil samples collected from a discharge or release subject to this Section shall be analyzed for alkane and aromatic carbon fraction classes using methods approved by the Director under 15A NCAC 02H .0805(a)(1);

(6) analytical methods specified in Subparagraphs (1), (2), (3), and (4) of this Paragraph shall be performed as specified in the following references or the most recent version of these references: Test Methods for Evaluating Solid Wastes:Physical/Chemical Methods, November 1990, U.S. Environmental Protection Agency publication number SW-846, is incorporated by reference and may be purchased for a cost of three hundred sixty seven dollars ($367.00) from the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, DC 20402; or in accordance with other methods or procedures approved by the Director under 15A NCAC 02H .0805(a)(1);

(7) other EPA-approved analytical methods may be used if the methods include the same constituents as the analytical methods specified in Subparagraphs (1), (2), (3), and (4) of this Paragraph and meet the detection limits of the analytical methods specified in Subparagraphs (1), (2), (3), and (4) of this Paragraph; and

(8) metals and acid extractable organic compounds shall be eliminated from analyses of soil samples collected pursuant to this Section if these compounds are not detected in soil samples collected during the construction of the source area monitoring well required under Rule .0405 of this Section.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(n);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0413 ANALYTICAL PROCEDURES FOR GROUNDWATER SAMPLES

(a) Analytical procedures for groundwater samples required under this Section shall be methods accepted by the US EPA as suitable for determining the presence and concentration of petroleum hydrocarbons for the type of petroleum released.

(b) Groundwater samples, including the most contaminated sample, shall be analyzed as follows in order to determine the risks of the constituents of contamination:

(1) groundwater samples collected from a discharge or release of low boiling point fuels, including gasoline, aviation gasoline, and gasohol, shall be analyzed for volatile organic compounds, including xylenes, isopropyl ether, and methyl tertiary butyl ether, using Standard Method 6200B or EPA Methods 601 and 602. Samples shall also be analyzed for ethylene dibromide using EPA Method 504.1 and lead using Standard Method 3030C preparation. 3030C metals preparation, using a 0.45 micron filter, shall be completed within 72 hours of sample collection;

(2) groundwater samples collected from a discharge or release of high boiling point fuels, including kerosene, diesel, varsol, mineral spirits, naphtha, jet fuels, and fuel oil no. 2, shall be analyzed for volatile organic compounds using EPA Method 602 and semivolatile organic compounds plus the 10 largest non-target peaks identified using EPA Method 625;

(3) groundwater samples collected from a discharge or release of heavy fuels shall be analyzed for semivolatile organic compounds plus the 10 largest non-target peaks identified using EPA Method 625;

(4) groundwater samples collected from a discharge or release of used or waste oil shall be analyzed for volatile organic compounds using Standard Method 6200B, semivolatile organic compounds plus the 10 largest non-target peaks identified using EPA Method 625, and chromium and lead using Standard Method 3030C preparation. 3030C metals preparation, using a 0.45 micron filter, shall be completed within 72 hours of sample collection;

(5) groundwater samples collected from a discharge or release subject to this Section shall be analyzed for alkane and aromatic carbon fraction classes using methods approved by the Director under 15A NCAC 02H .0805(a)(1);

(6) analytical methods specified in Subparagraphs (1), (2), (3) and (4) of this Paragraph shall be performed as specified in the following references or the most recent version of these references:

(A) Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act, 40 CFR Part 136, is incorporated by reference and may be obtained electronically free of charge from the United States Environmental Protection Agency website at https://www.epa.gov/cwa-methods;

(B) Standard Methods for the Examination of Water and Wastewater, published jointly by American Public Health Association, American Water Works Association and Water Pollution Control Federation, is incorporated by reference and is available for purchase from the American Water Works Association (AWWA), 6666 West Quincy Avenue, Denver, CO 80235 for a charge of one hundred sixty dollars ($160.00) for the 18th Edition, one hundred eighty dollars ($180.00) for the 19th Edition, and two hundred dollars ($200.00) for the 20th Edition; or

(C) in accordance with methods or procedures approved by the Director under 15A NCAC 02H .0805(a)(1);

(7) other EPA-approved analytical methods may be used if the methods include the same constituents as the analytical methods specified in Subparagraphs (1), (2), (3), and (4) of this Paragraph and meet the detection limits of the analytical methods specified in Subparagraphs (1), (2), (3), and (4) of this Paragraph; and

(8) metals and acid extractable organic compounds shall be eliminated from analyses of groundwater samples collected pursuant to this Section if these compounds are not detected in the groundwater sample collected from the source area monitoring well installed pursuant to Rule .0405 of this Section.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(o);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0414 REQUIRED LABORATORY CERTIFICATION

In accordance with 15A NCAC 02H .0804, laboratories shall obtain North Carolina Division of Water Resources laboratory certification for parameters that are required to be reported to the State in compliance with the State's surface water, groundwater, and pretreatment rules.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(p);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0415 DISCHARGES OR RELEASES FROM OTHER SOURCES

This Section shall not relieve any person responsible for assessment or cleanup of contamination from a source other than a commercial or noncommercial underground storage tank from its obligation to assess and clean up contamination resulting from the discharge or releases.

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(q);
Amended Eff. December 1, 2005;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0416 ELIGIBILITY OF SITES TO CONTINUE REMEDIATION UNDER RULES EXISTING BEFORE THE EFFECTIVE DATE OF 15A NCAC 02L .0115

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(r);
Amended Eff. December 1, 2005;
Expired Eff. April 1, 2018 pursuant to G.S. 150B-21.3A.

15A NCAC 02L .0417 ESTABLISHING CLEANUP REQUIREMENTS FOR SITES ELIGIBLE TO CONTINUE REMEDIATION UNDER RULES EXISTING BEFORE THE EFFECTIVE DATE OF 15A NCAC 02L .0115

History Note: *Authority G.S. 143-215.2; 143-215.3(a)(1); 143-215.94A; 143-215.94E; 143-215.94T; 143-215.94V; 143B-282; 1995 (Reg. Sess. 1996) c. 648,s. 1;*
Recodified from 15A NCAC 02L .0115(s);
Amended Eff. December 1, 2005;
Expired Eff. April 1, 2018 pursuant to G.S. 150B-21.3A.

SECTION .0500 – RISK-BASED ASSESSMENT AND CORRECTIVE ACTION FOR PETROLEUM RELEASES FROM ABOVEGROUND STORAGE TANKS AND SOURCES

15A NCAC 02L .0501 PURPOSE

(a) The purpose of this Section is to establish procedures for risk-based assessment and corrective action sufficient to:

(1) protect human health and the environment;
(2) abate and control contamination of the waters of the State as deemed necessary to protect human health and the environment;
(3) permit management of the State's groundwaters to protect their designated current usage and potential future uses;
(4) provide for anticipated future uses of the State's groundwater;
(5) recognize the diversity of contaminants, the State's geology, and the characteristics of each individual site; and
(6) accomplish these goals in a cost-efficient manner to assure the best use of the limited resources available to address groundwater pollution within the State.

(b) Section .0100 of this Subchapter shall apply to this Section unless specifically excluded.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0502 DEFINITIONS

The definitions as set out in Rule .0102 of this Subchapter and the following definitions shall apply throughout this Section:

(1) "Aboveground storage tank" or "AST" means any one or a combination of tanks, including pipes connected thereto, that is used to contain an accumulation of petroleum.
(2) "AST system" means an aboveground storage tank, connected piping, ancillary equipment, and containment system, if any.
(3) "Discharge" includes any emission, spillage, leakage, pumping, pouring, emptying, or dumping of oil into groundwater or surface water or upon land in such proximity to such water that it is likely to reach the water and any discharge upon land which is intentional, knowing, or willful.
(4) "Non-UST means as defined in G.S. 143-215.104AA(g) and excludes underground storage tank releases governed by G.S. 143-215.94V.
(5) "Operator" means any person in control of or having responsibility for the daily operation of the AST system.
(6) "Owner" means any person who owns a petroleum aboveground storage tank or other non-UST petroleum tank, stationary or mobile, used for storage, use, dispensing, or transport.
(7) "Person" means an individual, trust, firm, joint stock company, Federal agency, corporation, state, municipality, commission, political subdivision of a state, or any interstate body. "Person" also includes a consortium, a joint venture, a commercial entity, and the United States Government.
(8) "Petroleum" or "petroleum products" means as defined in G.S. 143-215.94A(10).
(9) "Release" means any spilling, leaking, emitting, discharging, escaping, leaching, or disposing into groundwater, surface water, or surface or subsurface soils.
(10) "Tank" means a device used to contain an accumulation of petroleum and constructed of non-earthen materials, such as concrete, steel, or plastic, that provides structural support.

History Note: *Authority G.S. 143-212(4); 143-215.3(a)(1); 143-215.77; 143-215.84; 143-215.104AA; 143B-282;*

Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0503 RULE APPLICATION

The requirements of this Section shall apply to the owner and operator of a petroleum aboveground storage tank or other non-UST petroleum tank, stationary or mobile, from which a discharge or release occurred and to any person determined to be responsible for assessment and cleanup of a discharge or release from a non-UST petroleum source, including any person who has conducted or controlled an activity that results in the discharge or release of petroleum or petroleum products (as defined in G.S. 143-215.94A(10)) to the groundwaters of the State or in proximity thereto. These persons shall be collectively referred to as the "responsible party" for purposes of this Section.

History Note: Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0504 REQUIRED INITIAL RESPONSE AND ABATEMENT ACTIONS BY RESPONSIBLE PARTY

Upon a discharge or release of petroleum from a non-UST petroleum source the responsible party shall:

(1) take actions to prevent all further discharge or release of petroleum from the non-UST petroleum source; identify and mitigate all fire, explosion, or vapor hazard; and report the release within 24 hours of discovery, in compliance with G.S. 143-215.83(a), 84(a), and 85(b);

(2) perform initial abatement actions to measure for the presence of a release where contamination is most likely to be present; confirm the source of the release; investigate to determine the possible presence of free product; begin free product removal; and to continue to monitor and mitigate all additional fire, explosion, or vapor hazards posed by vapors or by free product; and submit a report to the Department of Environmental Quality, UST Section, Regional Office Supervisor in accordance with 15A NCAC 02B .0309 and .0311, within 20 days after release confirmation summarizing these initial abatement actions;

(3) remove contaminated soil that would act as a continuing source of contamination to groundwater. For a new release, no further action shall be necessary if:

  (a) initial abatement actions involving control and removal of contaminated materials are initiated within 48 hours from discovery and before contaminated materials begin to impact groundwater; and

  (b) analysis, in accordance with the approved methods in Rule .0412 of this Subchapter, of representative samples of remaining soils shows concentrations:

    (i) at or below the more stringent of the soil-to-groundwater concentration value and the residential maximum soil contamination concentration value; or

    (ii) using other EPA-approved analytical methods in accordance with Rule .0412(b)(7) of this Subchapter, concentration values below the more stringent of the soil-to-groundwater concentration alkane and aromatic carbon fraction class values and the residential maximum soil contamination concentration alkane and aromatic carbon fraction class values;

  For new releases, if the abatement actions cannot be initiated within 48 hours of discovery or if soil concentrations remain above the values in this Paragraph, the responsible party shall conduct all activities under Items (1) through (5) of this Rule;

(4) conduct initial site assessment, assembling information about the site and the nature of the release, including the following:

  (a) a site history and site characterization, including data on nature and estimated quantity of release and data from available sources and site investigations concerning surrounding populations, water quality, use, and approximate locations of wells, surface water bodies, and subsurface structures potentially affected by the release, subsurface soil conditions, locations of subsurface utilities, climatological conditions, and land use;

  (b) the results of free product investigations and free product removal, if applicable;

  (c) the results of groundwater and surface water investigations, if applicable;

  (d) a summary of initial response and abatement actions; and

(5) submit as required in Item (2) of this Rule, within 90 days of the discovery of the discharge or release:
  (a) an initial assessment and abatement report as required in Item (4) of this Rule;
  (b) soil assessment information sufficient to show that remaining unsaturated soil in the side walls and at the base of the excavation does not contain contaminant levels that exceed either the soil-to-groundwater or the residential maximum soil contaminant concentrations established by the Department pursuant to Rule .0511 of this Section, whichever is lower; and
  (c) documentation to show that neither bedrock nor groundwater was encountered in the excavation or, if groundwater was encountered, that contaminant concentrations in groundwater were equal to or less than the groundwater quality standards established in Rule .0202 of this Subchapter. If such showing is made, the discharge or release shall be classified as low risk by the Department.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0505 REQUIREMENTS FOR LIMITED SITE ASSESSMENT

(a) If the required showing cannot be made by the responsible party under Rule .0504 of this Section, the responsible party shall submit within 120 days of the discovery of the discharge or release, a report as required in Rule .0504 of this Section, containing information needed by the Department to classify the level of risk to human health and the environment posed by a discharge or release under Rule .0506 of this Section.

(b) The responsible party may submit a written request an extension to the 120 day deadline set forth in Paragraph (a) of this Rule to the Department for the Department's consideration prior to the deadline. The request for deadline extension by the responsible party shall demonstrate that the extension, if granted by the Department, would not increase the risk posed by the release. When considering a request from a responsible party for additional time to submit the report, the Department shall consider the following:

(1) the extent to which the request for additional time is due to factors outside of the control of the responsible party;
(2) the previous history of the person submitting the report in complying with deadlines established under the Commission's rules;
(3) the technical complications associated with assessing the extent of contamination at the site or identifying potential receptors; and
(4) the necessity for action to eliminate an imminent threat to public health or the environment.

(c) The report shall include:

(1) a location map, based on a USGS topographic map, showing the radius of 1500 feet from the source area of a confirmed release or discharge and depicting all water supply wells, surface waters, and designated "wellhead protection areas" as defined in 42 U.S.C. 300h-7(e) within the 1500-foot radius. 42 U.S.C. 300h-7(e), is incorporated by reference including subsequent amendments and editions. Copies may be obtained at no cost from the U.S. Government Bookstore's website at http://www.gpo.gov/fdsys/pkg/USCODE-2010-title42/html/USCODE-2010-title42-chap6A-subchapXII-partC-sec300h-7.htm. The material is available for inspection at the Department of Environmental Quality, UST Section, 217 West Jones Street, Raleigh, NC 27603. For purposes of this Section, "source area" means point of release or discharge from the non-UST petroleum source, or if the point of release cannot be determined precisely, "source area" means the area of highest contaminant concentrations;
(2) a determination of whether the source area of the discharge or release is within a designated "wellhead protection area" as defined in 42 U.S.C. 300h-7(e);
(3) if the discharge or release is in the Coastal Plain physiographic region as designated on a map entitled "Geology of North Carolina" published by the Department in 1985, incorporated by reference including subsequent amendments or editions and may be obtained electronically free of charge from the Department's website at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/1985-geologic-map-of-nc, a determination of whether the source area of the discharge or release is located in an area in which there is recharge to an unconfined or semi-confined deeper aquifer that is being used or may be used as a source of drinking water;
(4) a determination of whether vapors from the discharge or release pose a threat of explosion due to the accumulation of vapors in a confined space; pose a risk to public health from exposure; or pose any other threat to public health, public safety, or the environment;

(5) scaled site maps showing the location of the following that are on or adjacent to the property where the source is located:
  (A) site boundaries;
  (B) roads;
  (C) buildings;
  (D) basements;
  (E) floor and storm drains;
  (F) subsurface utilities;
  (G) septic tanks and leach fields;
  (H) underground and aboveground storage tank systems;
  (I) monitoring wells;
  (J) water supply wells;
  (K) surface water bodies and other drainage features;
  (L) borings; and
  (M) the sampling points;

(6) the results from a limited site assessment that shall include the following actions:
  (A) determine the presence, the lateral and vertical extent, and the maximum concentration levels of soil and, if possible, groundwater contamination and free product accumulations;
  (B) install monitoring wells constructed in accordance with 15A NCAC 02C .0108 within the area of maximum soil or groundwater contamination to determine the groundwater flow direction and maximum concentrations of dissolved groundwater contaminants or accumulations of free product. During well construction, the responsible party shall collect and analyze soil samples that represent the suspected highest contaminant-level locations by exhibiting visible contamination or elevated levels of volatile organic compounds from successive locations at five-foot depth intervals in the boreholes of each monitoring well within the unsaturated zone; collect potentiometric data from each monitoring well; and collect and analyze groundwater or measure the amount of free product, if present, in each monitoring well;

(7) the availability of public water supplies and the identification of properties served by the public water supplies within 1500 feet of the source area of a confirmed discharge or release;

(8) the land use, including zoning if applicable, within 1500 feet of the source area of a confirmed discharge or release;

(9) a discussion of site-specific conditions or possible actions that may result in lowering the risk classification assigned to the release. Such discussion shall be based on information known or required to be obtained under this Item; and

(10) names and current addresses of all responsible parties for all petroleum sources for which a discharge or release is confirmed, the owners of the land upon which such petroleum sources are located, and all potentially affected real property owners. Documentation of ownership of ASTs or other sources and of the property upon which a source is located shall be provided.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0506 DISCHARGE OR RELEASE CLASSIFICATIONS

The Department shall classify the risk of each known discharge or release as high, intermediate, or low risk, unless the discharge or release has been classified under Rule .0504 of this Section. For purposes of this Section:

(1) "High risk" means that:
  (a) a water supply well, including one used for non-drinking purposes, has been contaminated by a release or discharge;
  (b) a water supply well used for drinking water is located within 1000 feet of the source area of a confirmed discharge or release;
  (c) a water supply well not used for drinking water is located within 250 feet of the source area of a confirmed discharge or release;
  (d) the groundwater within 500 feet of the source area of a confirmed discharge or release has the potential for future use in that there is no source of water supply other than the groundwater;

 (e) the vapors from a discharge or release pose a serious threat of explosion due to accumulation of the vapors in a confined space or pose a risk to public health from exposure; or
 (f) a discharge or release poses an imminent danger to public health, public safety, or the environment.

(2) "Intermediate risk" means that:
 (a) surface water is located within 500 feet of the source area of a confirmed discharge or release and the maximum groundwater contaminant concentration exceeds the applicable surface water quality standards and criteria found in 15A NCAC 02B .0200 by a factor of 10;
 (b) in the Coastal Plain physiographic region as designated on a map entitled "Geology of North Carolina" published by the Department in 1985, the source area of a confirmed discharge or release is located in an area in which there is recharge to an unconfined or semi-confined deeper aquifer that the Department determines is being used or may be used as a source of drinking water;
 (c) the source area of a confirmed discharge or release is within a designated wellhead protection area, as defined in 42 U.S.C. 300h-7(e);
 (d) the levels of groundwater contamination for any contaminant except ethylene dibromide, benzene, and alkane and aromatic carbon fraction classes exceed 50 percent of the solubility of the contaminant at 25 degrees Celsius or 1,000 times the groundwater standard or interim standard established in Rule .0202 of this Subchapter, whichever is lower; or
 (e) the levels of groundwater contamination for ethylene dibromide and benzene exceed 1,000 times the federal drinking water standard as referenced in 15A NCAC 18C .1518, incorporated by reference including subsequent amendments and editions and is available free of charge at http://reports.oah.state.nc.us/ncac/title 15a - environmental quality/chapter 18 - environmental health/subchapter c/15a ncac 18c .1518.pdf.

(3) "Low risk" means that:
 (a) the risk posed does not fall within the high or intermediate risk categories; or
 (b) based on review of site-specific information, limited assessment, or interim corrective actions, the discharge or release poses no significant risk to human health or the environment.

If the criteria for more than one risk category applies, the discharge or release shall be classified at the highest risk level identified in Rule .0507 of this Section.

History Note: Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0507 RECLASSIFICATION OF RISK LEVELS

(a) Each responsible party shall have the continuing obligation to notify the Department of any changes that may affect the level of risk assigned to a discharge or release by the Department if the change is known or should be known by the responsible party, including changes in zoning of real property, use of real property, or the use of groundwater that has been contaminated or is expected to be contaminated by the discharge or release.

(b) The Department shall reclassify the risk posed by a release if warranted by further information concerning the potential exposure of receptors to the discharge or release or upon receipt of new information concerning changed conditions at the site. After initial classification of the discharge or release, the Department may require limited assessment, interim corrective action, or other actions that the Department believes will result in a lower risk classification.

(c) Remediation of sites with off-site migration shall be subject to the provisions of G.S. 143-215.104AA.

(d) If the risk posed by a discharge or release is determined by the Department to be high risk, the responsible party shall comply with the assessment and cleanup requirements of Rule .0106(c), (g), and (h) of this Subchapter. The goal of a required corrective action for groundwater contamination shall be restoration to the level of the groundwater standards set forth in Rule .0202 of this Subchapter, or as closely thereto as is economically and technologically feasible. In a corrective action plan submitted pursuant to this Paragraph, natural attenuation may be used when the benefits of its use do not increase the risk to the environment and human health. If the responsible party demonstrates that natural attenuation prevents the further migration of the plume, the Department may approve a groundwater monitoring plan.

(e) If the risk posed by a discharge or release is determined by the Department to be an intermediate risk, the responsible party shall comply with the assessment requirements of Rule .0106(c) and (g) of this Subchapter. As part of the comprehensive site assessment, the responsible party shall evaluate, based on site specific conditions, whether the release poses a significant risk to human health or the environment. If the Department determines, based on the site-specific conditions, that the discharge or release does not pose a significant threat to human health or the environment, the site shall be reclassified as a low risk site. If the site is not reclassified, the responsible party shall, at the direction of the Department, submit a groundwater monitoring plan or a corrective action plan, or a combination thereof, meeting the cleanup standards of this Paragraph and containing the information required in Rule .0106(h) of this Subchapter. Discharges or releases that are classified as intermediate risk shall be remediated, at a minimum, to a cleanup level of 50 percent of the solubility of the contaminant at 25 degrees Celsius or 1,000 times the groundwater standard or interim standard established in Rule .0202 of this Subchapter, whichever is lower, for any groundwater contaminant except ethylene dibromide, benzene, and alkane and aromatic carbon fraction classes. Ethylene dibromide and benzene shall be remediated to a cleanup level of 1,000 times the federal drinking water standard as referenced in 15A NCAC 18C .1518, incorporated by reference including subsequent amendments and editions and available free of charge at http://reports.oah.state.nc.us/ncac/title 15a - environmental quality/chapter 18 - environmental health/subchapter c/15a ncac 18c .1518.pdf. Additionally, if a corrective action plan or groundwater monitoring plan is required under this Paragraph, the responsible party shall demonstrate that the groundwater cleanup levels are sufficient to prevent a violation of:

(1) the rules contained in 15A NCAC 02B;
(2) the standards contained in Rule .0202 of this Subchapter in a deep aquifer as described in Rule .0506(2)(b) of this Section; and
(3) the standards contained in Rule .0202 of this Subchapter at a location no closer than one year time of travel upgradient of a well within a designated wellhead protection area, based on travel time and the natural attenuation capacity of the subsurface materials or on a physical barrier to groundwater migration that exists or will be installed by the person making the request.

In any corrective action plan submitted pursuant to this Paragraph, natural attenuation may be used if the benefits of its use does not increase the risk to the environment and human health and shall not increase the costs of the corrective action.

(f) If the risk posed by a discharge or release is determined to be a low risk, the Department shall notify the responsible party that no cleanup, no further cleanup, or no further action is required by the Department, unless the Department later determines that the discharge or release poses an unacceptable risk or a potentially unacceptable risk to human health or the environment. No notification shall be issued pursuant to this Paragraph, however, until the responsible party has:

(1) completed soil remediation pursuant to Rule .0508 of this Section or as closely thereto as economically or technologically feasible;
(2) submitted proof of public notification, if required pursuant to Rule .0409(b) of this Section;
(3) recorded all required land-use restrictions pursuant to G.S. 143B-279.9 and 143B-279.11; and
(4) paid any applicable statutorily authorized fees.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Amended Eff. March 1, 2017;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0508 ASSESSMENT AND REMEDIATION PROCEDURES

Assessment and remediation of soil contamination shall be addressed as follows:

(1) At the time that the Department determines the risk posed by the discharge or release, the Department shall also determine, based on site-specific information, whether the site is "residential" or "industrial/commercial." For the purposes of this Section, a site is presumed residential, but may be classified as industrial/commercial if the Department determines based on site-specific information that exposure to the soil contamination is limited in time due to the use of the site and does not involve exposure to children. For the purposes of this Item, "site" means both the property upon which the discharge or release occurred and any property upon that soil has been affected by the discharge or release.
(2) For a discharge or release the responsible party shall submit a report to the Department assessing the vertical and horizontal extent of soil contamination.
(3) For a discharge or release classified by the Department as low risk, the responsible party shall submit a report demonstrating that soil contamination has been remediated to either the residential or industrial/commercial maximum soil contaminant concentration established by the Department pursuant to Rule .0511 of this Section, whichever is applicable.
(4) For a discharge or release classified by the Department as high or intermediate risk, the responsible party shall submit a report demonstrating that soil contamination has been remediated to the lower of:

(a) the residential or industrial/commercial maximum soil contaminant concentration, whichever is applicable, that has been established by the Department pursuant to Rule .0511 of this Section; or
(b) the "soil-to-groundwater" maximum soil contaminant concentration that has been established by the Department pursuant to Rule .0511 of this Section.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0509 NOTIFICATION REQUIREMENTS

(a) A responsible party who submits a corrective action plan that proposes natural attenuation, to cleanup groundwater contamination to a standard other than a standard as set forth in Rule .0202 of this Subchapter, or to cleanup soil other than to the standard for residential use or soil-to-groundwater contaminant concentration established pursuant to this Section, whichever is lowest, shall give notice to:

(1) the local Health Director and the chief administrative officer of each political jurisdiction in which the contamination occurs;
(2) all property owners and occupants within or contiguous to the area containing the contamination; and
(3) all property owners and occupants within or contiguous to the area where the contamination is expected to migrate.

The notice shall describe the nature of the plan and the reasons supporting it. Notification shall be made by certified mail concurrent with the submittal of the corrective action plan. Approval of the corrective action plan by the Department shall be postponed for a period of 30 days following receipt of the request so that the Department may receive and consider comments. The responsible party shall, within 60 days, provide the Department with a copy of the notice and proof of receipt of each required notice or of refusal by the addressee to accept delivery of a required notice. If notice by certified mail to occupants under this Paragraph is impractical, the responsible party shall give notice as provided in G.S. 1A-1, Rule 4(j) or 4(j1). If notice is made to occupants by posting, the responsible party shall provide the Department with a copy of the posted notice and a description of the manner in which such posted notice was given.

(b) A responsible party who receives a notice pursuant to Rule .0507(e) of this Section for a discharge or release that has not been remediated to the groundwater standards or interim standards established in Rule .0202 of this Subchapter or to the lower of the residential or soil-to-groundwater contaminant concentrations established under Rule .0511 of this Section, shall, within 30 days of the receipt of such notice, provide a copy of the notice to:

(1) the local Health Director and the chief administrative officer of each political jurisdiction in which the contamination occurs;
(2) all property owners and occupants within or contiguous to the area containing contamination; and
(3) all property owners and occupants within or contiguous to the area where the contamination is expected to migrate.

Notification shall be made by certified mail. The responsible party shall, within 60 days, provide the Department with proof of receipt of the copy of the notice or of refusal by the addressee to accept delivery of the copy of the notice. If notice by certified mail to occupants under this Paragraph is impractical, the responsible party shall give notice as provided in G.S. 1A-1, Rule 4(j) or 4(j1). If notice is made to occupants by posting, the responsible party shall provide the Department with a description of the manner in which such posted notice was given.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0510 DEPARTMENTAL LISTING OF DISCHARGES OR RELEASES

The Department shall maintain in each of the Department's regional offices a list of all non-UST petroleum discharges or releases discovered and reported to the Department within the region.

History Note: *Authority G.S. 143-215.3(a)(1); 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0511 ESTABLISHING MAXIMUM SOIL CONTAMINATION CONCENTRATIONS

For the purposes of risk-based assessment and remediation for non-UST petroleum releases, establishment of maximum soil contamination concentrations shall be in accordance with Rule .0411 of this Subchapter.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0512 ANALYTICAL PROCEDURES FOR SOIL SAMPLES

For the purposes of risk-based assessment and remediation for non-UST petroleum releases, analytical procedures for soil samples shall be in accordance with Rule .0412 of this Subchapter.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0513 ANALYTICAL PROCEDURES FOR GROUNDWATER SAMPLES

For the purposes of risk-based assessment and remediation for non-UST petroleum releases, analytical procedures for groundwater samples shall be in accordance with Rule .0413 of this Subchapter.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0514 REQUIRED LABORATORY CERTIFICATION

In accordance with 15A NCAC 02H .0804, laboratories shall obtain North Carolina Division of Water Resources laboratory certification for parameters that are required to be reported to the State in compliance with the State's surface water, groundwater, and pretreatment rules.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

15A NCAC 02L .0515 DISCHARGES OR RELEASES FROM OTHER SOURCES

This Section shall not relieve any person responsible for assessment or cleanup of contamination from a source other than a non-UST petroleum release from its obligation to assess and clean up contamination resulting from the discharge or releases.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.84; 143-215.104AA; 143B-282;*
Eff. March 1, 2016;
Readopted Eff. June 1, 2019.

I/A

Hart Exhibit 9
Docket No. E-2, Sub 1219

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United States
Environmental Protection
Agency

Drinking Water Health Advisory for Manganese

Drinking Water Health Advisory for Manganese

Prepared by:

U.S. Environmental Protection Agency
Office of Water (4304T)
Health and Ecological Criteria Division
Washington, DC 20460

http://www.epa.gov/safewater/

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CONTENTS

ABBREVIATIONS

ALS	Amyotrophic lateral sclerosis
CDC	Centers for Disease Control and Prevention
CJD	Creutzfeldt-Jakob Disease
g	gram
kg	kilogram
IOM	Institute of Medicine
L	liter
m^3	cubic meters
mg	milligram
mL	milliliter
mM	millimolar
Mn	manganese
min	minute
mmol	millimole
MMT	methylcyclopentadienyl manganese tricarbonyl
MND	motor neuron disease
NTP	National Toxicology Program
OST	Office of Science and Technology
OW	Office of Water
ppm	parts per million
PWS	public water system
RfD	Reference Dose
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
UCM	unregulated contaminant monitoring
µg	microgram
µmol	micromole

FOREWORD

The Drinking Water Health Advisory Program, sponsored by the Health and Ecological Criteria Division of the Office of Science and Technology (OST), Office of Water (OW), provides information on the health and organoleptic (color, taste, odor, etc.) effects of contaminants in drinking water. This Drinking Water Health Advisory contains Health Advisories as well as aesthetic properties (e.g., taste, odor, color) of manganese in drinking water.

A Drinking Water Health Advisory is not an enforceable standard for action. This Health Advisory describes nonregulatory concentrations of the contaminant in water that are expected to be without adverse effects on both health and aesthetics. Health Advisories serve as technical guidance to assist Federal, State, and local officials responsible for protecting public health when emergency spills or contamination situations occur. They are not to be construed as legally enforceable Federal standards. They are subject to change as new information becomes available. This draft supersedes any previous draft advisories for this chemical.

This Document is based, in part, on the Health Effects Support Document for Manganese (U.S. EPA, 2003a), the ATSDR's final Toxicological Profile for Manganese (ATSDR, 2000), and the Institute of Medicine's Dietary Reference Intakes for Manganese (IOM, 2002). The sections on analytical method and treatment technology are based on the Contaminant Candidate List Preliminary Regulatory Determination Support Document for Manganese (U.S. EPA, 2001).

EXECUTIVE SUMMARY

The EPA Office of Water is issuing this health advisory to provide guidance to communities that may be exposed to drinking water contaminated with high manganese (Mn) concentrations. The advisory provides guidance on the concentrations below which potential health and organoleptic problems would unlikely occur. This Drinking Water Health Advisory does not mandate a standard for action; rather it provides practical guidelines for addressing Mn contamination problems. The advisory provides an analysis of the current health hazard information and information on the organoleptic (i.e., taste and odor) associated with Mn-contaminated water, because organoleptic problems will affect consumer acceptance of water resources.

Manganese is a naturally-occurring element that can be found ubiquitously in the air, soil, and water. Manganese is an essential nutrient for humans and animals. Adverse health effects can be caused by inadequate intake or over exposure. Manganese deficiency in humans is thought to be rare because manganese is present in many common foods.

The greatest exposure to manganese is usually from food. Adults consume between 0.7 and 10.9 mg/day in the diet, with even higher intakes being associated with vegetarian diets (Freeland-Graves et al., 1987; Greger, 1999; Schroeder et al., 1966).

Manganese intake from drinking water is normally substantially lower than intake from food. At the median drinking-water level of 10 µg/L determined in the National Inorganic and Radionuclide Survey (NIRS), the intake of manganese from drinking water would be 20 µg/day for an adult, assuming a daily water intake of 2 L. Exposure to manganese from air is generally several orders of magnitude less than that from the diet, typically around 0.04 ng/day on average (U.S. EPA, 1990), although this can vary substantially depending on proximity to a manganese source.

Although manganese is an essential nutrient at low doses, chronic exposure to high doses may be harmful. The health effects from over-exposure of manganese are dependent on the route of exposure, the chemical form, the age at exposure, and an individual's nutritional status. Regardless, the nervous system has been determined to be the primary target organ with neurological effects generally observed. Many of the reports of adverse effects from manganese exposures in humans are from inhalation exposures in occupational settings.

Although there are substantial data supporting the neurological effects of *inhaled* manganese in both humans and animals, there are few data for the association between *oral* exposure to manganese and toxic effects. For example, several epidemiological studies (Kondakis et al., 1989; He et al., 1994) associate adverse neurological effects with exposure to manganese from drinking water; however, due to a lack of qualitative and quantitative details of the exposure scenario, these studies cannot be used for quantitative assessment. On the other hand, rodents do not provide a good experimental model for manganese neurotoxicity. Therefore, the assessment in this document focuses more on what is believed to be a safe oral intake of manganese for the general human population. Finally, it is important to emphasize that individual requirements for, as well as adverse reactions to, manganese may be highly variable. The lifetime health advisory derived from the reference dose is estimated to be an intake for the general population that is not associated with adverse health effects; this is not meant to imply that intakes above the reference dose are necessarily associated with toxicity. Some individuals may, in fact, consume a diet that contributes more than 10 mg Mn/day without any cause for concern.

There were no studies found that reported exposure to elevated inorganic manganese with cancer in humans. Cancer studies in animals have provided equivocal results. Therefore, there are little data to suggest that inorganic manganese is carcinogenic.

As an element, manganese cannot go through metabolic transformation, but it can exist in many oxidative states and can be converted from one oxidative state to another within the body. Manganese is almost entirely excreted in the feces, only a small proportion being eliminated in the urine (Davis and Greger, 1992). Fecal manganese is comprised of unabsorbed dietary manganese and manganese excreted in bile.

Groups possibly sensitive to manganese would be those who absorb greater amounts of manganese or those who excrete less. These would include the very young (who may absorb more and excrete less), the elderly, and those with liver disease (with impaired biliary excretion).

In order to enhance consumer acceptance of water resources, this advisory recommends reducing manganese concentrations to or below 0.050 mg/L, the EPA’s Secondary Maximum Contaminant Level (SMCL) for Mn. The SMCL is based on staining and taste considerations. It is not a federally enforceable regulation, but is intended as a guideline for States. States may establish higher or lower levels depending on the local conditions, such as unavailability of alternate water sources or other compelling factors, provided that public health and welfare are not adversely affected. The lifetime health advisory value of 0.3 mg/L will protect against concerns of potential neurological effects. In addition, this document provides a One-day and 10-day HA of 1 mg/L for acute exposure. However, it is advised that for infants younger than 6 months, the lifetime HA of 0.3 mg/L be used even for an acute exposure of 10 days, because of the concerns for differences in manganese content in human milk and formula and the possibility of a higher absorption and lower excretion in young infants.

1.0 INTRODUCTION

Manganese is a naturally-occurring element that can be found ubiquitously in the air, soil, and water. Manganese is also an essential nutrient for humans and animals (Leach and Harris, 1997; U.S. EPA, 2003a). Adverse health effects can be caused by inadequate intake or over exposure (See a review by Keen et al., 1999 and Keen et al., 2000). The main exposure of humans to manganese is from ingestion of food. Manganese deficiency in humans appears to be rare because manganese is present in many common foods. Manganese is essential to the proper functioning of both humans and other animals as it is required by many cellular enzymes (e.g., manganese superoxide dismutase, pyruvate carboxylase) and can serve to activate many others (e.g., kinases, decarboxylases, transferases, hydrolases, etc.; Hurley et al., 1984; Wedler, 1994; WHO, 2002).

Although manganese is an essential nutrient at low doses, chronic exposure to high doses may be harmful. There are substantial data supporting the neurological effects of *inhaled* manganese in both humans and animals, however, there are little data for the association between *oral* exposure to manganese and toxic effects.

There is a need for EPA to issue a health advisory to provide guidance to communities on the concentrations for avoiding health and organoleptic problems. This Drinking Water Health Advisory does not mandate a standard for action; rather it provides practical guidelines for addressing Mn contamination problems. The advisory provides an analysis of the current health hazard and organoleptic (i.e., taste and odor) information associated with Mn-contaminated water, because organoleptic problems will affect consumer acceptance of water resources.

Uses

Manganese is used principally in the manufacture of iron and steel alloys, manganese compounds, and as an ingredient in various products (ATSDR, 2000; IPCS, 1999). Manganese dioxide and other manganese compounds are used in products such as batteries, glass, and fireworks. Potassium permanganate is used as an oxidant for cleaning, bleaching, and disinfection purposes (ATSDR, 2000; HSDB, 2001). Potassium and manganese greensands are used in some locations for potable water treatment (ATSDR, 2000). Methylcyclopentadienyl manganese tricarbonyl (MMT), an organic manganese compound, is used as an octane-enhancing agent in unleaded gasoline in Canada, the United States, Europe, Asia, and South America (Lynam et al., 1999). Other manganese compounds are used in fertilizers, varnish, fungicides, and as livestock feeding supplements (HSDB, 2001).

2.0 MANGANESE IN THE ENVIRONMENT

Manganese is one of the most abundant metals on the earth's surface, making up approximately 0.1% of the earth’s crust. Manganese is not found naturally in its pure (elemental) form, but is a component of over 100 minerals (ATSDR, 2000).

2.1 Water

Manganese is naturally occurring in many surface and ground water sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas.

Ambient manganese concentrations in sea water have been reported to range from 0.4 to 10 :g/L (ATSDR, 2000), with an average of about 2 :g/L (Barceloux, 1999). Levels in freshwater typically range from 1 to 200 :g/L (Barceloux, 1999). ATSDR reported that a U.S. river water survey found dissolved manganese levels of less than 11 to more than 51 :g/L (ATSDR, 2000). The United States Geological Survey's National Ambient Water Quality Assessment (NAWQA) has gathered limited data since 1991 on representative study basins around the U.S. This report indicates a median manganese level of 16 :g/L in surface waters, with 99th percentile concentrations of 400 to 800 :g/L (Leahy and Thompson, 1994; USGS, 2001). Higher levels in aerobic waters are usually associated with industrial pollution.

Overall, the detection frequency of manganese in U.S. ground water is high (approximately 70% of sites assayed have measurable manganese levels) due to the ubiquity of manganese in soil and rock, but the levels detected in ground water are generally below levels of public health concern (U.S. EPA 2003a). Similarly, manganese is detected in about 97% of surface water sites (at levels far below those likely to cause health effects) and universally in sediments and aquatic biota tissues (at levels which suggest that it does not bioaccumulate; U.S. EPA 2003a).

Between 1984 and 1986, the National Inorganic and Radionuclide Survey (NIRS) collected data from 989 U.S. community public water systems (PWSs) served by ground water in 49 states and found that 68% of the ground water PWSs reported detectable levels of manganese, with a median concentration of 10 :g/L. Supplemental survey data from PWSs supplied by surface waters in five states reported occurrence ranges similar to those of ground water PWSs.

2.2 Soil

Manganese constitutes approximately 0.1% of the earth's crust, and is a naturally occurring component of nearly all soils (ATSDR, 2000). Natural levels of manganese range from less than 2 to 7,000 ppm, with a geometric mean concentration of 330 ppm (Shacklette and Boerngen, 1984). The estimated arithmetic mean concentration is 550 ppm. Accumulation of manganese occurs in the subsoil rather than on the soil surface (ATSDR, 2000). An estimated 60–90% of soil manganese is associated with the sand fraction (WHO, 1981, as cited in ATSDR, 2000).

No published reports quantify exposure to manganese associated with soil ingestion. Assuming a concentration range of < 2 to 7,000 mg/kg soil and average ingestion of 50 mg soil/day, the average manganese intake of a 70-kg adult would be <0.0014 to 5 :g/kg-day. The corresponding intake for a 10-kg child consuming 100 mg of soil/day would be <0.02 to 70 :g/kg-day (U.S. EPA, 2003a).

2.3 Air

Air levels of manganese compounds vary widely depending on the proximity of point sources such as ferroalloy production facilities, coke ovens, or power plants. Average ambient levels near industrial sources have been reported to range from 220 to 300 nanograms of manganese per cubic meter (ng Mn/m^3), while levels in urban and rural areas without point sources have been reported to range from 10 to 70 ng Mn/m^3 (Barceloux, 1999). Existing data indicate that little difference is found between ambient manganese levels in areas where MMT is used in the gasoline and areas where MMT is not used (Lynam et al., 1999). The U.S. EPA estimated 40 ng Mn/m^3 as an average annual background concentration in urban areas based on measurements in 102 U.S. cities (U.S. EPA, 1990).

2.4 Food

Manganese is found in a variety of foods including many nuts, grains, fruits, legumes, tea, leafy vegetables, infant formulas, and some meat and fish. Food is the most important source of manganese exposure in the general population (ATSDR, 2000; IOM, 2002; U.S. EPA, 2003a).

Heavy tea drinkers may have a higher manganese intake than the general population. An average cup of tea may contain 0.4 to 1.3 mg manganese (ATSDR, 2000). In addition to dietary sources, approximately 12% of the adult population of the U.S. consumed manganese supplements in 1986 (Moss et al., 1989). The median amount of manganese in these dietary supplements was determined to be 2.4 mg/day, similar to the amount of the element consumed in the diet (based on survey information from the Third National Health and Nutrition Estimation Survey; IOM, 2002).

Freeland-Graves et al. (1987) have suggested a daily intake range of 3.5 to 7 mg Mn/day for adults based on a review of human studies. After reviewing dietary surveys, Greger (1999) presented a range for average intakes from adult Western and vegetarian diets of 0.7 to 10.9 mg Mn/day.

Infant formulas contain 50 to 300 μg/L manganese (Collipp et al., 1983), compared to human milk which contains approximately 3.5 to 15 μg/L manganese (ATSDR, 2000; U.S. EPA, 1997). Assuming an intake of 742 millilitres (mL) of breast milk/day (U.S. EPA, 1996a), a breast-fed infant would have an estimated daily manganese intake of 2.6 to 11.1 μg/day. An infant consuming the same volume of infant formula would have an estimated daily manganese intake of 37.1 to 223 μg/day. Assuming an average weight of 6 kg for an infant of age 6 months, the weight-adjusted average daily intake would range from 0.4 to 1.85 μg/kg-day for breast-fed infants. The corresponding weight-adjusted intake for a formula-fed infant would be 6.2 to 37.2 μg/kg-day. Given the high manganese content of milk-based formula, the underexposure of infants to manganese appears less probable than their overexposure (Davidsson et al., 1989a; Dörner et al., 1987; Keen et al., 1986). Once solid foods are introduced, however, the contribution of manganese intake from milk becomes less significant.

In addition to concentration, an important consideration for determining human exposure to manganese from food is bioavailability (Kies, 1994). Several factors can influence the degree to which manganese in foods is absorbed following ingestion. These include intake of dietary fiber, oxalic acids, tannins, and phytic acids, which tend to decrease manganese absorption (Gibson, 1994; U.S. EPA, 2003a), as well as possibly sex-specific iron status (low iron can result in increased manganese absorption; Finley, 1999 while high levels of iron can inhibit manganese uptake). In addition, the status of the GI tract (e.g., the presence of material in the GI tract - fed vs fasted) also affects bioavailability.

Manganese Intake

Adequate Intake (AI) values have been determined for manganese by the Food and Nutrition Board of the Institute of Medicine as follows: 3 :g/day for infants 0-6 months, 0.6 mg/day for infants 7-12 months, 1.2 mg/day for children 1-3 years, 1.5 mg/day for children 4-8 years, 1.9 mg/day for boys 9-13 years, 2.2 mg/day for boys 14-18 years, 1.6 mg/day for girls 9-18 years, 2.3 mg/day for men 19 years or older, 1.8 mg/day for women 19 years or older, 2 mg/day during pregnancy, and 2.6 mg/day during lactation (IOM, 2002).

Adequate Manganese Intakes for Men, Women and Children

Age Group	Males	Females
Infants, 0-6 months	3 :g/day	3 :g/day
Infants, 7-12 months	0.6 mg/day	0.6 mg/day
Children, 1-3 years	1.2 mg/day	1.2 mg/day
Children, 4-8 years	1.5 mg/day	1.5 mg/day
Boys, 9-13 years	1.9 mg/day	--
Boys, 14-18 years	2.2 mg/day	--
Girls, 9-18 years	--	1.6 mg/day
Adults, $19 years	2.3 mg/day	1.8 mg/day
Women, pregnant (lactating)	--	2 mg/day (2.6 mg/day)

According to IOM, the AI for infants (newborn to 6 months) was set based on "an average manganese concentration of 0.0035 mg/L in human milk" and an average milk consumption of 0.78 L/day. As indicated previously, the manganese concentration in human milk varies. For example, ATSDR (2000) listed a manganese concentration in human milk ranging from 0.003 to 0.01 mg/L, and U.S. EPA (1997), from 0.007 to 0.015 mg/L. Assuming an intake of 0.78 liters milk per day, an infant (0 to 6 months) would ingest 0.003 to 0.012 mg Mn/day from human milk (using the minimum and maximum values in the two concentration ranges); the AI set by the IOM (i.e., 0.003 mg/day) is at the lower end of this range.

Tolerable Upper Intake

The IOM (2002) also set a tolerable upper intake level of 11 mg/day for adults, based on a recent review (Greger, 1999) which stated that the average manganese intake for adults eating typical Western and vegetarian diets in various surveys ranged from 0.7 to 10.9 mg Mn/day. Davis and Greger (1992) reported that women given daily supplements of 15 mg manganese (as an amino acid-chelated manganese supplement) for 90 days experienced no effects other than a significant increase in lymphocyte manganese-dependent superoxide dismutase, a "biomarker" that increases in direct relation to manganese exposure (Greger 1998, 1999). There are insufficient data to set tolerable upper intakes for infants or children.

2.5 Environmental Fate

Manganese compounds may be present in the atmosphere as suspended particulates resulting from industrial emissions, soil erosion, volcanic emissions, application of manganese-containing pesticides, and the burning of MMT-containing gasoline (IPCS, 1999). Early analysis of emissions suggested that manganese from combustion of MMT is emitted primarily as manganese tetroxide (Mn_3O_4; Ter Haar et al., 1975, as cited in ATSDR, 2000). However, more recent testing suggests that when very low levels of MMT are combusted (i.e., concentrations comparable to the currently allowed levels), manganese is emitted primarily as manganese phosphate and sulfate. The reported formal charge of the emitted manganese is +2.2, with a mass median aerodynamic diameter of 1 to 2 microns (Ethyl Corporation, 1997, as cited in Lynam et al., 1999). Uncombusted MMT rapidly decomposes to manganese oxide, carbon dioxide, and organic compounds in the atmosphere and has a half-life of only a few seconds in the presence of sunlight (Lynam et al., 1999; Zayed et al., 1999). Because particle size is small, atmospheric manganese distribution can be widespread. These particles will eventually settle out into surface waters or onto soils via the process of dry deposition. Little information is available on the chemical reactions of atmospheric manganese, but it is expected to react with sulfur and nitrogen dioxide. The half-life of manganese in air is only a few days (ATSDR, 2000).

The primary sources for surface and ground water releases are industrial facility effluent discharge, landfill and soil leaching, and underground injection. Manganese, in the form of potassium permanganate, may be used in drinking water treatment to oxidize and remove iron, manganese, and other contaminants (ANSI/NSF, 2000). Transport and partitioning of manganese in water is dependent on the solubility of the manganese form. In surface waters, manganese occurs in both dissolved and suspended forms, depending on such factors as pH, anions present, and oxidation-reduction potential (ATSDR, 2000). Often, manganese in water will settle into suspended sediments. Anaerobic groundwater often contains elevated levels of dissolved manganese. The divalent form (Mn^{2+}) predominates in most water at pH 4–7, but more highly oxidized forms may occur at higher pH values or result from microbial oxidation (ATSDR, 2000). It can bioaccumulate in lower organisms (e.g., phytoplankton, algae, mollusks, and some fish), but not in higher organisms, and biomagnification in food-chains is not expected to be significant (ATSDR, 2000). Little information is available on the biodegradation of manganese-containing compounds in water, but factors such as pH and temperature are important for microbial activities.

Approximately 91% of environmental manganese is released to soil. The main source of this release is land disposal of manganese-containing wastes. The ability of manganese compounds to adsorb to soils and sediments is contingent upon the cation exchange capacity and organic content of the soil or sediment. Adsorption can vary widely based on differences in these two factors. Oxidative microbial activity may increase the precipitation of manganese minerals and increase the dissolution of manganese in subsurface environments.

2.6 Summary

The greatest exposure to manganese is usually from food. Adults consume between 0.7 and 10.9 mg/day in the diet, with even higher intakes being associated with vegetarian diets (Freeland-Graves et al., 1987; Greger, 1999.; Schroeder et al., 1966) or the consumption of large amounts of tea.

Manganese intake from drinking water is normally substantially lower than intake from food. At the median drinking-water level of 10 μg/L determined in the National Inorganic and Radionuclide Survey (NIRS), the intake of manganese would be 20 μg/day for an adult, assuming a daily water intake of 2 L. Exposure to manganese from air is generally several orders of magnitude less than that from the diet, typically around 0.04 ng/day on average (U.S. EPA, 1990), although this can vary substantially depending on proximity to a manganese source.

3.0 CHEMICAL AND PHYSICAL PROPERTIES

Manganese can exist in multiple oxidative states; the most environmentally and biologically important manganese compounds are those that contain Mn^{2+}, Mn^{4+}, and Mn^{7+} (U.S. EPA, 1994). The physical and chemical properties of different manganese compounds vary substantially, as demonstrated in Table 1 on the next page.

ORGANOLEPTIC PROPERTIES

At concentrations exceeding 0.1 milligrams per litre (mg/L), the manganese ion imparts an undesirable taste to beverages and stains plumbing fixtures and laundry (Griffin, 1960). When manganese (II) compounds in solution undergo oxidation, manganese precipitates, resulting in encrustation problems. At concentrations as low as 0.02 mg/L, manganese can form coatings on water pipes that may later slough off as a black precipitate (Bean, 1974). The U. S. and a number of other countries have set secondary standards of 0.05 mg/L for manganese. This is an aesthetic level above which problems with discoloration may occur.

Table 1.
Chemical and Physical Properties of Manganese and Common Manganese Compounds

	Mn	$MnC1_2$	Mn_3O_4	MnO_2	$KMnO_4$
CAS No.	7439-96-5	2145-07-3	1317-35-7	479-93-7	7722-64-7
Valance	0	+2	+2 and +3	+4	+7
Molecular Weight	54.9	125.8	228.8	86.9	158
Synonyms	Elemental manganese	Manganese dichloride; Manganese chloride; Manganese (II) chloride	Manganese oxide; Manganese (II,III) oxide; Manganese tertoxide	Manganese dioxide; Black dioxide; Cement black; Manganese peroxide; Manganese (IV) oxide	Potassium permanganate; permanganic acid, potassium salt
Physical State (25°C)	Solid	Solid	Solid	Solid	Solid
Boiling Point (°C)	1962	1190	—	—	—
Melting Point (°C)	1244	650	1564	535 (loses oxygen)	240
Density (g/cm^3)	7.4	2.98	4.86	5.026	2.703
Vapor Pressure (20°C)	1.9	—	—	—	—
Water Solubility (g/100 mL)	Decomposes	723 (25°C)	insoluble	insoluble	63.8 (20°C)
Log Octanol/Water Partition – Coefficient (Log K_{ow})	—	—	—	—	—
Taste Threshold	—	—	—	—	—
Odor Threshold (air)	—	—	—	—	—
Conversion Factor	—	—	—	—	—

— No date available.

4.0 TOXICOKINETICS

The absorption, distribution, metabolism and excretion of manganese in the body are reviewed, discussed, and summarized in Greger (1999), Kies (1994), U.S. EPA (1984; 1993; 2003a), and ATSDR (2000). Age, chemical species, dose, route of exposure, and dietary conditions all affect manganese absorption and retention (Lönnerdal et al., 1987). Uptake of dietary manganese appears to be influenced by several dose-dependent processes: biliary excretion, intestinal absorption, and intestinal elimination.

4.1 Absorption

Manganese speciation and the route of exposure affects its absorption (Andersen et al., 1999; Tjälve et al., 1996). Thomson et al. (1971) and Gibbons et al. (1976) reported that the divalent form of manganese is absorbed most efficiently. However, as Bales et al. (1987) reported, the efficiency of absorption also varies for different manganese salts with manganese chloride more efficiently absorbed than the sulfate or acetate salts. Recent studies show that significant differences exist in the amounts of manganese that are absorbed across different exposure routes, with inhaled manganese being absorbed more rapidly and to a greater extent than ingested manganese (Roels et al., 1997; Tjälve et al., 1996). Very little manganese is absorbed through the skin. Absorption of manganese via inhalation, intratracheal instillation, or intravenous infusion bypasses the control processes of the gastrointestinal tract. Absorption from inhalation exposure is mainly a function of particle size with smaller particles reaching the lower airways where they can be absorbed and larger particles deposited in the upper airways where they are subject to possible mucociliary transport to the throat followed by entrance into the gastrointestinal tract.

From animal experiments, it is known that inhaled manganese (even the insoluble MnO_2) is transported in a retrograde direction from the olfactory epithelium to the striatum of the brain (Gianutsos et al., 1997; Roels et al., 1997). During its uptake through the olfactory nerve endings (Bench et al., 2001; Brenneman et al., 2000; Tjälve et al., 1996; Vitarella et al., 2000) it may damage the astrocytes (Henriksson and Tjälve, 2000). After peroral uptake, manganese, like all other metals, is filtered from the blood by the choroid plexus (Ingersoll et al., 1995; Zheng et al., 1991). The retrograde transport of manganese through the olfactory epithelium directly into certain regions of the central nervous system or the brain could explain why the safe dose following inhalation exposure is much lower than after oral ingestion (Wang et al., 1989). The following sections discuss absorption of manganese following oral exposure only.

Absorption of manganese across the gastrointestinal tract is regulated by normal physiological processes to help maintain manganese homeostasis. Manganese absorbed in the divalent form from the gut via the portal blood is complexed with plasma proteins that are efficiently removed by the liver. A 7-week study in which 7 adult males ingested high- fiber diets containing 12.0 to 17.7 mg Mn/day (0.17 to 0.25 mg/kg-day) found that an average of 7.7% $\pm$ 6.3% of the manganese was absorbed during weeks 5 to 7, with no measurable net retention of manganese (Schwartz et al., 1986). Similarly, an average absorption of 8.4% $\pm$ 4.7% was observed in 7 adults ingesting infant formula containing manganese (Sandström et al., 1986).

Manganese retention may be greater for young animals and infants (Keen et al., 1986) due to the fact that the biliary system, the primary route of excretion, is not completely developed in human infants (Lönnerdal, 1994). Keen et al. (1986) demonstrated a strong effect of age on intestinal manganese uptake and retention. Sprague-Dawley rat pups were fasted overnight and then intubated with 0.5 mL of human milk containing 0.005 mg ^{54}Mn/mL. Manganese retention was highest ($\geq$ 80%) in pups less than 15 days old. In older pups (16-19 days old), the average retention was 40%. Lönnerdal et al. (1987) showed that manganese uptake from brush border membranes was higher in 14-day-old rats than in 18-day-old rats. Although Rehnberg et al. (1985) found that younger animals had a slower distal intestinal transit time than older animals (potentially contributing to a higher proportional uptake), Bell et al. (1989) showed that the uptake rate was similar in pre- and post-weanling animals, suggesting that age-dependent differences in manganese retention were not due to immature intestinal transport mechanisms. Fechter (1999) determined that neonatal mice are unable to maintain manganese homeostasis until 17-18 days of age. When considered together, these data indicate that human infants, at certain ages, may not have developed the capacity to completely excrete manganese following ingestion.

Davidsson et al. (1989b) studied whole-body retention of ^{54}Mn in adult humans after intake of radiolabeled infant formula. These authors observed reproducible retention figures at day 10, after repeated administrations of the labeled formula to six subjects. Absorption ranged from 0.8-16%, with a mean value of 5.9 ± 4.8%. This range corresponds to a 20-fold difference between the highest and lowest values. Retention at day 10 ranged from 0.6-9.2%, with a mean value of 2.9 ± 1.8%, when measured in 14 healthy individuals. These results suggest substantial variation in absorption between individuals.

The absorption of manganese is closely linked to iron absorption; iron-deficient diets lead to an increased absorption of both iron and manganese (Finley, 1999; Sandström et al., 1986; Thomson et al., 1971). Rehnberg et al. (1982) administered dietary Mn_3O_4 (450, 1,150, or 4,000 ppm Mn) to young rats. These authors amended the basal diets with varying levels of iron, and demonstrated that iron deficiency promoted the intestinal absorption of manganese. Conversely, manganese absorption was inhibited by large amounts of dietary iron. Absorption is also related inversely to the level of calcium in the diet (Lutz et al., 1993; McDermott and Kies, 1987; Kies, 1994; Schroeder et al., 1966). Johnson et al. (1991) studied the absorption of radiolabeled manganese from various plant foods in adult men and women and reported that the absorption values ranged from 1.4 to 5.5% and were significantly lower than the mean values of 7.8 to 10.2% from controls ($MnC1_2$ dissolved in water). Certain constituents of tea, such as tannins, can result in reduced manganese absorption (Freeland-Graves and Llanes, 1994). Other factors can also influence the degree to which manganese in foods is absorbed upon ingestion. These include intake of dietary fiber, oxalic acids, and phytic acids as well as contents in the gut, which tend to decrease manganese absorption (Gibson, 1994; U.S. EPA, 2003a).

4.2 Distribution

Manganese is present in all tissues of the body, the highest levels usually being found in the liver, kidney, pancreas, and adrenals (Sumino et al., 1975; Tipton and Cook, 1963). Intermediate concentrations occur in the brain, heart and lungs (ATSDR, 2000), with accumulations preferential in certain regions of the brain in infants and young animals (Kontur and Fechter, 1988; Zlotkin and Buchanan, 1986). The lowest concentrations of manganese are observed in bone and fat. Some data suggest that tissues rich in mitochondria (for example, liver, kidney, and pancreas) contain higher levels of manganese (Kato, 1963; Maynard and Cotzias, 1955).

After absorption into the blood system by routes other than the gastrointestinal tract, manganese is apparently oxidized, and the trivalent manganese binds to transferrin. Transferrin-bound trivalent manganese is not as readily removed by the liver, as are protein complexes with divalent manganese. Thus, manganese delivered by routes other than the gastrointestinal tract would be available for uptake into tissues for a longer period of time than the orally administered manganese, leading to quantitative differences in tissue uptake (Andersen et al., 1999).

Factors that may alter tissue distribution include co-exposure to other metals (Shukla and Chandra, 1987) and the chemical form (Gianutsos et al., 1985). Age may also be a factor. Animal studies have shown that manganese crosses the blood-brain barrier in neonates at a rate four times higher than that in adults (Mena, 1974).

4.3 Metabolism

As a metallic element, manganese does not undergo metabolic conversion to other products. However, manganese has the potential to exist in several oxidation states in biological systems. Circumstantial evidence from the study of manganese-containing enzymes and from electron spin trapping experiments suggests that manganese undergoes conversion from Mn(II) to Mn(III) within the body (ATSDR, 2000). The conversion from Mn(II) to Mn(III) appears to be catalyzed by the "-globulin protein ceruloplasmin (Andersen et al., 1999).

A small fraction of absorbed manganese is present as the free ion. However, manganese readily forms complexes with a variety of organic and inorganic ligands. The complexes formed include 1) low molecular weight complexes with bicarbonate, citrate or other ligands; 2) an exchangeable complex with albumin; and 3) tightly bound complexes with proteins such as transferrin and "$_2$-macroglobulin. In addition, manganese can assume a structural role in metalloproteins such as mitochondrial superoxide dismutase, pyruvate decarboxylase, and liver arginase. Manganese also plays a catalytic or regulatory role in enzymatic reactions involving select hydrolases, dehydrogenases, kinases, decarboxylases and transferases.

4.4 Excretion

Manganese is almost entirely eliminated in the feces, with only a small proportion (0.1-2%) being excreted in the urine (Davis and Greger, 1992). Fecal manganese is comprised of unabsorbed dietary manganese plus manganese excreted in bile. In humans, elimination is biphasic, with half-lives of 13 and 37 days (Davidsson et al., 1989b; Sandström et al., 1986). Sweat, hair and the milk of lactating mothers also contribute to excretion (Roels et al., 1992).

5.0 HEALTH EFFECTS DATA

Manganese is an essential element for many living organisms, including humans. It is necessary for proper functioning of some enzymes (manganese superoxide dismutase) and for the activation of others (kinases, decarboxylases, etc). Adverse health effects can be caused by inadequate intake or over exposure. Manganese deficiency in humans appears to be rare because manganese is present in many common foods. Animals experimentally maintained on manganese-deficient diets exhibit impaired growth, skeletal abnormalities, reproductive deficits, ataxia of the newborn, and defects in lipid and carbohydrate metabolism (Keen et al., 1999; Hurley and Keen, 1987; U.S. EPA, 1984).

The health effects from over-exposure of manganese are dependent on the route of exposure, the chemical form, the age at exposure, and an individual's nutritional status.

Irrespective of the exposure route, the nervous system has been determined to be the primary target with neurological effects generally observed.

5.1 Human Studies

Humans are exposed to inorganic manganese compounds in food and water, but there are few reports of adverse effects in humans from ingesting excess manganese. Most human studies reporting adverse effects are of inhalation exposure. There is conclusive evidence from occupational studies in humans that inhalation exposure to high levels of manganese compounds can lead to a disabling syndrome of neurological effects referred to as "manganism." Although it is typical for symptoms to occur after several years of exposure, some individuals may begin to show signs after 1-3 months of exposure (Rodier, 1955).

5.1.1 Short-term Exposure Studies

Neurological

Kawamura et al. (1941) reported health effects resulting from the ingestion of manganese-contaminated well water for an estimated 2-3 months by 25 individuals. The source of contamination was identified as leachate from approximately 400 dry cell batteries buried near the drinking water well. The concentration of manganese in the well water was analyzed 7 weeks after the first case appeared and was determined at that time to be ~14 mg Mn/L (as Mn_3O_4). However, when re-analyzed 1 month later, the levels were decreased about half. Therefore, the actual exposure was probably to drinking water containing ~28 mg Mn/L or higher. Assuming a daily water intake of 2 L, with a minimum of 2 mg Mn from food, a dose of at least 58 mg Mn/day is estimated. This exposure level is quite uncertain and it is estimated that it is around 25-30 times the level considered to be safe and adequate by the Food and Nutrition Board of the Institute of Medicine (IOM, 2002).

Health effects reported by Kawamura et al. (1941) included lethargy, increased muscle tonus, tremor and mental disturbances. Out of 25 people examined, 15 had symptoms. Five cases were considered severe, 2 cases were categorized as moderate, and 8 cases were described as mild. The most severe symptoms were observed in the elderly. Younger people were less affected, and symptoms of intoxication were completely absent in young children (age 1 to 6 years). Three deaths occurred, including one from suicide. Upon autopsy, the concentration of manganese in the brain of one person was found to be 2 to 3 times higher than concentrations measured in two unexposed individuals (controls). Extreme macroscopic and microscopic changes were seen in the brain tissue, especially in the globus pallidus. Although there were also elevated levels of zinc in the well water, the authors concluded that the zinc appeared to have no relation to the observed symptoms or tissue pathology. This conclusion was largely based on the observation of morphological changes in the corpus striatum, which are characteristic of manganese poisoning, but are not a feature of zinc poisoning.

While toxicity in the Kawamura et al. (1941) study is attributed to manganese, several aspects of the observed health effects are inconsistent with traits of manganism observed in humans following chronic inhalation exposure. Inconsistencies include the rapid onset of symptoms and rapid progression of the disease. Two adults who came to tend the members of one family developed symptoms within 2 to 3 weeks. The course of the disease was very rapid, progressing in one case from initial symptoms to death in 3 days. Some survivors recovered prior to significant decreases in the manganese concentration of the well water which resulted when the dry-cell batteries were removed from the site. This pattern contrasts with the longer latency period and irreversible damage caused by inhalation exposure to manganese (as observed in several occupational exposure studies; ATSDR, 2000). These observations may represent differences in the pharmacokinetics of ingested versus inhaled manganese, but there is little information to support this conclusion. Although the individuals in the Kawamura et al. (1941) study were clearly exposed to high levels of manganese, it is possible that additional factors contributed to the observed effects (ATSDR, 2000; U.S. EPA, 1993).

Symptoms resembling Parkinson's disease have also been noted in an individual who ingested 1.8 mg/kg-day potassium permanganate for 4 weeks (Bleich et al., 1999; Holzgraefe et al., 1986). The symptoms occurred 9 months after the exposure.

5.1.2 Long-term Exposure Studies

Neurological

The neurological effects of inhaled manganese have been well documented in humans chronically exposed to elevated levels in the workplace (ATSDR, 2000; Canavan et al., 1934; Cook et al., 1974; Roels et al., 1999). The syndrome known as “manganism” is caused by exposure to very high levels of manganese dusts or fumes and is characterized by a “Parkinson-like syndrome” including weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless “mask-like” facial expression, and slow clumsy movement of the limbs. In general, these effects are irreversible. Some motor functions may already be affected following chronic exposure to levels of manganese $\leq$ 1 mg/m^3 (if the inhaled manganese is respirable), but individuals in these situations have not shown the overt, clinical symptoms of those exposed to much higher levels (Mergler et al., 1994; Roels et al., 1992).

By the oral route, manganese is often regarded as one of the least toxic elements, although there is some controversy as to whether the neurological effects observed with inhalation exposure also occur with oral exposure. Several case reports of oral exposure to high doses of manganese have described neurological impairment as an effect, but the quantitative and qualitative details of exposure necessary to establish direct causation are lacking. An individual who took large mineral supplements over several years displayed symptoms of manganism (Banta and Markesbery, 1977).

An epidemiological study was conducted in Greece to investigate the possible correlation between long-term (i.e., more than 10 years) manganese exposure from drinking water and neurological effects in elderly people (Kondakis et al., 1989). The levels of manganese in the drinking-water of 3 different geographical areas were 3.6-14.6 :g/L in the control area and 81-253 :g/L and 1800-2300 :g/L in the manganese-containing areas. The total population in the three areas being studied range from 3200 to 4350 people. The study included only individuals over the age of fifty drawn from a random sample of 10% of all households. The number of subjects sampled were 62, 49, and 77 for control, low-, and high-exposed groups. The authors performed a neurological examination of the subjects (weakness/fatigue, gait disturbances, tremors, dystonia, etc.) and expressed the results as composite scores. They found no differences in the manganese content in the blood, but a statistically-significant difference in both the manganese content in the hair and composite neurological scores between the high-exposed area (concentrations 1800-2300 : g/L) and the control area, suggesting neurological impairment in the high exposed area. The investigators estimated a dietary intake of 5-6 mg/day (personal communication), but data were not provided. Because of the uncertainty in the amount of manganese in the diet, and possible exposure from other sources such as dust, and little information on nutritional status and other possible confounding variables, it is difficult to estimate the total exposure to manganese.

The incidence of motor neuron disease (MND) in a small Japanese town was positively correlated with a significantly increased manganese concentration in local rice and a low magnesium concentration in the drinking-water (Iwami et al., 1994). The study did not provide good estimates of overall exposure to manganese in either the control population or the population with MND; therefore, development of the disease could not be conclusively attributed to manganese exposure. The simultaneous exposure to manganese and the deficiency of other essential minerals was possibly the reason for the enhanced incidence of neurotoxicological symptoms found in this study in Japan and in another population in Guam (Florence and Stauber, 1989; Yoshida et al., 1988).

There was also some speculation on a link between mineral deficiency, enhanced oral manganese uptake and Mn-catalyzed denaturation of copper-free prion protein to the pathogenic prion protein (Brown et al., 2000), which might explain the enhanced occurrence of some prion diseases in certain world regions (Purdey, 2000).

Goldsmith et al. (1990) investigated a Parkinson's disease cluster within southern Israel in which the prevalence of the disease was increased among persons 50 to 59 years old, suggesting an early onset. Well water and soils in the region reportedly contained high levels of manganese, although no quantitative data were provided. In addition, the manganese-containing fungicide Maneb was commonly used in the area. Several factors limit the use of this study for evaluation of the human health effects of excess manganese exposure. Lack of environmental concentration data prevent reliable estimation of exposure rates. Potentially confounding factors include the high levels of aluminum, iron, and other metals in the soil and water, and the use of the herbicide paraquat in the area (ATSDR, 2000). Paraquat is structurally related to N-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP), which causes irreversible symptoms of parkinsonism in humans.

Contrary to the above studies, another long-term drinking-water study in a rural northern area of Germany (Vieregge et al., 1995) found no neurological effects following ingestion of increased manganese. No significant differences in neurological tests were found in older people (41 subjects older than 40 years with a mean age of 57.5) consuming well water containing at least 0.3 mg/L of manganese (0.3 to 2.16 mg/L of manganese) for 10 to 40 years. The control group (74 subjects, mean age 56.9 years) was exposed to water containing less than 0.05 mg/L of manganese. Subjects of both groups were randomly selected and matched with respect to age, sex, nutritional habits, and drug intake. However, like the Kondakis et al. (1989) study, this study lacks exposure data from other routes and sources, and the manganese concentration range in the water was very broad.

Two other studies involving ingestion exposure to manganese reported no increases in adverse health effects. In one area of Japan, a manganese concentration of 0.75 mg/L in the drinking-water supply had no apparent adverse effects on the health of consumers (Suzuki, 1970). No signs of toxicity were observed in patients given 30 mg of manganese citrate (9 mg of manganese) per day for many months (Schroeder et al., 1966).

One epidemiological study has been identified which attempts to link potential overexposure to ingested manganese with neurotoxicity in children. Adverse neurological effects (decreased performance in school and in neurobehavioral examinations of the WHO core test battery) were reported in 11- to 13-year-old children who were exposed to excess manganese through ingestion of contaminated water and consumption of food made of wheat fertilized with sewage water (He et al., 1994; Zhang et al., 1995). The exposed and control groups were both from farming communities and were matched for age, sex, grade, family income level, and parental education level. The average manganese concentration of the drinking-water was 0.241 mg/L for the exposed area compared to the control level of 0.04 mg/L. However, the total exposure data, including manganese exposure from food, water and air, exposure duration, as well as other confounding factors and the nutritional status of the children were not well-characterized.

A recently published case study (Woolf et al., 2002) reported increased manganese levels in the hair and blood of a 10-year-old child exposed to increased manganese in drinking water. The child had been ingesting drinking water supplied by a well for 5 years prior to a clinic visit for evaluation of over-exposure to manganese. In addition, the family lived in a house near a toxic waste dump. An evaluation of the well water performed four months prior to the child's health assessment indicated that manganese and iron levels in the water were both elevated, with concentrations of 1.21 (reference level, 0.05 mg/L) and 15.7 mg/L, respectively. The child's whole blood and serum manganese levels were 3.82 μg/100 mL (reference normal, <1.4 μg/100 mL) and 0.90 μg/100 mL (reference normal, <0.265 μg/100 mL), respectively. The child's hair manganese level was 3,091 ppb of washed, acid-digested hair (reference normal, <260 ppb hair). Although the child's 16-year-old brother did not exhibit elevated blood manganese, he did have increased manganese in his hair. The 10-year-old did not exhibit any clinical effects of manganese over-exposure (cogwheeling, abnormally high muscle tone, fixed facies, etc.) and had good balance with closed eyes, although he did have trouble coordinating rapid alternating motor movements (this deficiency is consistent with the test performance of occupational workers chronically exposed to airborne manganese). Magnetic resonance imaging (MRI) of the child's brain did not indicate any hyperintense signaling of the globus pallidus, basal ganglia, mid-brain or pons, which would indicate manganese deposition in these areas of the brain. Selective deposition of manganese in the globus pallidus and basal ganglia has been shown to occur in children and adults with chronic manganese overexposure (Devenyi et al., 1994; Hauser et al., 1996). The absence of the signaling argues against manganese toxicity. Results from a battery of neuropsychologic tests on the child indicated that global cognition was unimpaired.

However, the child had difficulties in both visual and verbal memory, which the study authors considered consistent with a deficit in free retrieval skills. The family was counseled to use bottled water for drinking and cooking; one month after the initial test, the child's whole blood manganese level was reduced to 1.71 :g/100 mL (Woolf et al., 2002). It is difficult to determine the total exposure from this study.

Results from studies of an Aboriginal population in Groote Eylandt have been cited as additional evidence for a relationship between elevated manganese exposure, violent behavior, and adverse health effects. The soil on this Australian island is exceptionally high in manganese (40,000 to 50,000 ppm), and the fruits and vegetables grown in the region are reported to contain elevated concentrations of the element. High alcohol intake, anemia, and a diet deficient in zinc and several vitamins (Florence and Stauber, 1989) may contribute to increased uptake and retention of manganese. The proportion of arrests in this native population is the highest in Australia, and high incidences of stillbirths and congenital malformations, as well as a high occurrence of Parkinson-like neurobehavioral syndrome, have been observed (Cawte and Florence, 1989; Kilburn, 1987). Clinical symptoms consistent with manganese intoxication are present in about 1% of the inhabitants. Quantitative data on oral intake have not been reported, but elevated concentrations of manganese have been determined in the blood and hair of the Aborigines (Stauber et al., 1987). However, Stauber et al. (1987) did not find a correlation between hair levels of manganese and the severity of neurological symptoms in individuals. A study of the neurologic status of the Aborigines in Groote Eylandt identified two general syndromes. One syndrome is characterized by muscle atrophy and weakness, while the other is characterized by ataxia and oculomotor disturbances (Kilburn, 1987). Although an association of adverse health effects with elevated manganese exposure is suggested by these observations, the small population of Groote Eylandt and the difficulty in defining an appropriate control population have prevented the identification of statistically-significant trends (U.S. EPA, 1993).

Several of the studies above utilized hair analysis as a method for estimating exposure to manganese. ATSDR (2000) has outlined several potential limitations to the use of hair analysis. The normal cycle of hair growth and loss restricts its usefulness to a period of a few months following exposure. External contamination of hair by dye, bleaching agents, or other materials may result in values which are not representative of absorbed doses. Further, the affinity of manganese for pigmented tissue may result in variations of manganese concentration with hair color.

Kihira et al. (1990) have associated manganese with amyotrophic lateral sclerosis (ALS). Spinal cord samples from ALS patients were found to have higher manganese concentrations in the lateral fasciculus and anterior horn than in the posterior horn. ALS patients also exhibited a positive correlation between manganese and calcium spinal cord content, while controls exhibited a negative correlation. It was suggested that an imbalance between manganese and calcium in ALS patients plays a role in functional disability and neuronal death. This study needs to be interpreted with caution, however, because it is not conclusive that the high manganese concentrations in these patients preceded the onset of the disease.

Creutzfeldt-Jakob Disease (CJD) clusters in central Slovakia have occurred near areas of high manganese in conjunction with low copper (Purdey, 2000). The level of manganese in natural uncultivated pasture in CJD-endemic areas was 210 ppm dry weight in comparison to CJD-free areas where the level was 85 ppm dry weight. The levels of manganese in pine needles and some specific crops were also measured and were approximately 1.5-16 times greater in the CJD-endemic regions (Purdey, 2000). It was suggested that manganese replaces copper in CNS prion proteins (PrP) causing a protease-resistant, misfolded PrP. Brown et al. (2000) determined that manganese can replace copper in recombinant PrP and reported that the PrP appears less stable and quickly converts to a misfolded form. Although the manganese-loaded PrP initially had a similar structure and activity as copper-loaded PrP, aging of the manganese-loaded PrP caused it to become proteinase-resistant and lose function.

Reproductive and Developmental Studies

Male workers afflicted with clinically identifiable symptoms of manganism also have loss of libido and impotence from occupational exposure to manganese for 1-21 years (Emara et al., 1971; Mena et al., 1967; Rodier, 1955; Schuler et al., 1957). Impaired fertility, as measured by fewer children/married couple, has been observed in male workers exposed for 1-19 years to manganese dust at levels that did not produce obvious manganism (0.97 mg/m^3; Lauwerys et al., 1985).

Three groups of men occupationally exposed to manganese for l or more years (63 miners or ore processors, 38 electric welders in mechanical fields, and 110 electric welders in shipbuilding) were reported to have increased semen liquification time and decreased sperm count and viability (Wu et al., 1996). Matched controls consisted of 99 men who were employed in the same occupation, but were not exposed to manganese or other reproductive toxins. Manganese levels, as well as those of a few other metals, were increased in the semen of the exposed group. Although this study suggests that manganese exposure may cause sperm toxicity, a stepwise regression analysis of the other metals present indicated that the higher nickel concentrations were also associated with lesser semen volume and a greater percentage of deformed sperm. This prevents any conclusive link between manganese and reproductive function.

By contrast, no significant differences in reproductive outcome were found between exposed men and matched controls in a reproductive epidemiology study involving 314 men in a manganese plant (Jiang et al., 1996). The geometric mean airborne manganese concentration was 0.145 mg/m^3 as MnO_2. The incidences of sexual dysfunction were evaluated through researchers' questions and judged by the occurrence of two positive responses to three potential conditions: impotence, abnormal ejaculation (early ejaculation or non-ejaculation), and lack of sexual desire.

No information was found regarding reproductive effects in women following manganese exposure.

Studies are limited regarding developmental toxicity in humans following oral exposures to manganese. Kilburn (1987) reported an increased incidence in birth defects and stillbirths in a small population of indigenous peoples in Groote Eylandt, Australia. Although the area was rich in manganese deposits and ingestion of excess amounts of the metal was suspected, the study suffered from a lack of exposure data, small sample sizes, and no suitable control group. Further, inhalation exposure to manganese could not be ruled out.

Cancer and Mutagenicity Studies

Mutagenicity

The genotoxic potential of high manganese exposure in humans is not known (IPCS, 1999). Elias et al. (1989) found an increase in the incidence of chromosomal aberration in metal active gas welding workers who had been welding for 10-24 years. Occupational exposure to nickel, as well as manganese, was reported. Since nickel is known to cause chromosomal aberration via inhalation, the results could not be attributed solely to the influence of manganese.

Carcinogenicity

No studies are available on the potential carcinogenicity of high exposure to manganese in humans (ATSDR, 2000).

Variation In Human Sensitivity

Individuals that have an impaired excretion and increased retention would be sensitive to manganese toxicity. Reasons for such susceptibility are genetic make-up, developmental stage, age, health and nutritional status. First, individuals with decreased excretion or impaired liver function can be at risk from exposure to excess manganese because the liver is the main organ for excreting manganese. This group may include the elderly who may have declining organ function, the very young who may have immature and developing organs, and those with liver disease. For example, Devenyi et al. (1994) reported observable neurological signs associated with manganese toxicity in individuals with chronic liver disease. Hauser et al. (1996) reported changes in brain MRI scans in liver failure patients which were identical to those observed in cases of manganese intoxication. Second, individuals with increased retention of manganese may be more sensitive to manganese toxicity including those whose nutritional status causes increased uptake of manganese. For example, the very young are considered a potential sensitive population due to the increased retention of manganese in animals (Keen et al., 1986; Kostial et al., 1978; Rehnberg et al., 1980) and humans (Zlotkin and Buchanan, 1986). This increased retention leads to increased manganese in the tissue, especially in the brain (Kontur and Fechter, 1985, 1988; Kostial et al., 1978; Kristensson et al., 1986; Miller et al., 1975; Rehnberg et al., 1981). This is a concern because the nervous system is the primary target organ. Although some data suggest that infants are potentially more susceptible to the toxic effects of manganese, evidence indicates that individual susceptibility varies greatly. The Kawamura et al. (1941) study suggested that young children (age 1 to 6 years) may be less sensitive to manganese toxicity than adults or older people. Current information is not sufficient to quantitatively assess the susceptibility of the young compared to adults.

Although studies are mixed, the majority have also suggested that the elderly (50 years of age or over) are more susceptible to manganese neurotoxicity than the general population (Kawamura et al., 1941; Rodier, 1955; Tanaka and Lieben, 1969). Loss of neuronal cells due to aging and/or accumulated damage from other environmental neurotoxicants, as well as less effective homeostatic control, may contribute to this increased susceptibility (Silbergeld, 1982).

5.2 Animal Studies

5.2.1 Short-term Exposure Studies

Lethality

Acute lethality of manganese in animals appears to vary depending on the chemical species and whether exposure is via gavage or dietary ingestion (ATSDR, 2000). Single-dose oral LD_{50} values in adult rats exposed by gavage ranged from 331 mg Mn/kg-day (as manganese chloride; Kostial et al., 1989) to 1,082 mg Mn/kg-day (as manganese acetate; Smyth et al., 1969), while a 14-day exposure of rats to 1,300 mg Mn/kg-day (as manganese sulfate) in feed resulted in no deaths (NTP, 1993).

Manganese compounds administered by parenteral routes generally result in mortality at lower doses. For example, Larsen and Grant (1997) administered a single intravenous dose of 150, 200, 300, or 400 :mol/kg in saline to male mice (5/group). These doses correspond to 8.2, 11, 16, and 22 mg Mn/kg, respectively. These study authors reported an LD_{50} value of 300 :mol/kg (16 mg Mn/kg). LD_{50} values for the intraperitoneal route ranged from 14 to 64 mg Mn/kg.

Age may be a factor in susceptibility to acute manganese toxicity. Kostial et al. (1978) found that $MnCl_2$ produced the greatest oral toxicity in the youngest and oldest groups of exposed rats. Roth and Adleman (1975) proposed that the increased susceptibility of older rats may result from a decrease in adaptive responsiveness, which is characteristic of the aging process. Increased susceptibility of younger rats may reflect high intestinal absorption and body retention of manganese.

General Toxicity

In a 14-day oral exposure study, NTP (1993) administered diets containing 0, 3, 130, 6,250, 12,500, 25,000, or 50,000 ppm manganese sulfate monohydrate to F344 rats (5/sex/dose). All rats survived the exposure period. Statistically-significant differences in manganese-treated rats included reduced body weight gain (57% decrease) and final body weight (13% decrease) in the high-dose males when compared to the control group. Decreased leukocyte and neutrophil counts and reduced liver weight were observed in high-dose males and females. The high-dose groups also exhibited diarrhea during the second week of the study. Manganese concentrations in the livers of animals receiving the 50,000 ppm diet were more than twice those of the controls. The NOAEL and LOAEL values based on decreased weight gain (males) and hematological changes were approximately 650 and 1,300 mg Mn/kg-day, respectively.

NTP (1993) also administered diets containing 0, 3, 130, 6,250, 12,500, 25,000, or 50,000 ppm manganese sulfate monohydrate to $B6C3F_1$ mice (5/sex/dose) for 14 days. However, study animals were poorly randomized at the beginning of the study, and no effects clearly attributable to manganese exposure were identified.

Exon and Koller (1975) reported that rats administered as little as 6 mg Mn/kg-day as Mn_3O_4 in feed for 28 days gained only 44% as much weight as control rats over the duration of the study. Since no histopathological changes were observed in the exposed animals, the authors suggested that the decrease in body weight gain might have been due to manganese interference in metabolism of calcium, phosphorous, and iron.

Hepatic

Shukla et al. (1978) administered a dose of 16 mg $MnC1_2$•$4H_2O$/kg (4.4 mg Mn/kg) in drinking water (dose calculated by investigators) to rats for 30 days and evaluated the effect on hepatic enzyme activity. Treated rats revealed significantly decreased succinic dehydrogenase, alcohol dehydrogenase, and \$-amylase activity when compared with controls. In contrast, manganese exposure resulted in significantly increased activities of monoamine oxidase (MAO), adenosine triphosphatase, arginase, glutamate pyruvate transaminase (alanine aminotransferase or ALT), ribonuclease, glucose-6-phosphatase, and "-amylase activity in the livers of treated rats.

Hietanen et al. (1981) studied the effect of manganese on hepatic and extrahepatic enzyme activities. Male Wistar rats were exposed to 0.5% Mn (as $MnC1_2$) in the drinking water for 1, 4, or 6 weeks. Assuming an average body weight of 0.35 kg and average water consumption of 0.045 L/day (U.S. EPA, 1986a), this corresponds to an exposure of 0.7 mg Mn/kg-day. Changes in the activity of several enzymes, including aryl hydrocarbon hydroxylase, ethoxycoumarin ?-deethylase, and epoxide hydrase, were observed at 1 week but not at 6 weeks. Enzyme activities were increased in the liver, and decreased in the intestines and kidney.

Neurological

The central nervous system is the chief target of manganese toxicity. Oral doses ranging from 1 to 150 mg per kg of body weight per day produced a number of neurological effects in rats and mice, mainly involving alterations in neurotransmitter and enzyme levels in the brain. These changes were sometimes accompanied by clinical signs, such as changes in coordination and activity level (ATSDR, 2000).

Deskin et al. (1980) studied neurological alteration induced by manganese chloride in neonatal CD rats. Rats were intubated with 1, 10 or 20 mg Mn/kg-day from birth to 24 days old. Manganese administration (10 and 20 mg/kg-day) resulted in a significant elevation of manganese in the hypothalamic area and corpus striatum, but neurochemical alterations (a decrease in dopamine concentration and turnover) were observed only in the hypothalamic area. The highest dose also resulted in an increase in monoamine oxidase activity in the hypothalamus of treated rats. A subsequent study by Deskin et al. (1981) using the same protocol (but doses of 10, 15 or 20 mg/kg-day) reported a significant elevation in serotonin levels in the hypothalamus, but not the striatum, following exposure to 20 mg/kg-day.

Kontur and Fechter (1988) intubated neonatal Long-Evans rats daily with 0, 25 or 50 mg/kg-day manganese chloride ($MnCl_2$•$4H_2O$) for 14 or 21 days. The level of manganese in the brain was increased at both 14 and 21 days, but was greater at 14 days. However, monoamine and metabolite levels were not altered by manganese treatment in any brain region. The authors suggest that the different results from short-term studies reported by different laboratories may be because of species or strain differences, the dosing regimen or vehicle, the route of administration, or the time points chosen for testing.

Kimura et al. (1978) provided rats with diets supplemented with 564 ppm of manganese as $MnC1_2$ for 3 weeks. Assuming a food consumption factor of 5% (i.e., 5g diet per l00 g body weight per day), this corresponds to a daily dose of 28 mg Mn/kg-day. The study authors reported that brain serotonin levels were decreased in manganese-treated rats. Monoamine oxidase activity was unchanged, but l-amino-acid decarboxylase activity in the brain was decreased by manganese treatment. Histopathological analysis of the brain was not conducted. Blood serotonin levels were increased in treated rats, and this change was accompanied by decreased blood pressure.

5.2.2 Long-term Exposure Studies

General Toxicology

Chronic ingestion of 1-2 mg Mn/kg-day produced changes in appetite and reduction in hemoglobin synthesis in rabbits, pigs, and cattle (Hurley and Keen, 1987). Transient effects on biogenic amine levels and activities of dopamine $-hydroxylase and monoamine oxidase in rat brain have been noted with long-term exposures to manganese (Eriksson et al., 1987; Lai et al., 1984; Subhash and Padmashree, 1990). An increase in physical activity level and a transient increase in dopaminergic function were observed in rats given 40 mg Mn/kg-day for 65 weeks (Nachtman et al., 1986). Two-year oral exposures to extremely high doses (1800-2250 mg/kg-day as $MnSO_4$) in male and female mice resulted in hyperplasia, erosion, and inflammation of the forestomach; no effects were seen in rats (NTP, 1993).

Mitochondria-rich organs, such as the liver and pancreas, are hypothesized to be most affected by oral exposure to manganese because of the interaction of manganese with mitochondrial enzymes. Wassermann and Wassermann (1977) reported ultrastructural changes of the liver cells in rats exposed to 200 mg/L of manganese chloride in their drinking water for 10 weeks. Assuming water consumption of 0.05 L/day and an average body weight of 0.35 kg (U.S. EPA, 1986a), this level of exposure corresponds to an average daily dose of approximately 12 mg Mn/kg-day. Increased metabolic activity was inferred from an increased amount of rough endoplasmic reticulum, the occurrence of multiple rough endoplasmic cisternae and prominent Golgi apparatus, and large Golgi vesicles filled with osmiophilic particles in the biliary area of the liver cell. The authors attributed this apparent increase in metabolic activity to biochemical processes related to the nutritional requirement for manganese, and homeostatic processes triggered by increased exposure. They noted that other observed liver effects, including the presence of glycogenosomes in the biliary area, groups of collagen fibers in the Disse's spaces, and degenerative changes in some centrilobular liver cells, may either be direct toxic phenomena or secondary responses to the effect exerted by manganese on other target tissues. ATSDR (2000) evaluated these data and designated 12 mg Mn/kg-day as the NOAEL in this study.

In a 13-week study, NTP (1993) administered diets containing manganese sulfate at 0, 1,600, 3,130, 6,250, 12,500, or 25,000 ppm (mg $MnSO_4 \bullet H_2O$ per kg diet) to F344 rats (l0/sex/dose). The baseline concentration of manganese in the control diets was approximately 92 ppm. Mean daily intake of manganese sulfate monohydrate ranged from 98 mg/kg-day (32 mg Mn/kg-day) for the low-dose to 1,669 mg/kg-day (542 mg Mn/kg-day) for the high-dose males. For females, the range was 114 mg/kg-day (37 mg Mn/kg-day) for the low-dose group and 1,911 mg/kg-day (621 mg Mn/kg-day) for the high-dose group. No rats died during the study, and no clinical or histopathology findings were attributed to manganese exposure. Females receiving diets with $\geq$6,250 ppm manganese sulfate experienced decreased body weight gain. Absolute and relative liver weights were decreased in males receiving diets with $\geq$1,600 ppm, and in females in the highest dose group only. Hematological effects were also reported. All groups of exposed males exhibited a significantly increased neutrophil count. Lymphocyte counts were decreased in males receiving $\geq$6,250 ppm in the diet and females in the three highest dose groups. The low dose of 1,600 ppm (about 32 mg Mn/kg-day) was identified as the LOAEL for this study, based on effects on liver weight and neutrophil counts in male rats.

In a concurrent 13-week study, NTP (1993) administered diets containing manganese sulfate (monohydrate) at 0, 3,130, 6,250, 12,500, 25,000, or 50,000 ppm to $B6C3F_1$ mice (10/sex/dose). The baseline concentration of manganese in the control diets was approximately 92 ppm. Mean daily intake of manganese sulfate monohydrate ranged from 328 mg/kg-day (107 mg Mn/kg-day) for the low-dose to 8,450 mg/kg-day (2,746 mg Mn/kg-day) for the high-dose group. No deaths were attributed to manganese exposure. Both male and female mice in the highest dose group exhibited significantly decreased body weight gain. The male mice in the highest dose group also had decreased relative and absolute liver weights. Both sexes at the highest dose exhibited decreased hematocrit and hemoglobin concentrations. The NTP report suggests that these findings may indicate microcytic anemia, which may have resulted from a sequestration or deficiency of iron. Males receiving $\geq$25,000 ppm also exhibited significantly lower leukocyte counts, although this finding was of questionable relevance to manganese exposure. No clinical findings were attributed to manganese exposure. The LOAEL for this study was 3,130 ppm (107 mg Mn/kg-day), based on significantly decreased body weight gain in male mice.

Komura and Sakamoto (1991) investigated the effect of different forms of manganese on potential adverse effects following ingestion exposure to the element. Male mice (8/group) were exposed either to a control diet containing 130 mg Mn/kg, or a diet supplemented with an additional 2,000 mg Mn/kg as $MnCl_2 \bullet 4H_2O$, $Mn(CH_3COO)_2 \bullet 4H_2O$, $MnCO_3$, or MnO_2. Assuming an average food consumption of 13% of body weight, the average daily dose from the control diet was approximately 17 mg Mn/kg-day, while the average daily dose from the manganese-enriched diet was 276 mg Mn/kg-day. The duration of treatment was 100 days. The mice were tested for spontaneous motor activity after 30 days. Blood and tissues were analyzed at the termination of the experiment. No significant difference in food intake among groups was seen. Body weight gain and red and white blood cell count was decreased in groups that received $Mn(CH_3COO)_2 \bullet 4H_2O$ or $MnCl_2 \bullet 4H_2O$. Motor activity was reduced in the $MnCO_3$ group. Tissue manganese concentrations in groups receiving supplemental manganese were 2 to 3 times that of controls. A LOAEL of 276 mg Mn/kg-day was identified in this study based on decreased weight gain and hematological effects.

Hepatic

Leung et al. (1982) administered 1,000, 10,000, or 20,000 mg $MnC1_2.•4H_2O$/L in drinking water to female Wistar rats. Exposure was initiated at conception by administration of manganese-containing drinking water to the dams, and continued through age 60 days. The estimated doses were 38.9, 389, and 778 mg Mn/kg-day (U.S. EPA, 1993). Treated rats exhibited liver necrosis and ultrastructural alterations that resembled human cholestasis. A LOAEL of 38.9 mg Mn/kg-day was identified in this study based on hepatic necrosis.

Suzuki et al. (1975) administered 250, 500, or 1,000 mg of MnO_2 in saline to 4 kg monkeys (*Macaca mullata*, age not specified) by subcutaneous injection. Injections were given once a week for 9 weeks. Estimated time-averaged doses correspond to 5.6, 11, and 23 mg Mn/kg-day. At autopsy, manganese-treated monkeys had irregular arrangement of hepatic cords and lymphocytic infiltration.

Neurological

Neurotoxicity is a known effect of long-term exposure to inhaled manganese in humans and animals, but the potential for neurotoxicity resulting from oral exposure is less well characterized. The only report of neurobehavioral toxicity in primates from orally administered manganese is by Gupta et al. (1980). Muscular weakness and lower limb rigidity were observed in 4 male rhesus monkeys given oral doses of manganese chloride (25 mg $MnCl_2•4H_2O$/kg, 6.9 mg Mn/kg-day) for 18 months. Histologic analysis showed degenerated neurons in the substantia nigra of the exposed animals at autopsy. There were no biochemical data. This study is of limited use for risk assessment because only one dose level was evaluated.

Studies involving oral exposures of manganese in drinking water or by gavage in neonatal rodent pups have reported changes in brain neurochemistry but generally do not show significant adverse effects on neurological development (ATSDR, 2000). Dorman et al. (2000) reported on neurological changes in rat pups dosed for 21 days postnatally with 11 or 22 mg Mn/kg-day by mouth in drinking water. The high dose group had significant increases in brain striatal DA (dopamine) and DOPAC (dihydroxyphenylacetic acid) concentrations and exhibited significant increases in the startle response, in the absence of pathological lesions. Because manganese is an essential nutrient in developing infants, the potential adverse effects from manganese deficiency may be of greater concern than potential toxicity from over-exposure.

Chandra et al. (1979) evaluated the neurological effects of manganese in mice exposed from birth. Neonatal mice were initially exposed by nursing from dams given 5 mg/mL $MnCl_2$ in their drinking water. After weaning at 25 days, the mice received manganese in their drinking water. Average exposures to manganese were determined to be 0.030 mg Mn/day for 60 days, 0.036 mg Mn/day through the 90th day, 0.075 mg Mn/day through the 120th day and 0.090 mg Mn/day for the interval between 150 and 180 days. Assuming a body weight of 0.03 kg at adulthood, the average daily dose at the termination of the experiment was approximately 3 mg Mn/kg-day. Elevated levels of striatal dopamine, norepinephrine, and homovanillic acid were observed at 60 and 90 days of age, with a concomitant increase in spontaneous locomotor activity. Exposure past 90 days did not influence motor activity. Chandra et al. (1979) proposed that the hyperactivity observed in these mice was an early behavioral effect of excess manganese exposure that resulted from elevated dopamine and norepinephrine levels. The study authors further suggested that the observed hyperactivity may be comparable to the psychomotor excitement observed in the early stages of human manganism.

Chandra and Shukla (1981) exposed male albino rats to 1,000 mg/L $MnCl_2 \cdot 4H_2O$ (436 mg Mn/L) in drinking water. Assuming water consumption of 0.049 L/day and an average adult body weight of 0.35 kg, this level of exposure corresponds to an average daily dose of 61 mg Mn/kg-day. Levels of catecholamines, homovanillic acid, manganese, and the activity of monoamine oxidase were determined in the corpus striatum at time intervals up to 360 days. The investigators found initial increases in dopamine, norepinephrine, and homovanillic acid levels. This initial increase was followed by a period of normal levels. After 300 days, a decrease in all levels was observed. These changes were not correlated with the tissue concentration of manganese. The authors suggested that the decreased locomotor activity observed during later periods of manganese exposure may be related to lowered dopamine and norepinephrine levels in the brain, and that this stage of chronic toxicity may correspond to the later neurologic phase of motor dyskinesia in humans. Ali et al. (1981) conducted concurrent behavioral studies, and found an initial increase in spontaneous locomotor activity followed by a decrease during later periods of manganese exposure.

Purdey (2000) examined an endemic of sheep scrapie (a form of transmissible spongiform encephalopathy) in North Central/Eastern Iceland. Purdey reported high (200 ppm dry weight) levels of manganese in the herbage of areas where the sheep had suffered from a high incidence of scrapie for decades. Areas that were scrapie free had a mean level of 80 ppm dry weight of manganese in the herbage. These data, along with the data on CJD in humans (Purdey, 2000; Brown et al., 2000), suggest a link between high manganese and low copper in the etiology of these degenerative neurologic diseases, but further data are needed to support the hypothesis.

Reproductive and Developmental Studies

Reproductive Effects

The results of several studies in rats and mice indicate that the ingestion of high dose of manganese can delay reproductive maturation in male animals (ATSDR, 2000). Testosterone levels were reduced in male rats given an oral dose of 13 mg Mn/kg-day for 100-224 days (Laskey et al., 1982), while delayed growth of the testes was observed in young rats ingesting 140 mg Mn/kg-day for 90 days (Gray and Laskey, 1980). These effects do not appear to be severe enough to affect male reproductive function (ATSDR, 2000). Several studies which found effects on male reproductive organs, however, did not assess reproductive performance (IPCS, 1999).

Laskey et al. (1982) found a slight decrease in pregnancy rate but no significant effect on litter size, ovulations, resorption, or fetal weight when male and female rats were exposed to 130 mg Mn/kg-day (as Mn_3O_4) in the diet for 90-100 days prior to breeding.

The results of most studies indicate that oral exposure to manganese does not result in reproductive toxicity in the female rodent (e.g., rats and mice) and rabbit (See also ATSDR, 2000), although increased postimplantation loss was observed in female rats in at least one study (Szakmáry et al., 1995).

Developmental Effects

Results from several developmental studies in rodents and rabbits are equivocal. Data from the majority of these studies indicate that manganese exposure during part or all of gestation results in increased manganese levels in the pups (Järvinen and Ahlström, 1975; Kontur and Fechter, 1988), but generally causes either no measurable effect (Grant et al., 1997), transient effects such as weight decreases and hyperactivity (Pappas et al., 1997), or reversible effects on skeletal and organ development (Szakmáry et al., 1995). Joardar and Sharma (1990) administered varying levels of $MnSO_4$ (10.25, 20.25, and 61.00 mg/100 g bw) and $KMnO_4$ (6.5, 13, and 36 mg/100 g bw) to mice by gavage over a 3-week period. Sperm head abnormalities and the percentage of abnormal sperm were significantly increased in all treated groups.

Cancer and Mutagenicity Studies

Mutagenicity

Laboratory evidence for the mutagenicity and genotoxicity of high dose manganese exposure is equivocal. Joardar and Sharma (1990) administered varying levels of $MnSO_4$ (10.25, 20.25, and 61.00 mg/100 g bw) and $KMnO_4$ (6.5, 13, and 36 mg/100 g bw) to mice over a 3-week period. The frequencies of chromosomal aberrations and micronuclei in bone marrow cells were significantly increased. Dikshith and Chandra (1978) administered repeat oral doses of 0.014 mg Mn/kg-day (as $MnC1_2$) to albino rats for 180 days with no significant chromosomal damage noted in either bone marrow or spermatogonial cells.

In vitro bacterial gene mutation tests have yielded both positive and negative results, while *in vitro* tests with fungi and mammalian cells have been predominantly positive. Manganese chloride produced an increased frequency of mutations in *Salmonella typhimurium* strain TA1537, but induced negative results in other strains; manganese sulfate was reported to be both positive and negative in separate studies in Salmonella strain TA97, but negative in other strains (IPCS, 1999). Positive results were obtained with various manganese compounds in *Phytobacterium fischeri* and *Escherichia coli*, as well as in *Saccharomyces cerevisiae* and hamster embryo cells (ATSDR, 2000). In spite of these results, the genotoxic potential of manganese in humans is not known (IPCS, 1999).

Carcinogenicity

No animal studies are available that have investigated the potential carcinogenicity of manganese following inhalation or dermal exposure (ATSDR, 2000). A 2-year oral study of manganese sulfate in rats and mice produced equivocal evidence of carcinogenicity (NTP, 1993). In rats fed manganese sulfate (30-331 mg Mn/kg-day in males, 26-270 mg Mn/kg day in females), no treatment-related increases in tumor incidence were reported. In mice fed manganese sulfate (63-722 mg Mn/kg-day in males, 77-905 mg Mn/kg-day in females), the incidence of follicular cell adenoma of the thyroid was increased slightly in high-dose animals compared to controls. These increases were not statistically significant, and the tumors were observed at the end of the study only. However, follicular cell adenoma of the thyroid appears with low frequency in historical control male mice of this strain. Thus, the significance of these results and their relevance to typical human oral exposure to manganese is questionable.

Stoner et al. (1976) tested manganese sulfate in a mouse lung adenoma screening bioassay. These investigators exposed 6- to 8-week-old Strain A/Strong mice of both sexes (10/sex) to 6, 15 or 30 mg $MnSO_4$/kg via intraperitoneal injection. Doses were administered three times a week for a total of 21 injections. The cumulative doses were 132, 330 and 660 mg $MnSO_4$/kg, corresponding to 42.9, 107.2 and 214.4 mg Mn/kg. Observation continued for 22 weeks after the dosing period, and the mice were sacrificed at 30 weeks. The percentage of mice with tumors was elevated at the highest dose level, but the difference was not significant when compared with the vehicle controls. An apparent increase in the average number of pulmonary adenomas per mouse was noted both at the middle and high doses, but the increase was significant only at the high dose (660 mg $MnSO_4$/kg; $p < 0.05$). Although the study results are suggestive of carcinogenic activity, they do not conclusively meet the positive-response criteria (increased tumor incidence and an observable dose-response relationship) for the interpretation of lung tumor data in this mouse strain (Shimkin and Stoner, 1975).

6.0 QUANTIFICATION OF TOXICOLOGICAL EFFECTS

Limitations of Using Rodent Data In Assessing Neurotoxicity of Manganese

There are considerable species differences between rodents and primates in nutritional requirements as well as neurotoxicity of manganese. Therefore, rodents are of limited value in assessing the neurobehavioral effects associated with extrapyramidal deficits (Chandra, 1983).

Manganese has a propensity for accumulation in the melanin pigment (Lyden et al., 1985) and there is a relative lack of neuromelanin in rodents. This may explain the fact that neurologic effects (e.g., tremor, gait disorders) seen in primates are often preceded or accompanied by psychologic symptoms (e.g., irritability, emotional lability) but are not apparent in rodents.

Contributing to the difficulties in interpreting the toxicologic data from exposure of rodents to manganese is the substantial difference in species' requirements for this dietary element. The estimated requirement for rats is 50 mg Mn/kg diet (Rogers, 1979). Assuming a food consumption equivalent to 5% of body weight (U.S. EPA, 1986a), this corresponds to a requirement for about 2.5 mg Mn/kg body weight (bw)/day. In contrast, the adequate intake for men and women (including lactating women) is about 2.3 -2.6 mg Mn/day, or about 0.03 - 0.07 mg Mn/kg bw/day, assuming a reference body weight of 70 kg. The dietary requirement for manganese in humans, then, is about two orders of magnitude lower than for rodents, suggesting that data derived from rodent studies may not be appropriate for use in deriving quantitative estimates of manganese levels that might be expected to result in adverse effects in humans.

As discussed above, rodent studies are limited in their use as a database from which to extrapolate effects in humans from over-exposure to manganese, because rodents do not exhibit the same neurologic deficits that humans do following exposure to manganese. On the other hand, the optimal levels of oral exposure to manganese for humans have not been well defined. For example, the available epidemiological studies in drinking water are of limited use in quantitative assessment of manganese toxicity, because of a lack of total exposure data. Balance studies are also not useful because short and moderate-tem manganese balance studies are found not to be proportional to manganese intakes (Greger, 1999). Therefore, the health advisories (acute and chronic) are based on human dietary studies (See Sections below).

Dose Response and Risk Characterization

Manganese is a ubiquitous element that is essential for normal physiologic functioning in all animal species. Several disease states in humans have been associated with both deficiencies and excess intakes of manganese. Thus any quantitative risk assessment for manganese must take into account aspects of both the essentiality and the toxicity of manganese. In humans, many data are available providing information about the range of essentiality for manganese. In addition, there are many reports of toxicity to humans exposed to manganese by inhalation; much less is known, however, about oral intakes resulting in toxicity. As discussed above, rodents do not provide a good experimental model for manganese toxicity, and only one limited study in primates by the oral route of exposure is available (Gupta et al., 1980). The following assessment, therefore, focuses more on what is known to be a safe oral intake of manganese for the general human population. Finally, it is important to emphasize that individual requirements for, as well as adverse reactions to, manganese may be highly variable. The reference dose is estimated to be an intake for the general population that is not associated with adverse health effects; this is not meant to imply that intakes above the reference dose are necessarily associated with toxicity. Some individuals may, in fact, consume a diet that contributes more than 10 mg Mn/day without any cause for concern.

Determination of Health Advisories

Health Advisories (HAs) are generally determined for one-day, ten-day and life time exposure if adequate data are available that identify a sensitive noncarcinogenic end point of toxicity. The HAs for noncarcinogenic toxicants are derived using the following formula:

$$\text{HA} = \frac{(\text{NOAEL or LOAEL}) \times (\text{BW})}{(\text{UF})\ (\text{L/day})} = \text{mg/L}\ (\mu\text{g/L})$$

where:

NOAEL or LOAEL = No- or Lowest-Observed-Adverse-Effect Level (in mg/kg bw/day).

BW = assumed body weight of a child (10 kg) or an adult (70 kg).

UF = uncertainty factor (10, 100, 1,000 or 10,000) in accordance with EPA or NAS/ODW guidelines.

L/day = assumed daily water consumption of a child (1 L/day) or an adult (2 L/day).

One-day HA

No suitable information was found in the available literature for determining the One-day HA for manganese. The Ten-day HA for a child of 1 mg/L, calculated below is recommended for use as a conservative estimate for a 1-day exposure for both children and adults.

Ten-day HA

The adequate intake for a child 7 to 12 months old is 0.6 mg/day, and that from a 1 to 3-year-old is 1.2 mg/day (IOM, 2002). Taking the upper end of the adequate intake for a 10 kg child (up to 1 mg/day), and assuming the manganese comes from a maximum of 1 liter of formula per day, this would correspond to a manganese concentration of 1 mg/L. This 10-day HA for a child should also be protective of adults.

The Ten-day HA for a 10-kg child is calculated as follows:

$$\text{1- and 10-day HA} = \frac{1\ \text{mg/day}}{1\ \text{L/day}} = 1\ \text{mg/L}$$

However, it is advised that for infants younger than 6 months, the lifetime HA of 0.3 mg/L be used even for an acute exposure of 10 days, because of the concerns for differences in manganese content in human milk and formula and the possibility of a higher absorption and lower excretion in young infants.

Lifetime Health Advisory

Lifetime health advisories are only developed for chemicals that are not likely to carcinogenic to humans. The Lifetime HA represents that portion of an individual's total exposure that is attributed to drinking water and is considered protective of noncarcinogenic adverse health effects over a lifetime exposure. The Lifetime HA is derived in a three-step process. Step 1 determines the Reference Dose (RfD), formerly called the Acceptable Daily Intake (ADI). The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious health effects during a lifetime, and is derived from the NOAEL (or LOAEL), identified from a chronic (or subchronic) study, divided by an uncertainty factor(s). From the RfD, a Drinking Water Equivalent Level (DWEL) can be determined (Step 2). A DWEL is a medium-specific (i.e., drinking water) lifetime exposure level, assuming 100% exposure from that medium, at which adverse, noncarcinogenic health effects would not be expected to occur. The DWEL is derived from the multiplication of the RfD by the assumed body weight of an adult and divided by the assumed daily water consumption of an adult. The Lifetime HA in drinking water alone is determined in Step 3 by factoring in other sources of exposure, e.g., the relative source contribution (RSC). The RSC from drinking water is based on actual exposure data or, if data are not available, a value of 20% is assumed.

Step 1: Determination of Reference Dose (RfD)

Choice of Principal Study and Critical Effect

Manganese is an essential trace element that is required for normal physiologic function in humans and animals. Excess exposure to manganese, particularly via the inhalation route, is associated with neurotoxicological symptoms that resemble parkinsonism. Thus, derivation of the RfD must consider issues of both essentiality and toxicity.

The RfD is not based on rodent studies, because rodents do not exhibit the same neurologic deficits that humans do following exposure to manganese. For example, manganese at high doses induces Parkinson-like symptoms in humans and primates, but not in rodents. Because of the species difference in the response to manganese exposure, rodents are not good models for manganese toxicity studies. More details on these species differences can be seen in IRIS (U.S. EPA, 1997).

The oral toxicity data on which risk assessments may be based are quite limited in scope. It is recognized that the information available in humans is inherently more useful than data obtained from laboratory animals, especially non-primates. However, the toxicity data in humans following ingestion of large amount of manganese are not suitable for a quantitative assessment (For details, See Section 5.1.2 Long-term Exposure).

Dose-Response Assessment

Based on the dietary information described by WHO (1973), Schroeder et al. (1966), and NRC (1989), EPA estimated that an intake of 10 mg Mn/day (0.14 mg Mn/kg-day, assuming a body weight of 70 kg) in the diet is safe for a lifetime of exposure. This level of manganese represents a NOAEL for chronic ingestion of manganese by humans. Application of a UF of 1 was used to derive the dietary RfD of 0.14 mg Mn/kg-day (U.S. EPA, 1997). The use of 1 as the UF is based on the following considerations. Manganese is an essential trace element for human health. The information used to derive the RfD was collected from many large human populations consuming normal diets over an extended period of time. The available data suggest that as long as physiological systems are not overwhelmed, humans exert effective homeostatic control over manganese so that body burden is kept relatively constant even when the concentration of manganese in the diet varies.

Application of Modifying Factor in Water

U.S. EPA (1997) has recommended the use of a modifying factor of 3 when assessing exposure to manganese from drinking water. Four reasons for this recommendation have been outlined:

- While toxicokinetic data suggest that there is no significant difference in absorption of manganese from food versus water, uptake of manganese from water appears to be greater in fasted individuals.

- The study by Kondakis et al. (1989) raises concern for possible adverse health effects associated with a lifetime consumption of drinking water containing 2 mg/L of manganese.

- Evidence exists that neonates absorb more manganese from the gastrointestinal tract, and excrete less of the absorbed manganese. Additional evidence suggests that absorbed manganese more easily crosses the blood-brain barrier in neonates. However, this evidence comes from animal studies; similar absorption studies in human neonates have not been performed, although Collipp et al. (1983) observed increased hair manganese levels in infants fed prepared formula compared with infants fed breast milk.

- Infant formula typically contains a much higher concentration of manganese than human or cows' milk. Powdered formula reconstituted with drinking water represents an additional source of manganese intake for a potentially sensitive population.

The potential impacts on children, when considered in conjunction with the likelihood that the most adverse effects of manganese (e.g., those seen in manganese miners or others with chronic overexposure to inhaled manganese) are likely to be irreversible and not manifested for many years after exposure, warrant caution until more definitive data are available (U.S. EPA, 1997). Recent data indicate, however, that in contrast to the symptoms of manganism, preclinical neurological effects of inhalation exposure of occupational workers to excess manganese are reversible (Roels et al., 1999). Similarly, symptoms of oral exposure to excess manganese in compromised individuals (e.g., individuals with liver disease who could not excrete manganese in the bile) were resolved when the exposure to excess manganese was decreased (Devenyi et al., 1994; Fell et al., 1996). These data indicate that the human body can recover from certain adverse effects of overexposure to manganese if the exposure is stopped and the body can clear the excess. Significant uncertainty still exists, however, concerning at what level of manganese intake these preclinical neurological symptoms might occur.

The RfD for chronic exposure to manganese in drinking water is therefore calculated as follows:

$$\text{RfD} = \frac{10\text{ mg/day}}{1 \;\times 70\text{ kg}} = 0.14\text{ mg/kg-day}$$

where:

10 mg/person-day = chronic no adverse effect level per person from dietary intake

1 = uncertainty factor

70 kg = assumed body weight of adult

Step 2: Determination of the Drinking Water Equivalent Level (DWEL)

$$DWEL = \frac{(0.14\ mg/kg\text{-}day)(70\ kg)}{3\ (2\ L/day)} = 1.6\ mg/L\ (1600\ \mu g/L)$$

where:

0.14 mg/kg-day = RfD

70 kg = assumed body weight of adult

2 L/day = assumed water consumption by 70-kg adult

3 = modifying factor for assessing exposure to manganese from drinking water (mainly for bioavailability concerns)

Step 3: Determination of the Lifetime HA

The Lifetime HA = (1.6 mg/L)(20%) = 0.3 mg/L (rounded from 0.32 mg/L)

where

1.6 mg/L = DWEL

20% = relative source contribution for manganese in drinking water

Evaluation of Carcinogenic Potential

- Available data are equivocal regarding carcinogenic potential of manganese.
- Based on the Draft Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2003b; 1999), there is inadequate information to assess the human carcinogenic potential for manganese.
- Based on 1986 Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986b) manganese has been classified in Group D: Not classified as to human carcinogenicity.

7.0 ANALYTIC METHODS AND TREATMENT TECHNOLOGY

Analytical Methods

Manganese can be measured by several well-documented analytical methods as shown in the Table 7-1.

Treatment Technology

The technologies include conventional treatment, ion exchange, reverse osmosis, lime softening, and chemical precipitation.

Conventional treatment usually includes pre-treatment steps of chemical coagulation, rapid mixing, and flocculation, followed by flocculation removal via sedimentation or flotation. After clarification, the water is then filtered. Common filter media include sand, and dual- and tri-media (e.g., silica sand, garnet sand, or anthracitic coal).

Ion exchange involves the selective removal of charged inorganic species from water using an ion-specific resin. The surface of the ion exchange resin contains charged functional groups that hold ionic species by electrostatic attraction. As water containing contaminant ions passes through a column of resin beds, charged ions on the resin surface are exchanged for the contaminant species in the water.

Reverse osmosis (RO) is similar to other membrane processes, such as ultrafiltration and nanofiltration, since water passes through a semi-permeable membrane. However, in the case of RO, the principle involved is not filtration. Instead, it involves the use of applied hydraulic pressure to oppose the osmotic pressure across a non-porous membrane, forcing the water from the concentrated solution side to the dilute solution side. The water does not travel through pores, but rather dissolves into the membrane, diffuses across, then dissolves out into the permeate. Most inorganic and many organic contaminants are rejected by the membrane and will be retained in the concentrate.

In the lime-softening process, the pH of the water being treated is raised sufficiently to precipitate calcium carbonate and, if necessary, magnesium hydroxide. Calcium and magnesium ions in water cause hardness. After mixing, flocculation, sedimentation, and pH readjustment, the softened water is filtered.

Results of a preliminary technology assessment and review indicate that all of the above-mentioned techniques remove manganese from water. However, data indicate that chemical precipitation is the most effective option.

Table 7-1: Analytical Methods for Manganese

Method	Type	Method Detection Limit (µg/L)
EPA 200.7	Inductively Coupled Plasma Optical Emission Spectrometry (ICP)/Atomic Emission Spectrometry	1.0
SM 3120 B	ICP/Atomic Emission Spectrometry	Estimated Detection Limit (EDL) 2.0
EPA 200.8	ICP/Mass Spectrometry	0.02
SM 3111B	Atomic Absorption, direct aspiration	Instrument Detection Level (IDL) 10 Optimum conc. range 100-10,000
EPA 200.9	Stabilized Temperature Graphite Furnace AA Spectrometry	0.3
SM 3113 B	Atomic Absorption, Furnace	EDL 0.2 Optimum conc. range 1-30

8.0 OTHER CRITERIA, GUIDANCE AND STANDARDS

- There is no current Maximum Contaminant Level (MCL) for manganese.

- OSHA (1998) has established a maximum permissible air exposure limit for manganese fumes at no greater than 5 mg/m^3 and elemental or inorganic manganese at no greater than 0.2 mg/m^3, averaged over any 8-hour period in the workplace environment.

- The World Health Organization (WHO) has established a provisional guideline value for manganese of 0.5 mg/L. This guideline is provisional because there is some evidence of a potential hazard, but available information on health effects is limited. Concentrations of this substance at or below the health-based guideline value may affect appearance, taste, or odor of water.

- EPA recommends a concentration of manganese in drinking water not to exceed 0.05 mg/L (ppm). This recommendation is to avoid staining of clothing and fixtures and is believed to be more than adequate to protect human health.

- The Food and Drug Administration (FDA) also recommends 0.05 mg/L of manganese in bottled water.

- EPA has also established rules setting limits on the amount of manganese factories can discharge to the water.

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Hart Exhibit 10
Docket No. E-2, Sub 1219

NORTH CAROLINA ADMINISTRATIVE CODE

TITLE 15

DEPARTMENT OF NATURAL RESOURCES
AND
COMMUNITY DEVELOPMENT

CHAPTER 2

ENVIRONMENTAL MANAGEMENT DIVISION

SUBCHAPTER 2L

CLASSIFICATIONS AND WATER QUALITY STANDARDS APPLICABLE TO THE GROUNDWATERS OF NORTH CAROLINA

SECTION .0100 AND .0200

EFFECTIVE DATE - JUNE 10, 1979

ENVIRONMENTAL MANAGEMENT COMMISSION
RALEIGH, NORTH CAROLINA

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SUBCHAPTER 2L - GROUNDWATER CLASSIFICATION AND STANDARDS

SECTION .0100 - GENERAL CONSIDERATIONS

.0101 INTRODUCTION

(a) N.C. General Statute 143-214.1 directs the Environmental Management Commission to develop and adopt, after proper study, a series of classifications and standards applicable to each classification, which will be appropriate for the purpose of classifying each of the waters of the state in such a way as to promote the policy and purposes of the act. Pursuant to this statute, this Regulation establishes a series of classifications and water quality standards applicable to the groundwaters of the state.

(b) Only in the very last few years has pollution been recognized as a major threat to the quality of the groundwaters of the state. The increasing incidence and potential for pollution results primarily from the change in the use of land from principally agricultural and silviculture activities to residential, commercial, and industrial activities. This change in land use has resulted in a large and continuing increase in the amount of wastes disposed on the land and in the number of other sources of pollution, such as landfills, waste disposal and processing facilities, chemical stockpiles, chemical and hydrocarbon spills and concentrations of septic tanks. Although the land in much of the state is capable of cycling many types of waste, unlimited and uncontrolled pollution sources will result in, not only pollution of the groundwaters, but eventual pollution of the surface waters as well. Poorly managed groundwater development is having a significant impact on the groundwater quality in some parts of the state.

(c) The regulations established in this Subchapter are intended to maintain and preserve the quality of groundwaters, prevent and abate pollution and contamination, protect public health, and permit management of groundwaters for best usage by the citizens of North Carolina.

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

.0102 DEFINITIONS

The definition of any word or phrase used in these regulations shall be the same as given in North Carolina General Statute 143-

213 except that the following words and phrases shall have the following meanings:

(1) Deleterious substance means those substances which may cause the water to be exceedingly unpleasant to taste, or unsightly, but which are not toxic.
(2) Fresh groundwaters are those groundwaters having a chloride concentration equal to or less than 250 milligrams per liter.
(3) Groundwaters are those waters in the saturated zone of the water-bearing consolidated and unconsolidated formations.
(4) Micrograms per liter (ug/l) gives the weight in micrograms of any constituent in one liter of solution.
(5) Milligrams per liter (mg/l) is the weight in milligrams of any specific constituent or constituents in a liter of the solution.
(6) Naturally occurring concentration means the concentration of chemical or biological substances or physical characteristics which exist naturally and which have not been changed by man's activities.
(7) Natural quality means the physical, biological and chemical quality which occurs naturally and which has not been changed by man's activities.
(8) Parts per million (ppm) and parts per billion (ppb) shall be construed to be equivalent to milligrams per liter and micrograms per liter, respectively.
(9) Point of discharge is the point of initial contact of waste with the existing soil or rock materials.
(10) Potable waters are those waters suitable for drinking, culinary and food processing purposes.
(11) Saline groundwaters are those groundwaters having a chloride concentration of more than 250 mg/l.
(12) The saturated zone is that part of the water-bearing consolidated and unconsolidated formations in which all the voids, large and small, are ideally filled with water under pressure greater than atmospheric. It does not include the capillary fringe.
(13) Source of water supply for drinking, culinary use or food processing shall mean any groundwater source either public or private, the waters from which are used for human consumption, or are used in connection with the processing of milk, beverages, or food.
(14) Toxic substances shall mean those substances which if ingested or assimilated into any organism either directly or indirectly will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in such organisms of their offspring).

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(15) The unsaturated zone is the portion of the consolidated and unconsolidated formations between land surface and the water table. It includes the capillary fringe.

(16) Water table is the surface of the saturated zone in the unconfined water-bearing formation or material at which the pressure is atmospheric.

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

.0103 GENERAL RULES

(a) The discharge of any wastes to the subsurface or groundwaters of the state by means of wells is prohibited [G.S. 143-214.2(b)].

(b) The maximum concentrations for toxic and deleterious substances shall not exceed the specified concentrations for each classification. Where not specified, the maximum concentrations for toxic substances in GA or GSA groundwaters shall not exceed the maximum recommended or established concentrations in the National Interim Primary Drinking Water Regulations. The maximum concentration for unspecified deleterious substances in GA and GSA groundwaters shall not exceed the maximum recommended or established concentration in the National Interim Primary Drinking Water Regulations or the naturally occurring concentration, as determined by the department, whichever is greater.

(c) Waters which, at the time of classification, contain toxic or deleterious substances in excess of the maximum allowable concentrations but for which it would be feasible to upgrade the quality by treatment to the standards established for classification, shall be designated restricted (RS).

(d) Any person subject to the provisions of General Statute 143-215.1 may apply to the Environmental Management Commission for a variance from the groundwater classification and quality standards established pursuant to these regulations and North Carolina General Statute 143-214.1. A variance may be granted by the commission pursuant to the requirements of North Carolina General Statute 143-215.3(e). The burden of proof in any public hearing or other proceeding pursuant to North Carolina General Statute 143-215.3(e) shall be upon the applicant for a variance.

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

.0104 ANALYTICAL PROCEDURES

Tests or analytical procedures to determine conformity or nonconformity with standards will, insofar as practicable and applicable, be made in accordance with the methods given in the latest pertinent issue of the Federal Register (presently December 1, 1976) as submitted by the U.S. Environmental Protection Agency for water programs. Other analytical procedures shall conform to those found in the latest edition of either "Standard Methods for the Examination of Water and Wastewater" (published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation) or "Methods for Chemical Analysis of Water and Wastes" (prepared by the U.S. Environmental Protection Agency and available from the Office of Technology Transfer, Washington, D.C. 20460).

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

SECTION .0200 - CLASSIFICATIONS AND WATER QUALITY STANDARDS APPLICABLE TO GROUNDWATERS OF NORTH CAROLINA

.0201 GROUNDWATER CLASSIFICATIONS

The groundwater classification for separately identified groundwaters shall be those specified in the following series of classifications:

(1) class GA waters; usage and occurrence:
  (a) Best Usage of Waters. Source of water supply for drinking, culinary use, and food processing;
  (b) Conditions Related to Best Usage. This class is intended for those groundwaters in which chloride concentrations are equal to or less than 250 mg/l, considered safe for drinking, culinary use, and food processing without treatment, but which may require disinfection or other treatment when necessary to reduce naturally occurring concentrations in order to meet the National Interim Primary Drinking Water Regulations;
  (c) Occurrence. At depths greater than 20 feet below land surface and in the saturated zone above a depth of 20 feet where these waters are a principal source of potable water supply;

(2) class GSA waters; usage and occurrence:
  (a) Best Usage. Sources of water supply for potable mineral water, culinary use, food processing, and conversion to fresh waters;
  (b) Conditions Related to Best Usage. This class is intended for those groundwaters in which chloride concentrations are greater than 250 mg/l, and which are considered safe for potable mineral water, culinary use, and food processing without treatment but may require disinfection or other treatment when necessary to reduce naturally occurring concentrations in order to meet the National Interim Primary Drinking Water Regulations;
  (c) Occurrence. At depths greater than 20 feet below land surface and in the saturated zone above a depth of 20 feet where these waters are a principal source of potable water supply;

(3) class GB waters; usage and occurrence:
  (a) Best Usage. Source of recharge to surface waters and groundwaters occurring below a depth of 20 feet;
  (b) Conditions Related to Best Usage. Precipitation is the principal source of recharge to the saturated zone.

The water in the saturated zone above a depth of 20 feet is of drinking water quality in much of the state. However, the upper 20 feet of the earth's surface is generally very vulnerable to pollution from man's activities, and should be considered a cycling zone for removing most or all of the contaminants from the water by adsorption, absorption, filtration or other natural treatment processes. In recognition of this fact, this classification is intended for those fresh groundwaters occurring at depths less than 20 feet below land surface that are of suitable quality for recharge to the deeper aquifers and surface waters of the state;

(c) Occurrence. In the saturated zone above a depth of 20 feet below land surface;

(4) class GSB waters; usage and occurrence:

(a) Best Usage. Source of recharge to saline surface waters and saline groundwaters occurring below a depth of 20 feet;

(b) Conditions Related to Best Usage. Precipitation is the principal source of recharge to the saturated zone. The water in the saturated zone above a depth of 20 feet is considered safe for potable mineral water in much of the state. However, the upper 20 feet of the earth's surface is generally very vulnerable to pollution from man's activities and should be considered a cycling zone for removing most or all of the contaminants from the water by adsorption, absorption, filtration or other natural treatment processes. In recognition of this fact, this classification is intended for those saline groundwaters occurring at depths less than 20 feet below land surface that are of suitable quality for recharge to the deeper aquifers and surface waters of the state;

(c) Occurrence. In the saturated zone above a depth of 20 feet below land surface;

(5) class GC waters; usage:

(a) Best Usage of Waters. Source of water supply for purposes other than human drinking, culinary use, or food processing;

(b) Conditions Related to Best Usage. This class includes those waters that do not meet the quality criteria requirements of waters having a higher classification and for which treatment to upgrade to a higher classification would technically or economically not be feasible, or not in the best interest of the public.

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

.0202 GROUNDWATER QUALITY STANDARDS

The water quality standards for separately identified groundwaters shall be those specified in the following series of standards:

(1) Class GA waters:
- (a) arsenic: not greater than 50 ug/l;
- (b) cadmium: not greater than 10 ug/l;
- (c) chloride: allowable increase not to exceed 50 percent of the naturally occurring chloride concentration or result in a concentration of more than 250 mg/l;
- (d) chromium: not greater than 50 ug/l;
- (e) coliform group total: not greater than 1.0/100 ml;
- (f) color: less than 5.0 units;
- (g) lead: not greater than 50 ug/l;
- (h) mercury: not greater than 2.0 ug/l;
- (i) nitrate (as N): not greater than 10 mg/l;
- (j) nitrite (as N): not greater than 1.0 mg/l;
- (k) oil and grease: free from taste or odor;
- (l) pesticides: shall not exceed maximum limits recommended or established by the National Interim Primary Drinking Water Regulations;
- (m) phenol: not greater than 1.0 ug/l;
- (n) phthalate esters: none in measurable quantities;
- (o) polychlorinated biphenyls: none in measurable quantities;
- (p) radioactive substances: shall not exceed maximum limits recommended or established by the National Interim Primary Drinking Water Regulations;
- (q) selenium: not greater than 10 ug/l;
- (r) silver: not greater than 50 ug/l;
- (s) total dissolved solids: allowable increase not to exceed 50 percent of the naturally occurring total dissolved solids concentration or result in a concentration of more than 1000 mg/l;

(2) Class GSA waters:
- (a) arsenic: not greater than 50 ug/l;
- (b) cadmium: not greater than 10 ug/l;
- (c) chloride: allowable increase not to exceed 100 percent of the naturally occurring chloride concentration;
- (d) chromium: not greater than 50 ug/l;
- (e) coliform group, total: not greater than 1.0 per 100 ml;
- (f) color: less than 5.0 units;
- (g) lead: not greater than 50 ug/l;

(h) mercury: not greater than 2.0 ug/l;
(i) nitrate (as N): not greater than 10 mg/l;
(j) nitrite (as N): not greater than 1.0 mg/l;
(k) pesticides: shall not exceed maximum limits recommended or established by the National Interim Primary Drinking Water Regulations;
(l) phenol: not greater than 1.0 ug/l;
(m) phthalate esters: none in measurable quantities;
(n) polychlorinated biphenyls: none in measurable quantities;
(o) radioactive substances: shall not exceed maximum limits recommended or established by the National Interim Primary Drinking Water Regulations;
(p) selenium: not greater than 10 ug/l;
(q) silver: not greater than 50 ug/l;

(3) Class GB Waters. All chemical, radioactive, biological, taste producing, odor producing, thermal, and other deleterious substances will be allowed only in such amounts, whether alone or in combination with other substances, as will not result in the contravention of established water quality standards;

(4) Class GSB Waters. All chemical, radioactive, biological, taste producing, odor producing, thermal, and other deleterious substances will be allowed only in such amounts, whether alone or in combination with other substances, as will not result in the contravention of established water quality standards;

(5) Class GC Waters. All chemical, radioactive, biological, taste producing, odor producing, thermal, and other deleterious substances shall not exceed the concentration existing at the time of classification.

History Note: Statutory Authority G.S. 143-214.1;
Eff. June 10, 1979.

I/A

Hart Exhibit 11
Docket No. E-2, Sub 1219

OFFICIAL COPY

Apr 13 2020

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

December 18, 2009

Ms. Brenda Brickhouse
Director of Environmental Health and Safety
Progress Energy Service Company, LLC
410 South Wilmington Street
PEB 4
Raleigh, North Carolina 27601

Dear Ms. Brickhouse:

Over the past several months, the Division of Water Quality (DWQ) has been reviewing the data and maps submitted by Progress Energy on April 30, 2009. Based on the review of the submitted data, specific recommendations and additional information requests on a site-by-site basis are attached. These attachments are formatted so that they can be sent to each individual site with the appropriate contact information for any follow up actions. All information requested is due no later than February 28, 2010.

During this review period, there has been a clarification by the Attorney General's Office of how Corrective Action (15A NCAC 02L .0106) requirements apply to facilities permitted prior to December 30, 1983. It was determined that facilities exceeding groundwater standards, permitted under G.S. 143-215.1, and permitted prior to December 30, 1983, fall under 15A NCAC 02L .0106(e). This clarification gives Progress Energy the option to seek approval of a corrective action plan that does not require remediation to groundwater standards [15A NCAC 2L .0106 (k)] or may allow attenuation by natural processes [15A NCAC 2L .0106 (l)].

As a result of the Attorney General's clarification, DWQ is requesting that each facility place groundwater monitoring wells at the compliance boundary. Where appropriate, monitoring of groundwater discharges to surface water will be required. As permits are renewed, groundwater monitoring will be added to the updated permits, and similar parameters will be required to be monitored at each site.

In light of concerns brought up by your staff in past discussions, combining compliance boundaries for adjacent DWQ permitted activities will be allowed, as well as encouraged. We will also continue to work with other Divisions in DENR to determine options for combining compliance boundaries with adjacent non-DWQ permitted activities.

A[illegible]ER PROTECTION SECTION
[illegible]6 Mail Service Center, Raleigh, North Carolina 27699-1636
Location: 2728 Capital Boulevard, Raleigh, North Carolina 27604
Phone: [illegible] \ FAX 1: 919-715-0588 \ FAX 2: 919-715-6048 \ Customer Service: 1-877-623-6748
Internet: www.ncwaterquality.org
[illegible]

One
NorthCarolina
Naturally

As this program progresses, we look forward to continue working with you. If you have any questions concerning the attached requests at any of your sites, please contact Debra Watts at (919) 715-6699 or Eric Smith at (919) 715-6196. Your prompt attention to these matters is appreciated.

Sincerely,

Ted L. Bush, Jr., Chief
Aquifer Protection Section

Attachments

cc: Coleen H. Sullins
Chuck Wakild
Jeff Poupart, NPDES
Landon Davidson - Asheville Regional Office APS
Jay Zimmerman - Raleigh Regional Office APS
David May Washington Regional Office APS
Art Barnhardt – Fayetteville Regional Office APS
Central Office Files

I/A

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

Beverly Eaves Perdue
Governor

[illegible]

Attachment 1

Site Name: Asheville Steam Station
County: Buncombe County
Division of Water Quality Aquifer Protection Section Regional Office: Asheville Regional Office (ARO)

Hydrogeology

- Recommend continued monitoring of GW-2 and GW-3. These wells are at the property boundary with the interstate right-of-way.
- The proposed "upgradient" well located at the southern portion of the map (between Interstate 26 and the French Broad River) should be called a downgradient well.
- Recommend adding a monitoring well southeast of PZ-23 at the Compliance Boundary. It appears that groundwater flow in this area may be toward the housing development near the southeastern boundary of the site property.
- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the ARO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The ARO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1/1/10.
- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Additional Information Requested

- Please submit the following updates to the maps by February 28, 2010:
    - Locations of proposed monitoring wells and/or groundwater seepage monitoring points.
    - Locations of all on-site inactive ash ponds and ash storage areas not previously identified, and
    - Locations of all on-site active and inactive Division of Waste Management (DWM) permitted solid waste facilities along with their associated Compliance Boundaries and monitoring wells,
- For the updated maps: Submit one (1) electronic copy and two (2) hard copies to the DWQ APS Central Office, and one (1) electronic copy and two (2) hard copies to the DWQ APS Regional Office.
    - Updates to the map can be made on the same aerial photo base as in the previous submittal. Please include elevation contours.

Contacts

DWQ APS Central Office Mailing Address:

1636 Mail Service Center
Raleigh, North Carolina 27699-1636

DWQ APS Central Office Staff:

Debra Watts
APS Groundwater Protection Unit Supervisor
debra.watts@ncdenr.gov
(919) 715-6699

Betty Wilcox
Environmental Chemist
betty.wilcox@ncdenr.gov
(919) 715-6169

Eric G. Smith, P.G.
Hydrogeologist
eric.g.smith@ncdenr.gov
(919) 715-6196

DWQ APS ARO Mailing Address:

2090 U.S. Highway 70
Swannanoa, North Carolina 28778

DWQ APS ARO Staff:

Landon Davidson
APS Supervisor
landon.davidson@ncdenr.gov
(828) 296-4500

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

[illegible]

Dee Freeman
[illegible]

Attachment 2

Site Name: Weatherspoon Steam Station
County: Robeson County
Division of Water Quality Aquifer Protection Section Regional Office: Fayetteville Regional Office (FRO)

Hydrogeology

- Based on the supplied maps, all monitoring wells are located between active ash basin and review boundaries. These wells are not suitable for determining compliance.
- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the FRO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The FRO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter.
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1/1/10.
- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Additional Information Requested

- Please submit the following updates to the maps by February 28, 2010:
  - Locations of proposed monitoring wells and/or groundwater seepage monitoring points,
  - Locations of all on-site inactive ash ponds and ash storage areas not previously identified, and
  - Locations of all on-site active and inactive Division of Waste Management (DWM) permitted solid waste facilities along with their associated Compliance Boundaries and monitoring wells,
- For the updated maps: Submit one (1) electronic copy and two (2) hard copies to the DWQ APS Central Office, and one (1) electronic copy and two (2) hard copies to the DWQ APS Regional Office.
  - Updates to the map can be made on the same aerial photo base as in the previous submittal. Please include elevation contours.

Contacts

DWQ APS Central Office Mailing Address:	1636 Mail Service Center Raleigh, North Carolina 27699-1636
DWQ APS Central Office Staff:	Debra Watts APS Groundwater Protection Unit Supervisor debra.watts@ncdenr.gov (919) 715-6699
	Betty Wilcox Environmental Chemist betty.wilcox@ncdenr.gov (919) 715-6169
	Eric G. Smith, P.G. Hydrogeologist eric.g.smith@ncdenr.gov (919) 715-6196
DWQ APS FRO Mailing Address:	Systel Building, 225 Green Street, Suite 714 Fayetteville, North Carolina 28301-5094
DWQ APS FRO Staff	Art Barnhardt APS Supervisor art.barnhardt@ncdenr.gov (910) 433-3300

I/A

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Water Quality
[illegible]

Attachment 3

Site Name: Cape Fear Steam Station
County: Chatham County
Division of Water Quality Aquifer Protection Section Regional Office: Raleigh Regional Office (RRO)

Hydrogeology

- Based on the supplied maps, you have the Compliance Boundary marked at 250 feet from the waste boundary. According to 15A NCAC 02L .0107(a), if your permit was issued prior to December 30, 1983, then the Compliance Boundary should be set at 500 feet from the waste boundary or at the property boundary (whichever is closer). Our records indicate that your original permit (NC0003433) was issued on August 30, 1976. Therefore, the Compliance/Review Boundaries needs to be adjusted.
- Based on the supplied maps, all monitoring wells are either located between Waste and Review Boundaries or on the Waste Boundary. These wells are not suitable for determining compliance.
- Based on the supplied water level data, recommend a background well be added north of the Active Ash Pond.
- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the RRO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The RRO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter.
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1/1/10.

- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Additional Information Requested

- Please submit the following updates to the maps by February 28, 2010:
    - Locations of proposed monitoring wells and/or groundwater seepage monitoring points,
    - Locations of all on-site inactive ash ponds and ash storage areas not previously identified, and
    - Locations of all on-site active and inactive Division of Waste Management (DWM) permitted solid waste facilities along with their associated Compliance Boundaries and monitoring wells,
- For the updated maps: Submit one (1) electronic copy and two (2) hard copies to the DWQ APS Central Office, and one (1) electronic copy and two (2) hard copies to the DWQ APS Regional Office.
    - Updates to the map can be made on the same aerial photo base as in the previous submittal. Please include elevation contours.

Contacts

DWQ APS Central Office Mailing Address:	1636 Mail Service Center Raleigh, North Carolina 27699-1636
DWQ APS Central Office Staff:	Debra Watts APS Groundwater Protection Unit Supervisor debra.watts@ncdenr.gov (919) 715-6699
	Betty Wilcox Environmental Chemist betty.wilcox@ncdenr.gov (919) 715-6169
	Eric G. Smith, P.G. Hydrogeologist eric.g.smith@ncdenr.gov (919) 715-6196
DWQ APS RRO Mailing Address:	1628 Mail Service Center Raleigh, North Carolina 27699-1628
DWQ APS RRO Staff:	Jay Zimmerman APS Supervisor jay.zimmerman@ncdenr.gov (919) 791-4200

I/A

North Carolina Department of Environment and Natural Resources
Division of Water Quality

Attachment 4

Site Name: Mayo Steam Station
County: Person County
Division of Water Quality Aquifer Protection Section Regional Office: Raleigh Regional Office (RRO)

Hydrogeology

- Based on the supplied maps, monitoring wells MW-2 and MW-3 are shown as located at the Review Boundary. These wells are not suitable for determining compliance.
- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the RRO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The RRO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter.
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1/1/10.
- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Additional Information Requested

- Please submit the following updates to the maps by February 28, 2010:
    - Similar scale map to the other plant maps (Asheville, Cape Fear, Lee),
    - Please include elevation contours,
    - Locations of proposed monitoring wells and/or groundwater seepage monitoring points,
    - Locations of all on-site inactive ash ponds and ash storage areas not previously identified, and
    - Locations of all on-site active and inactive Division of Waste Management (DWM) permitted solid waste facilities along with their associated Compliance Boundaries and monitoring wells,
- For the updated maps: Submit one (1) electronic copy and two (2) hard copies to the DWQ APS Central Office, and one (1) electronic copy and two (2) hard copies to the DWQ APS Regional Office.

Contacts

DWQ APS Central Office Mailing Address:	1636 Mail Service Center Raleigh, North Carolina 27699-1636
DWQ APS Central Office Staff:	Debra Watts APS Groundwater Protection Unit Supervisor debra.watts@ncdenr.gov (919) 715-6699
	Betty Wilcox Environmental Chemist betty.wilcox@ncdenr.gov (919) 715-6169
	Eric G. Smith, P.G. Hydrogeologist eric.g.smith@ncdenr.gov (919) 715-6196
DWQ APS RRO Mailing Address:	1628 Mail Service Center Raleigh, North Carolina 27699-1628
DWQ APS RRO Staff:	Jay Zimmerman APS Supervisor jay.zimmerman@ncdenr.gov (919) 791-4200

I/A

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

Attachment 5

Site Name: Roxboro Steam Station
County: Person County
Division of Water Quality Aquifer Protection Section Regional Office: Raleigh Regional Office (RRO)

Hydrogeology

- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the RRO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The RRO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter.
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1 1 10.
- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Additional Information Requested

- Please submit to us the information requested on our March 3, 2009 letter to Progress Energy for this site
- Please submit the following maps by February 28, 2010:
    - Similar scale map to the other plant maps (Asheville, Cape Fear, Lee).
    - Make sure that the Waste and Compliance Boundaries shown extending all the way around the permitted site(s).

I/A

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

Attachment 6

Site Name: Lee Steam Station
County: Wayne County
Division of Water Quality Aquifer Protection Section Regional Office: Washington Regional Office (WaRO)

Hydrogeology

- Based on the supplied water level data, recommend a background well be added in the location of the northern edge of the property away from the Active Ash Pond.
- Based on the supplied maps, monitoring wells MW-1, MW-2, MW-3, and MW-4 are located inside the Review Boundary. These wells are not suitable for determining compliance.
- Based on a clarification of the 15A NCAC 02L rules, monitoring wells are now required to be located at the Compliance Boundary. The proposed locations of these wells must be shown on the requested maps. Construction of these monitoring wells may begin after approval from the WaRO.
- Where constructing wells at the Compliance Boundary may not be feasible due to the proximity of surface water, groundwater seepage monitoring will be required. The proposed locations of these monitoring points must be shown on the requested maps. The WaRO will approve the final locations of the monitoring points.
- Combining Compliance Boundaries around any adjacent Division of Water Quality (DWQ) permitted activities is acceptable as well as recommended.
- Compliance Boundaries must not cross your property boundaries.

Groundwater Sampling and Data

- Please make sure that you sample the monitoring wells for the following constituents during each sampling event:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chloride
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Nitrate
pH (field)
Potassium
Selenium
Silver
Sodium
Sulfate
Thallium
TDS
Vanadium
Zinc

- The listed parameters are intended to monitor constituents from the coal ash; additional parameters may be necessary to address contributions to the ash ponds from any other waste sources.
- All of the requested groundwater sampling parameters should be instituted starting with the next sampling round after receiving this letter.
- Please send the groundwater sampling data in both electronic (Microsoft Excel) and hardcopy forms.
- Please report all metals in micrograms per liter (µg/L) with the exception of Copper and Zinc which should be reported in milligrams per liter (mg/L) in accordance with the 15A NCAC 02L standard changes effective 1/1/10.
- The Aquifer Protection Section (APS) may allow some groundwater sampling parameters to be deleted based on non-detects over several sampling rounds or historical data provided.

Hart Exhibit 12
Docket No. E-2, Sub 1219

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Water Quality
Coleen H. Sullins
Director

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

June 17, 2011

MEMORANDUM

To: Aquifer Protection Section Staff
Interested Parties

From: Ted L. Bush, Chief
Aquifer Protection Section

Subject: Policy for Compliance Evaluation of Long-Term Permitted Facilities with No Prior Groundwater Monitoring Requirements

Adherence to state regulations is fundamental to the protection of the waters of the state and is mandated in permits issued by the Division of Water Quality (DWQ). Evaluating permit conformity can be challenging, and oftentimes regulatory staff will add permit conditions to a permit to help determine if a facility is in compliance with state requirements. When groundwater monitoring requirements are added to a permitted facility that has operated for some period of time, it may be necessary to place wells at or near the compliance boundary (defined by 15A NCAC 2L .0107), rather than the review boundary (defined by 15A NCAC 2L .0108). This is determined by considering, at minimum, the following factors:

1) *Type of Permitted Activity.* Some permitted activities are more conducive to potential contamination than others. For instance, an unlined lagoon has a higher probability of contaminating the subsurface than a lined lagoon due to infiltration of the permitted waste into the underlying soil.

2) *Subsurface Geology.* Groundwater flow in the subsurface is controlled by the local geology. Some geological formations due to their structure and composition, such as unconsolidated sand or fractured bedrock, allow for greater groundwater flow rates. These formations have open pathways that can allow contaminants to easily migrate throughout the subsurface.

3) *Duration of Permitted Activity.* The longer a permitted activity takes place, the more opportunity there is for potential contamination to migrate away from the source. If the subsurface geology allows for greater groundwater flow, the amount of time it takes for potential contaminants to move away from the source is decreased. For the purpose of this document, a "Long-Term Permitted Facility" is a facility that has operated long enough that resulting contamination from the permitted source has a high probability of having reached or passed the compliance boundary.

4) *Location of the Review and Compliance Boundaries.* The distance of the review and compliance boundaries from the source is determined by rule. However, in some instances these boundaries can be closer to the source based on the location of the property boundaries.

Once the factors above have been considered and wells have been installed and sampled, the attached flowchart will be used to determine facility compliance. The flowchart outlines the steps to be taken to assess whether or not groundwater standards have been exceeded at the compliance boundary, and only apply to long-term permitted facilities as defined above. The flowchart is designed to apply to any DWQ permitted facility where groundwater monitoring requirements have recently been added to the permit.

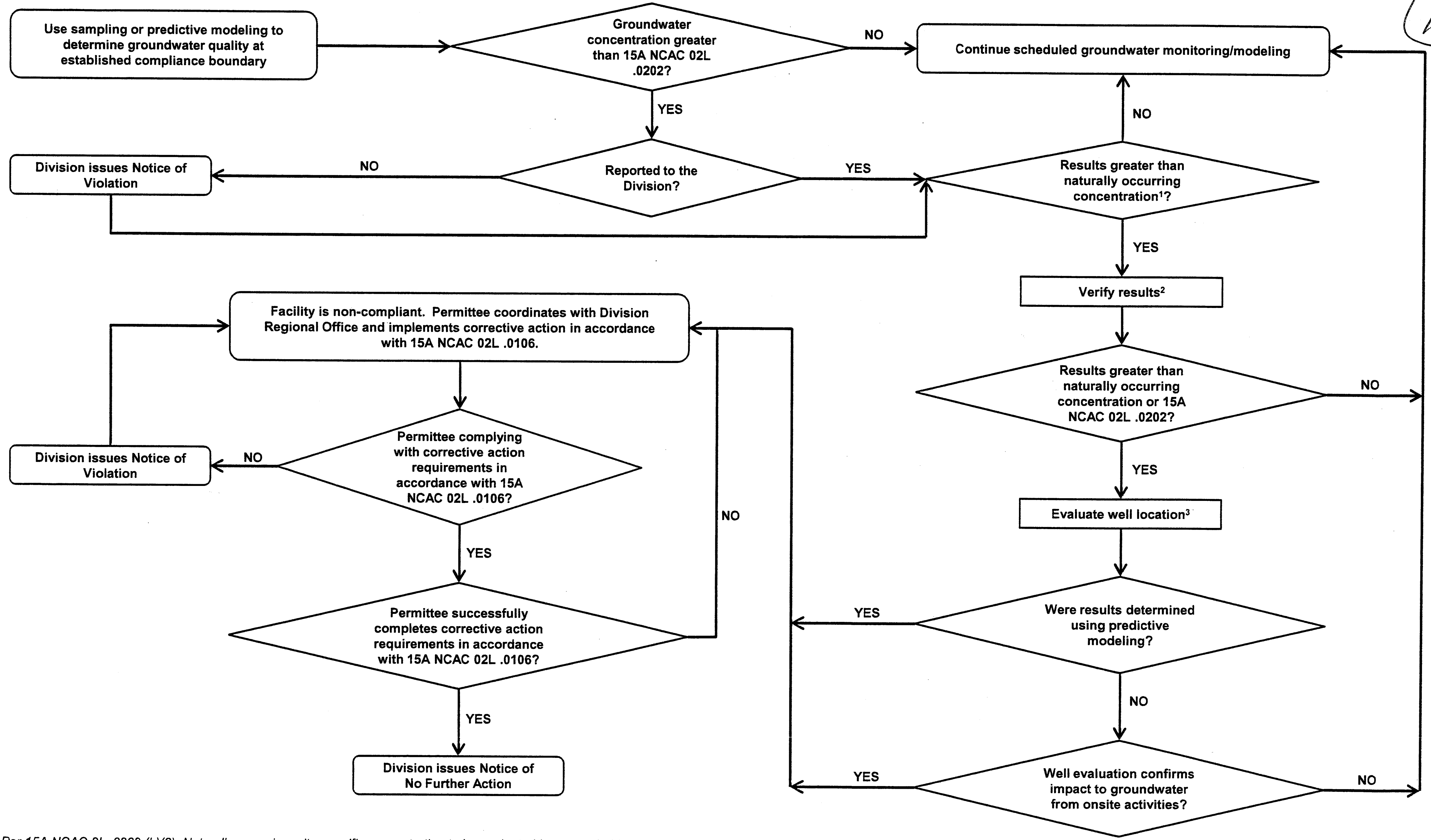
If the permitted facility is determined to be in non-compliance after following the steps outlined on the attached flowchart, adherence to the corrective action requirements specified in 15A NCAC 2L .0106 will be required. However, as long as the permittee is cooperative with the Division in taking all necessary steps to bring the facility into compliance, a notice of violation may not be necessary. The overall determination of whether or not a notice of violation is necessary will largely be based on the overall compliance history of the facility and the potential for impacts to human health and the environment.

cc: Surface Water Protection (Matt Matthews)

Compliance Evaluation of Long-Term Permitted Facilities with No Prior Groundwater Monitoring Requirements

(Refer to Policy Dated 6/17/11)

6/17/11



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[1] Per 15A NCAC 2L .0202 (b)(3). Naturally occurring, site-specific concentration to be evaluated by permit holder and approved by DWQ.

[2] Verification may include re-sampling, further well development, consideration of other analytical methods, comparison to split-sample results, review of model parameters (if determined using predictive modeling), etc.

[3] Evaluation will include a review of an array of hydrogeologic, site-specific features, related well location and construction specifications, groundwater flow direction, compliance boundaries, other contaminant sources, etc.

USWAG

I/A

Hart Exhibit 13
Docket No. E-2, Sub 1219

OFFICIAL COPY

Apr 13 2020

UTILITY INDUSTRY ACTION PLAN FOR THE MANAGEMENT OF COAL COMBUSTION PRODUCTS

Submitted to the
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Solid Waste
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

by the
UTILITY SOLID WASTE ACTIVITIES GROUP
701 Pennsylvania Avenue, NW
Washington, D.C. 20004-2696
202-508-5645

October 2006

Contents

UTILITY INDUSTRY ACTION PLAN

I. Introduction

A. Background

The Utility Solid Waste Activities Group ("USWAG")[1] is pleased to submit this Utility Industry Action Plan for the Management of Coal Combustion Products (the "Action Plan"). The Action Plan is an important component of the utility industry's response to the Environmental Protection Agency's ("EPA's") Resource Conservation Challenge, an initiative that calls for the industry to partner with the Agency to find innovative ways to prevent pollution and promote the beneficial use of residues from the combustion of coal in boilers used to generate electricity, commonly called "coal combustion products" or "CCPs".[2] In response to the Resource Conservation Challenge, EPA and the industry also are jointly implementing the Coal Combustion Products Partnership ("C^2P^2"), a collaborative effort to reduce barriers and encourage increased beneficial use of CCPs.

CCPs are beneficially used in numerous applications, including, among others, as raw material in portland cement, for mine reclamation, as replacement for cement in concrete and grout, as mineral filler in asphaltic concrete, as aggregate for highway subgrades and road base material, as a component of flowable fill, and as structural fill.[3]

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[1] USWAG is an association of the Edison Electric Institute ("EEI"), the American Public Power Association ("APPA"), the National Rural Electric Cooperative Association ("NRECA") and approximately 80 electric utility operating companies located throughout the country. EEI is the principal national association of investor-owned electric power and light companies. APPA is the national association of publicly-owned electric utilities. NRECA is the national association of rural electric cooperatives. Together, USWAG members represent more than 85 percent of the total electric generating capacity of the United States and service more than 95 percent of the nation's consumers of electricity and over 93 percent of the nation's consumers of natural gas.

[2] For purposes of this Action Plan, CCPs are the materials generated from the combustion of coal subject to the Bevill Amendment study provision (RCRA § 8002(n), 42 U.S.C. § 6982(n)). In addition to materials generated solely from the combustion of coal, CCPs include "[f]ly ash, bottom ash, boiler slag, and flue gas emission control wastes from the combustion of coal by electric utility power plants, when such wastes are mixed with, codisposed, cotreated, or otherwise comanaged with other wastes generated in conjunction with the combustion of coal or other fossil fuels." *See* EPA, REPORT TO CONGRESS, WASTES FROM THE COMBUSTION OF FOSSIL FUELS, Vol. 1, p. 1-2, Vol. 2, p. 1-1 (March 1999) ("1999 RTC"), quoting *Gearhart v. Reilly*, Civil No. 91-2345 (D.D.C. June 30, 1992) (Consent Decree). CCPs also include the residuals from the combustion of coal and other fuels and materials where coal makes up at least 50 percent of the mixture. *See id.*, Vol. 2, p. 3-9. This description of the scope of the Bevill exclusion (and hence the definition of "CCPs" in this Action Plan) was first contained in a 1981 interpretive letter from EPA to USWAG (Letter from G. Dietrich, EPA, to P. Emler, USWAG, dated Jan. 13, 1981, pp. 7-8) and was later clarified in EPA's first Bevill determination. *See* 58 Fed. Reg. 42466, 42469 n.4 (Aug. 9, 1993).

[3] *See* 1999 RTC, Vol. 2, pp. 3-36–3-37; 65 Fed. Reg. 32214, 32229 (May 22, 2000).

Currently, just over 40 percent of CCPs produced by electric power generating plants are used in such applications.[4] The balance of CCPs must be managed in landfills and surface impoundments. The goal of C^2P^2 is to increase the percentage of CCPs diverted to beneficial uses and thereby to decrease the volume of CCPs managed in landfills and surface impoundments.

The industry is committed to C^2P^2 as a means of ultimately achieving complete resource conservation of CCPs. Until full beneficial use of CCPs is achieved, continued management of CCPs in an environmentally responsible manner will remain an essential component of electric power generation. The utility industry through USWAG developed this Action Plan to complement the goals of C^2P^2 by ensuring that until complete resource conservation of CCPs is achieved, the remaining CCPs will be managed in a manner that protects human health and the environment.

This Action Plan details the industry's commitment to (1) adopt groundwater performance standards at facilities that manage CCPs, (2) implement a comprehensive monitoring program to measure conformance with the groundwater performance standards at CCP facilities, (3) ensure that no CCPs are placed in sand and gravel pits without appropriate engineering controls, and to (4) consider the option of using dry handling technology prior to constructing a new landfill or surface impoundment to manage fly ash on their property. These commitments are designed to address concerns previously raised by EPA regarding CCP management. The Action Plan does not supersede any federal, state, local or tribal law, regulation, or any existing permit, agreement or approval by an appropriate governmental agency. The following section briefly describes the process used to develop the Action Plan, followed by a presentation of the elements of the Plan.

B. The Development of the Utility Industry Action Plan

USWAG designed this Action Plan to address concerns raised by the EPA in the Agency's Regulatory Determination on Wastes from the Combustion of Fossil Fuels, 65 Fed. Reg. 32214 (May 22, 2000) (the "Regulatory Determination") and in subsequent communications with the industry. In the Regulatory Determination, EPA announced its decision that CCPs do not warrant regulation under RCRA Subtitle C, a decision that USWAG supported in comments filed with the Agency. USWAG Comments on the Regulatory Determination, Sept. 19, 2000 ("USWAG Comments"). The Regulatory Determination also announced EPA's intent to develop national standards under RCRA Subtitle D for CCPs disposed of in landfills and surface impoundments. 65 Fed. Reg. at 32230. In support of the proposed Subtitle D regulation of CCPs, EPA pointed to a group of "damages cases" involving CCP disposal sites at which, according to the Agency, environmental damage had either been proved or alleged in a manner that suggested that some CCP management practices may pose a risk to human health and the environment.

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[4] American Coal Ash Association, 2005 Coal Combustion Product (CCP) Production and Use Survey (Sept. 29, 2006).

Id. In addition, the Agency found that some CCP management units lacked groundwater monitoring. *Id.*

Following the Regulatory Determination, USWAG submitted comments that questioned the need for regulating CCPs under RCRA Subtitle D. *See*, *e.g.*, USWAG Comments at 4-6. In particular, USWAG noted that the damage cases relied on by EPA primarily involve outdated CCP management scenarios (*e.g.*, historic disposal in older uncontrolled sites) that do not provide an accurate representation of current industry practices. The cases relied on by EPA presented incomplete data sets, failed to take account for site specific conditions, and often focused on sites that either have been closed or whose management practices have been substantially changed since the incidents causing the alleged damage. Furthermore, in the few instances where the damage cases indicated significant problems with CCP management, EPA failed to recognize that the utilities involved had already acted responsibly to address the environmental issues. In short, USWAG believes that EPA has not, and indeed cannot, demonstrate that mandatory Subtitle D regulation of CCPs is necessary to protect human health and the environment. To the contrary, prescriptive Federal regulations would have the opposite effect of inhibiting environmentally protective, site-specific, and risk-based remedies currently available to states to address the small percentage of CCP management units posing environmental concerns. For these reasons, USWAG continues to oppose any prescriptive Federal regulation of CCPs. At the same time, USWAG reaffirms the utility industry's strong commitment to managing CCPs in a manner protective of human health and the environment.

As part of this commitment, USWAG has reached out to staff from EPA's Office of Solid Waste ("OSW") in an effort to understand and address the Agency's concerns relating to CCP management units. OSW staff invited USWAG to draft a plan to address the following Agency concerns: (1) the low percentage of existing CCP surface impoundments and landfills with groundwater monitoring programs; (2) the placement of CCPs in sand and gravel pits without appropriate engineering controls; and (3) the Agency's desire that the utility industry consider dry handling technology prior to constructing new landfills or surface impoundments to manage fly ash. USWAG members accept OSW's invitation and welcome the opportunity to work in partnership to reassure the public that the utility industry is managing CCPs in a manner protective of human health and the environment.

In response to this invitation, USWAG's Ash Management & Solid Waste Committee convened a panel of industry CCP technical experts to develop an action plan to address the concerns identified. This Utility Industry Action Plan is the result of USWAG's efforts. The Action Plan has the following four operative sections designed to address the concerns raised by OSW staff: Section III (Groundwater Performance Standards for CCP Units); Section IV (Groundwater Monitoring Program for CCP Units); Section V (Restrictions on Placement of CCPs in Sand and Gravel Pits); and Section VI (Dry Handling of Fly Ash). USWAG expects that technical work to implement Sections III, IV and V will be conducted by persons having professional qualifications to perform the tasks required by the Plan.

In developing comprehensive groundwater performance standards and groundwater monitoring program guidelines for facilities with CCP landfills and surface impoundments (Sections III and IV of the Action Plan), the industry panel relied on EPA's solid waste guidance and extant regulations. *See, e.g.,* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT, EPA530-R-03-001 (Feb. 2003); Criteria for Classification of Solid Waste Disposal Facilities and Practices, 40 C.F.R. Part 257; and Criteria for Municipal Solid Waste Landfills, 40 C.F.R. Part 258. The groundwater monitoring program incorporates an implementation schedule modeled on EPA's municipal solid waste landfill regulations. *See* 40 C.F.R. § 258.50(c). The monitoring program also includes design and operating guidelines (*i.e.*, location and number of wells, sampling parameters and frequency of monitoring, recordkeeping) to detect a CCP-related exceedance of groundwater performance standards as defined in Section III. The plan also includes procedures for conducting assessment monitoring and directs participating owners or operators to coordinate corrective action when necessary with appropriate federal, state, tribal or local regulatory agencies (collectively "appropriate governmental agencies").

Section V of the Action Plan addresses the Agency's concerns over placement of CCPs in sand and gravel pits. Section V states that CCPs shall not be placed in sand and gravel pits without appropriate site-specific engineering and management controls.

Finally, Section VI of the Action Plan was developed to respond to the Agency's request for the industry to take steps to encourage the use of dry fly ash handling technology in place of wet sluicing of fly ash prior to constructing new landfills or surface impoundments used to manage fly ash on company property. Section VI of the Action Plan responds to EPA's request by prompting owners and operators of power plants to consider the option of using dry handling technology prior to constructing a new landfill or surface impoundment to manage fly ash on their property.

II. Overview and Schedule of Implementation

This Action Plan applies to owners and operators of electric power generating plants that generate and manage CCPs and that choose to adopt the Action Plan as part of their standard operating procedures ("participating owners or operators"). Participating owners or operators agree to (1) adopt the groundwater performance standards in Section III of the Plan at their facilities with surface impoundments and landfills that receive CCPs after agreeing to participate in the Plan[5] ("CCP Units"),[6] (2) implement the groundwater monitoring program in Section IV at their facilities with CCP Units, (3) comply with the restrictions on the placement of CCPs in sand and gravel pits in

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[5] *See, e.g.,* 40 C.F.R. § 258.1(c).

[6] The term "CCP Unit" includes landfill and surface impoundment units whose primary function is to manage CCPs. The term does not include, for example, a wastewater treatment impoundment that only incidentally contains small quantities of CCPs in wastewater received by the unit after a participating owner or operator elects to participate in the Plan.

Section V, and (4) consider the option of using dry handling technology for fly ash prior to constructing a new landfill or surface impoundment to manage fly ash on their property in accordance with Section VI. This Action Plan is effective at a facility six months after the date on which a participating owner or operator notifies USWAG of its agreement to participate in the Plan with respect to that facility (the "Effective Date").

Participating owners or operators agree to implement groundwater performance monitoring following a schedule patterned after that applicable to owners or operators of municipal solid waste landfills.[7] Specifically, participating owners or operators of CCP Units located less than one mile upgradient from a groundwater well that is an active source of drinking water ("active drinking water well") agree to comply with the provisions of Section III and IV within three years of agreeing to participate in this Plan. Furthermore, participating owners or operators of CCP Units located one mile or more but less than two miles upgradient from an active drinking water well agree to implement the provisions of Sections III and IV within four years of agreeing to participate in this Plan. Finally, participating owners or operators of CCP Units that are located two miles or more upgradient from an active drinking water well agree to implement the provisions of Section III and IV within five years of agreeing to participate in this Plan.

Notwithstanding the foregoing, and as substantially provided for existing municipal solid waste landfills, participating owners or operators of facilities with CCP Units can adopt an alternative schedule to implement Sections III and IV of this Action Plan so long as the alternative schedule addresses potential risks to human health and the environment by considering the following factors: (a) proximity of human and environmental receptors; (b) design of the CCP Unit; (c) age of the CCP Unit; (d) size of the CCP Unit; (e) resource value of the underlying aquifer, including (i) current and future uses, (ii) proximity and withdrawal rate of users, (iii) groundwater quality and quantity.[8] Participating owners or operators will coordinate with the appropriate governmental agency in adopting an alternative schedule to implement Sections III and IV of this Action Plan.

After the Effective Date of this Action Plan, participating owners or operators, in accordance with Section V and VI, agree to adopt the restrictions on the placement of CCPs in sand and gravel pits and agree to consider the option of using dry handling technology prior to constructing a new landfill or surface impoundment to manage fly ash on their property. In accordance with the foregoing implementation schedule, USWAG and the participating owners or operators commit to execute this Action Plan in a manner protective of human health and the environment.

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[7] *See* 40 C.F.R. § 258.50(c).

[8] *See* 40 C.F.R. § 258.50(d).

Nothing in this Action Plan supersedes any applicable federal, state, tribal or local laws and regulations, or any existing permit, agreement, or approval by an appropriate governmental agency.

III. Groundwater Performance Standards For CCP Units

Each CCP Unit is subject to a designated groundwater performance standard. The default groundwater performance standard for CCP-derived constituents in a designated drinking water source aquifer is the national primary drinking water maximum contaminant levels ("MCLs") occurring at the lesser of 150 meters from the CCP Unit boundary or the property boundary as detected by sampling conducted in accordance with Section IV.[9]

Alternatively, as allowed in EPA's regulations for solid waste disposal facilities, an owner or operator may adopt a groundwater quality performance standard for a CCP Unit approved by an appropriate governmental agency, provided the alternative considers factors such as (a) the hydrogeological characteristics of the facility and surrounding land including any natural attenuation and dilution characteristics of the aquifer, (b) the volume, physical and chemical characteristics of the leachate, (c) the quantity, quality, and direction of flow of groundwater underlying the facility, (d) the proximity and withdrawal rates of groundwater users, (e) the availability of alternative drinking water supplies, (f) the existing quality of the groundwater, including other sources of contamination and their cumulative impacts on the water, (g) public health, safety and welfare effects, and (h) whether the groundwater is currently used or reasonably expected to be used for drinking water.[10] The default groundwater performance standard and any alternative groundwater performance standard adopted pursuant to this paragraph are collectively referred to herein as the "Groundwater Performance Standards."

IV. Groundwater Monitoring Program For CCP Units

A. Applicability of Groundwater Monitoring Program

Participating owners or operators agree to implement a groundwater monitoring program that meets the guidelines set forth in this Section IV. The goal of the groundwater monitoring program is to yield groundwater samples that will, to the extent reasonably possible, (a) represent the quality of background groundwater unaffected by the CCP Unit, and (b) detect CCP-related exceedances of Groundwater Performance Standards.

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[9] *See* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT, EPA530-R-03-001 (Feb. 2003) at 9-8.

[10] *See* 40 C.F.R. § 258.40(d).

To meet the standards set forth in Section IV, participating owners or operators of facilities with CCP Units may either install and operate a separate groundwater monitoring system for each CCP Unit or, alternatively, a multi-CCP unit groundwater monitoring system. A multi-CCP Unit groundwater monitoring system used in lieu of an individual CCP Unit monitoring system must meet the requirements of Section IV and be as protective of human health and the environment as individual monitoring systems based on the following factors: (1) the number, spacing, and orientation of CCP Units; (2) the hydrogeologic setting; (3) the site history; (4) the engineering design of the CCP Units; and (5) the nature of the CCPs placed in the CCP Unit.[11] Any groundwater monitoring system that covers a CCP Unit and is conducted pursuant to a federal, state or tribal regulatory provision, permit, agreement or approval shall be deemed to conclusively meet the guidelines in Section IV of this Action Plan.

Additionally, the groundwater monitoring program guidelines in Section IV may be waived if participating owners or operators of a CCP Unit can demonstrate that there is no reasonable potential for migration of CCP-derived primary drinking water constituents from the CCP Unit to an aquifer designated as a drinking water source.[12] In accordance with EPA regulations, this demonstration must be based on (1) site specific field measurements, sampling, and analysis of physical, chemical and biological processes affecting constituent fate and transport, and (2) constituent fate and transport predictions that maximize constituent migration and consider impacts on human health and the environment.[13] The demonstration shall be retained in the files of the participating owner or operator in accordance with established records retention policies and shall be made available to appropriate governmental agencies upon request.

B. Groundwater Monitoring Program

As set forth in EPA's GUIDE FOR INDUSTRIAL WASTE MANAGEMENT, EPA530-R-03-001 (Feb. 2003), participating owners or operators agree to install a monitoring system of at least three monitoring wells downgradient from a CCP Unit and at least one upgradient well to assess background water quality.[14] The monitoring system may be modified based on site-specific conditions, if approved by the appropriate governmental agency. A determination of background quality of groundwater may include sampling at a location that is not hydraulically upgradient of the CCP Unit where (i) hydrological conditions do not allow the owner or operator to determine what well is hydraulically upgradient, or (ii) sampling at other locations will provide an indication of background

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[11] *See* 40 C.F.R. § 258.51(b).

[12] *See* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT at 9-14.

[13] 40 C.F.R. §§ 257.21(b), 258.50(b).

[14] *See, e.g.,* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT at 9-16, Table 3.

groundwater quality that is as representative or more representative than that provided by an upgradient well.[15]

Participating owners or operators agree to conduct semi-annual monitoring for CCP-related primary drinking water constituents (*i.e.*, constituents with MCLs) that are reasonably expected to migrate to the groundwater based on site-specific factors.[16] Participating owners or operators agree to maintain records of sampling results generated by monitoring performed pursuant to this Section IV in accordance with established records retention policies.

Participating owners or operators agree to determine within a reasonable period of time after completing semi-annual sampling and analysis whether there has been a statistically significant increase over background levels for CCP-related constituents that exceed the Groundwater Performance Standards.[17] If such an exceedance of a Groundwater Performance Standard is detected, the participating owner or operator agrees to take steps to determine whether the increase was caused by factors unrelated to the CCP Unit. Factors unrelated to the unit include, but are not limited to (i) constituent sources other than the CCP Unit being monitored, (ii) natural variations in groundwater quality, (iii) statistical errors, (iv) analytical errors, and (v) sampling errors.[18] If the participating owner or operator determines that the increase was caused by a factor unrelated to the CCP Unit, no additional measures are necessary and the original groundwater monitoring program may be resumed.[19] If factors unrelated to the CCP Unit have been ruled out, the participating owner or operator agrees to consult with the appropriate governmental agency to determine the type of assessment monitoring to conduct at the CCP Unit.[20]

If assessment monitoring and analysis confirms a statistically significant CCP-derived increase over background that exceeds Groundwater Performance Standards for one or more constituents, then a participating owner or operator shall, within 90 days of such confirmation, consult with the appropriate governmental agency and begin to develop a risk-based management plan to address contamination.[21]

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[15] *See* 40 C.F.R. § 258.51(a).

[16] *See* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT at 9-13.

[17] *See* 40 C.F.R. §§ 257.25(a), 258.55(a). For a description of appropriate methods for determining statistically significant increases over background, *see* 40 C.F.R. §§ 257.23(g), (h), 258.53(g), (h).

[18] *See* EPA, GUIDE FOR INDUSTRIAL WASTE MANAGEMENT at 9-46.

[19] *Id.*

[20] *Id*. at 9-46 to 9-47.

[21] *See, e.g.,* 40 C.F.R. §§ 257.26(a), 258.56(a).

V. Restrictions On Placement Of CCPs In Sand And Gravel Pits

After the Effective Date of this Action Plan, participating owners or operators agree not to place or contract for the placement of CCPs into sand and gravel pits without appropriate site-specific engineering and management controls to protect groundwater. Appropriate site-specific engineering and management controls may include compaction, encapsulation, grading, capping, natural or synthetic barriers, or placement above seasonal high-groundwater table fluctuations.

VI. Dry Handling Of Fly Ash

After the Effective Date, participating owners or operators agree to consider the option of using dry handling technology for fly ash prior to constructing a new landfill or surface impoundment to manage fly ash on their property. Participating owners or operators that consider the option of dry handling technology in the construction of a new fly ash landfill or surface impoundment but decide not to proceed with the option agree to maintain records that indicate the basis for that determination in accordance with established records retention policies. Nothing in this section of the Action Plan shall be deemed to (1) supersede or add to the requirements of 40 C.F.R Part 423, where applicable, (2) affect the management of CCPs other than fly ash, or (3) prohibit the use of water to condition fly ash for management or to prepare fly ash for a beneficial use.

I/A

Hart Exhibit 14
Docket No. E-2, Sub 1219

OFFICIAL COPY

Apr 13 2020

Regulation 61-68

Water Classifications and Standards

Disclaimer

dhec
S.C. Department of Health and Environmental Control

2600 Bull Street | Columbia, SC 29201

Statutory Authority:	S.C. Code Sections 48-1-10 et seq.

Regulation History as Published in State Register

Date	Document Number	Volume	Issue
July 24, 1981	-	5	14
June 28, 1985	458	9	6
January 22, 1988	771	12	1
April 27, 1990	1039	14	5
April 26, 1991	1313	15	4
April 24, 1992	1385	16	4
May 28, 1993	1565	17	5, Part I
June 26, 1998	2218	22	6, Part 2
June 22, 2001	2572	25	6
June 25, 2004	2855	28	6
April 25, 2008	3161	32	4
February 24, 2012	4161	36	2
June 22, 2012	4212	36	6
June 27, 2014	4425	38	6

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A.PURPOSE AND SCOPE.

1. These regulations, promulgated pursuant to authority in the S. C. Pollution Control Act, Section 48-1-10 et seq., 1976 Code of Laws, establish a system and rules for managing and protecting the quality of South Carolina’s surface and ground water. They establish the State's official classified water uses for all waters of the State, establish general rules and specific numeric and narrative criteria for protecting classified and existing water uses, and establish procedures for classifying waters of the State. The water quality standards include the uses of the waters, the numeric and narrative criteria, and the antidegradation rules contained in this regulation.

a. The uses of the waters of the State are defined and described in Sections B, C, E, F, G, and H of this regulation.

b. Numeric criteria for aquatic life and human health are numeric values for specific parameters and pollutants or water quality levels which have been assigned for the protection of the existing and classified uses for each of the classifications in South Carolina and are listed in Section D, E, G, H, and the Appendix. Narrative criteria for aquatic life and human health are general goals and statements of attainable or attained conditions of biological integrity and water quality of the waterbody. These narrative criteria rely upon the use of standardized measures and data analyses to make qualitative determinations of the water quality and use attainment. The Department uses scientifically sound and, where applicable, EPA-approved methods in making these determinations. Narrative criteria are listed in Sections C, D, E, F, G, and H.

c. Antidegradation rules provide a minimum level of protection to all waters of the State and also include provisions and requirements necessary to determine when and if water quality degradation is allowed. Antidegradation rules are described in Section D of this regulation.

2. Waters which meet standards shall be maintained. Waters which do not meet standards shall be improved, wherever attainable, to achieve those standards. However, the Department cannot assure that classified waters shall at all times meet the numeric water quality standards for such uses.

3. Recognizing the technical and economic difficulty in restoring water quality, the Department shall emphasize a preventive approach in protecting waters of the State.

4. It is a goal of the Department to maintain and improve all surface waters to a level to provide for the survival and propagation of a balanced indigenous aquatic community of flora and fauna and to provide for recreation in and on the water. It is also a goal to provide, where appropriate and desirable, for drinking water after conventional treatment, shellfish harvesting, and industrial and agricultural uses.

5. It is a goal of the Department to maintain or restore ground water quality so it is suitable as a drinking water source without any treatment.

B.DEFINITIONS.

1. The definition of any word or phrase employed in this regulation shall be the same as given in the South Carolina Pollution Control Act, 48-1-10, et seq, S.C. Code of Laws, 1976, hereafter referred to as the Act. Words or phrases which are not defined in the Act are defined as follows:

2. **7Q10** means the annual minimum seven day average flow rate that occurs with an average frequency of once in ten years as published or verified by the U. S. Geological Survey (USGS) or an estimate extrapolated from published or verified USGS data.

3. **30Q5** means the annual minimum thirty day average flow rate that occurs with an average frequency of once in five years as published or verified by the U. S. Geological Survey (USGS) or an estimate extrapolated from published or verified USGS data.

4. **Acute** means a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less typically is considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.

5. **Acute-to-chronic ratio** (ACR) means the ratio of the acute toxicity of an effluent or a toxicant to its chronic toxicity. It is used as a factor for estimating chronic toxicity on the basis of acute toxicity data, or for estimating acute toxicity on the basis of chronic toxicity data.

6. **Agricultural** means the use of water for stock watering, irrigation, and other farm purposes.

7. **Annual average flow** means the annual mean flow rate of a stream at a specific point as published or verified by the U. S. Geological Survey (USGS) or an estimated annual mean flow rate extrapolated from published or verified USGS data.

8. **Aquaculture** means a defined managed water area which uses discharges of pollutants into that designated area for the maintenance or production of harvestable freshwater, estuarine, or marine plants or animals.

9. **Aquatic farm** means the cultivation, production, or marketing of domestic aquatic organisms which are any fish, aquatic invertebrates, or aquatic plants that are spawned, produced, or marketed as a cultivated crop in the waters of the State.

10. **Aquatic toxicity test** mean laboratory experiments that measure the biological effect (e.g., growth, survival, and reproduction) of effluents or receiving waters on aquatic organisms.

11. **Aquifer** means a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of ground water to wells or springs.

12. **Balanced indigenous aquatic community** means a natural, diverse biotic community characterized by the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollutant tolerant species.

13. **Best management practice** (BMP) means a practice or combination of practices that are the most effective, practical ways of controlling or abating pollution from widespread or localized sources.

14. **Bioaccumulation** means the process by which a compound is taken up and retained by an aquatic organism, both from water and through food.

15. **Bioavailability** means a measure of the physiochemical access that a toxicant has to the biological processes of an organism. The less the bioavailability of a toxicant, the less its toxic effect on an organism.

16. **Bioconcentration** means the process by which a compound is absorbed from water through gills or epithelial tissues and is concentrated in the body.

17. **Bioconcentration factor** (BCF) means the ratio of a substance’s concentration in tissue versus its concentration in water, in situations where the food chain is not exposed or represents equilibrium partitioning between water and organisms.

18. **Biological assessment** means an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters and sediments.

19. **Biological criteria**, also known as biocriteria, mean narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions. Biological criteria serve as an index of aquatic community health.

20. **Biological monitoring**, also known as biomonitoring, means a description of the living organisms in water quality surveillance used to indicate compliance with water quality standards or permit effluent limits and to document water quality trends. Methods of biological monitoring may include, but are not limited to, toxicity testing such as ambient toxicity testing, whole effluent toxicity testing, and ambient assessment of the resident biological community.

21. **Chlorophyll *a*** means a photosynthetic pigment present in all types of green plants. It is used as a measure of algal biomass and is an indicator of nutrient enrichment.

22. **Chronic** means a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of a chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

23. **Classified uses** means those uses specified in Section G for surface waters and Section H for ground waters, whether or not those uses are being attained.

24. **Concentrated aquatic animal production facility** means a hatchery, fish farm, or other facility related to aquatic animal production which is not located in waters of the State and is subject to a National Pollutant Discharge Elimination System (NPDES) permit.

25. **Conventional treatment as applying to potable water supplies** means treatment including at least flocculation, sedimentation, filtration, and disinfection.

26. **Criterion continuous concentration** (CCC) means the highest instream concentration of a toxicant or an effluent to which the organisms can be exposed to protect against chronic (long-term) effects. EPA derives chronic criteria from longer term (often greater than 28 days) tests that measure survival, growth, reproduction, and in some cases bioconcentration.

27. **Criterion maximum concentration** (CMC) means the highest instream concentration of a toxicant or an effluent to which the organisms can be exposed for a brief period of time without causing an acute effect. EPA derives acute criteria from 48 to 96 hour tests of lethality or immobilization.

28. **Daily average** means the average of all samples taken during any 24 hour period.

29. **Daily maximum** (for bacterial indicators only) means the highest arithmetic average of bacterial samples collected [for each of the bacterial indicator species (i.e., *E. coli*, enterococci, and /or fecal coliform)] in any 24 hour period during a calendar month.

30. **Deleterious substances** mean those substances which in sufficient concentrations or levels have a harmful effect on classified or existing water uses.

31. **Ecoregions** mean areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources and are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. The EPA has published a document that outlines the Level III ecoregions (please refer to U.S. Environmental Protection Agency. 1999. Level III ecoregions of the continental United States (revision of Omernik, 1987). Corvallis, Oregon, U.S. E.P.A.-National Health and Environmental Effects Research Laboratory, Map M-1.) The following are South Carolina Level III ecoregions: Blue Ridge Mountains, Piedmont, Southeastern Plains, and Middle Atlantic Coastal Plains.

32. **Ephemeral streams** mean streams that generally have defined natural watercourses that flow only in direct response to rainfall or snowmelt and in which discrete periods of flow persist no more than 29 consecutive days per event.

33. **Existing uses** means those uses actually being attained in or on the water, on or after November 28, 1975, regardless of the classified uses.

34. **Fishing** means the taking, harvesting, or catching of finfish or crustaceans for human consumption.

35. **Full pool elevation** means the maximum lake level attained before water releases over a fixed weir, spillway, or other discharge structure. In larger lakes and reservoirs, the full pool elevation is the maximum level established for management.

36. **Groundwater** means water below the land surface in a zone of saturation.

37. **Hydrograph controlled release** (HCRs) means the onsite storage or holding of treated wastewater or the use of an alternative discharge option contained in Section D.2.a. of this regulation, during specified critical streamflow conditions and then discharging the treated wastewater to the stream when streamflow is sufficient to assimilate the wastewater.

38. **Intermittent streams** means streams that generally have defined natural watercourses which do not flow year around, but flow beyond periods of rainfall or snowmelt.

39. **Lake** means any water of the State that is a freshwater pond, reservoir, impoundment, or similar body of water located wholly or partially within the State.

40. **LC50** means the concentration of a toxicant at which lethality occurs to 50 percent of the test organisms during a specified exposure time period.

41. **Mixing zone** means:

a. For surface waters, an area where a discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented (except as defined within a Zone of initial dilution) and public health and welfare are not endangered.

b. For ground waters, a hydrogeologically controlled three-dimensional flow path in the subsurface which constitutes the pathway for waste constituents to migrate from a source.

42. **Monthly average** (for bacterial indicators only) means the calendar month (i.e., 28 days, 29 days, 30 days, or 31 days) geometric mean of all bacterial samples collected [for each of the bacterial indicator species (i.e., *E. coli*, enterococci, and/or fecal coliform)] during that calendar month.

43. **Natural conditions** mean those water quality conditions unaffected by anthropogenic sources of pollution.

44. **No discharge zone** (NDZ) means a waterbody (or a portion of a waterbody) so designated that no discharging Marine Sanitation Devices (MSDs) are allowed on vessels on waterbodies so designated. All vessels located on such designated waterbodies shall be equipped with MSDs which discharge to a holding tank which shall be pumped out at a designated pump-out location or shall discharge legally outside the boundary of the United States.

45. **No observed effect concentration** (NOEC) means the highest tested concentration of an effluent or a toxicant at which no adverse effects are observed on the aquatic test organisms at a specific time of observation and determined using hypothesis testing.

46. **Nutrients** mean an element or chemical essential to life including, but not limited to, nitrogen and phosphorus.

47. **Organoleptic** effects mean those sensory effects associated with taste and smell.

48. **Outstanding recreational or ecological resource waters** means waters which are of exceptional recreational or ecological importance or of unusual value. Such waters may include, but are not limited to: waters in national or state parks or wildlife refuges; waters supporting threatened or endangered species; waters under the National Wild and Scenic Rivers Act or South Carolina Scenic Rivers Act; waters known to be significant nursery areas for commercially important species or known to contain significant commercial or public shellfish resources; or waters used for or having significant value for scientific research and study.

49. **Practical quantitation limit** (PQL) means a concentration at which the entire analytical system must give a recognizable signal and acceptable calibration point. It is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method-specific sample weights volumes, and processing steps have been followed..

50. **Prohibited area** means an area adjacent to point source discharges or other sources of potential contamination in shellfish growing waters where the gathering of clams, mussels, or oysters is prohibited to protect public health.

51. **Primary contact recreation** means any activity with the intended purpose of direct water contact by the human body to the point of complete submergence, including but not limited to swimming, water skiing, and skin diving.

52. **Propagation** means the continuance of species through reproduction and growth in the natural environment, as opposed to the maintenance of species by artificial culture and stocking.

53. **Public water system** means any public or privately owned waterworks system which provides drinking water for human consumption, except those serving a single private residence or dwelling.

54. **Recharge area** means an area where an underground source of drinking water is poorly confined, is under water table conditions, and has a downward component of flow from the water table into the underground source of drinking water.

55. **Secondary contact recreation** means any activity occurring on or near the water which does not have an intended purpose of direct water contact by the human body to the point of complete submergence, including but not limited to fishing, boating, canoeing, and wading.

56. **Shellfish** mean bivalve mollusks, specifically clams, mussels, or oysters.

57. **Shellfish harvesting** means taking of bivalve mollusks, specifically clams, mussels, or oysters, for direct marketing or human consumption.

58. **Source for drinking water supply** means any source of surface water which is used for domestic consumption, or used in connection with the processing of milk, beverages, food or for other purposes which required finished water meeting regulations (40 CFR Part 141 and 40 CFR Part 143) established pursuant to the Safe Drinking Water Act (Public Law 93- 523, 95-190) applicable to public water systems.

59. **Tidal conditions** mean conditions determined by the Department as appropriate for tidally influenced waters of the State to be analogous to the 7Q10 or the annual average flow for flowing waters of the State.

60. **Tidal saltwaters** means those waters whose elevation is subject to changes due to oceanic tides and which have chloride ion content in excess of 250 milligrams per liter (mg/l) (salinity = 0.48 parts per thousand).

61. **Toxic wastes** means those wastes or combinations of wastes including disease-causing agents which, discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict or impair growth in such organisms or their offspring.

62. **Underground source of drinking water** (USDW) means an aquifer or its portion:

a. Which supplies any public water system or individual residential well; or

b. Which contains a sufficient quantity of ground water to supply a public water system or individual residential well; and,

(1) Currently supplies drinking water for human consumption; or

(2) Contains water with less than ten thousand milligrams per liter total dissolved solids.

63. **Variance** means a short-term exemption from meeting certain otherwise applicable water quality standards.

64. **Water table** means that level below the land surface at which all the voids are filled with water at a pressure equal to atmospheric.

65. **Weekly average** means the average of all samples taken during any consecutive seven day period.

66. **Whole effluent toxicity** (WET) means the aggregate toxic effect of an aqueous sample measured directly by an aquatic toxicity test.

67. **Zone of initial dilution** (ZID) means that minimal area of a mixing zone immediately surrounding the outfall where water quality criteria are not met, provided there is no acute toxicity to drifting organisms and public health and welfare are not endangered.

C.APPLICABILITY OF STANDARDS.

1. The water quality standards are applicable to both surface waters and ground waters.

2. Any exception specified in this regulation is to be applied exclusively to the situation for which it was incorporated and not as a general rule applicable to all situations or waters of the State.

3. Uses in all waters shall be protected, wherever attainable, regardless of flow and classification of waters.

4. Critical flows for determining permit effluent limitations and/or permit conditions or requirements, including permit development such as wasteload allocations or load allocations in TMDL's, will be calculated in accordance with the following:

a. Aquatic life numeric criteria.

(1) The applicable critical flow conditions for aquatic life criteria shall be defined as 7Q10 or tidal conditions as determined by the Department. The numeric criteria of this regulation are not applicable to waters of the State when the flow rate is less than 7Q10 except as prescribed below.

(2) The Department shall consider conditions that are comparable to or more stringent than 7Q10 where appropriate to protect classified and existing uses, such as below dams and in tidal situations. Only those situations where the use of 7Q10 flows are determined to be impracticable, inappropriate, or insufficiently protective of aquatic life uses shall be considered as a situation in which the Department may consider other flow conditions.

(3) NPDES Permit conditions shall be based on a critical condition analysis (e.g., critical flow, temperature or pH, or a combination of factors which would represent a critical conditions). Regarding ambient water temperature as a component of a critical condition analysis, the Department may consider less stringent limits during November through February based on a critical ambient water temperature during November through February.

b. Human health and organoleptic numeric criteria.

(1) The applicable critical flow conditions for human health shall be defined as annual average flow for carcinogens, 7Q10 (or 30Q5 if provided by the applicant) for noncarcinogens, or tidal conditions as determined by the Department. The applicable critical flow conditions for organoleptic criteria shall be defined as annual average flow or tidal conditions as determined by the Department. The numeric criteria of this regulation are not applicable to waters of the State when the flow rate is less than the annual average flow for carcinogens or 7Q10 (or 30Q5 if provided by the applicant) for noncarcinogens, except as prescribed below.

(2) The Department shall consider conditions that are comparable to or more stringent than annual average flow, 7Q10, or 30Q5 (if provided by the applicant) where appropriate to protect the classified and existing uses, such as below dams and in tidal situations. Only those situations where the use of annual average flow, or 7Q10, or 30Q5 (if provided by the applicant) are determined to be impracticable, inappropriate, or insufficiently protective of human health uses shall be considered as a situation in which the Department may consider other flow conditions.

c. As described below, the Department may also consider conditions other than 7Q10 for use with an HCR.

(1) After a complete antidegradation review in compliance with Section D.2., an HCR for oxygen-demanding substances may be permitted by the Department for the following situations:

i. If other flow-related effluent conditions are allowed by federal effluent guidelines as specified in 40 CFR Parts 400 499 (Chapter I, Subchapter N) and when used the numeric criteria shall not be exceeded and all water quality standards are maintained and protected;

ii. For industrial discharges, after application of advanced wastewater treatment, as determined by the Department, for the type of wastewater discharged;

iii. For other discharges, after application of advanced wastewater treatment which will be defined, for this purpose, at or below the following permit effluent limitations of BOD5 = 10 mg/l, NH3-N = 1 mg/l, and DO = 6 mg/l.

(2) In cases where an HCR may be allowed, the permit effluent limitations for toxics will not be variable and will be based on the critical flow conditions (chemical-specific or WET).

(3) In cases where an HCR may be allowed, new or proposed expansions of existing permits shall require instream biological assessments and existing permits may require instream biological assessments.

5. Intermittent streams and ephemeral streams shall be considered waters of the State. The water quality standards of the class of the stream to which intermittent and ephemeral streams are tributary shall apply, disregarding any site-specific numeric criteria for the named waterbody. This does not preclude the development of site-specific numeric criteria for intermittent and ephemeral streams.

6. The standards of adjacent waters must be maintained in basins excavated from high ground and constructed solely for berthing vessels. The standards of the adjacent waters must also be maintained with regard to impacts from created marina basins.

7. The existing and classified uses of downstream waters shall be maintained and protected and existing uses shall be protected regardless of the classification of the downstream waters. In tidally-influenced waters, the existing and classified uses of both upstream and downstream waters shall be maintained and protected and the existing uses shall be protected regardless of the classification of the upstream and downstream waters.

8. Where surface waters are not classified by name (unlisted) in R.61-69, Classified Waters, the water quality standards of the class of the stream to which they are tributary shall apply, disregarding any site specific numeric criteria for the named waterbody. In tidal areas where an unlisted tributary may affect or flows between two differently classified waterbodies, regardless of whether the location is upstream or downstream, the more stringent numeric criteria of the classified waters apply to the unlisted tributary, disregarding any site-specific numeric criteria for those waterbodies. This does not preclude the development of site- specific numeric criteria for unlisted tributaries.

9. Because of natural conditions some surface and ground waters may have characteristics outside the standards established by this regulation. Such natural conditions do not constitute a violation of the water quality standards; however, degradation of existing water quality is prohibited unless consistent with Section D.4. of this regulation.

10. A mixing zone for surface waters may be allowed by the Department. All water quality standards of the classification of the surface waters, including affected downstream waters, are applicable unless a mixing zone, setting forth certain conditions, is granted by the Department. When the Department grants a mixing zone, the mixing zone shall not be an area of waste treatment nor shall it interfere with or impair the existing uses of the waterbody. The size of the mixing zone shall be minimized, as determined by the Department, and shall be based upon applicable critical flow conditions. Since mixing zones are allocated impact zones where human health and aquatic life numeric criteria can be exceeded, the Department shall restrict their use. The following prohibitions and restrictions are established in order to support these important uses of the waters of the State.

a. In order to protect human health, mixing zones are not allowed when: they would endanger public health and welfare, the mixing zone would adversely affect shellfish harvesting, or the mixing zone would be for bacteria (e.g. fecal coliform).

b. In order to protect aquatic life, mixing zones are not allowed when: a pollutant, excluding temperature or thermal, in a discharge would attract biota; the mixing zone would result in undesirable aquatic organisms or a dominance of nuisance species outside of the mixing zone; there is a reasonable expectation that a discharge would adversely affect a federally-listed endangered or threatened aquatic species, its habitat, or a proposed or designated critical habitat; the mixing zone would not allow safe passage of aquatic organisms when passage would otherwise be unobstructed; or the mixing zone would not allow for the protection and propagation of a balanced indigenous aquatic community in and on the water body.

c. In order to protect both human health and aquatic life, mixing zones are not allowed when: a discharge would not be predicted to or does not produce adequate mixing at the point of discharge; or a discharge would be to a waterbody where multiple discharges interact if the combined mixing zone would impair the waterbody outside the mixing zone. The Department may prohibit or limit mixing zones in waters of the State that may be considered a significant estuarine nursery habitat for resident species.

d. The size of the mixing zone shall be kept to a minimum and may be determined on an individual project basis considering biological, chemical, engineering, hydrological, and physical factors.

11. Mixing zones for ground waters may be allowed by the Department. In order to ensure the maintenance and protection of the uses of the waters of the State and in compliance with Section D of this regulation, any mixing zone granted by the Department shall be determined on an individual basis by the Department as prescribed below.

a. The numeric standards for Class GB ground water, Section H.9., are applicable unless a mixing zone solely within the bounds of the property, setting forth certain conditions, is granted by the Department. Such a mixing zone shall be granted upon satisfactory demonstration to the Department that:

(1) Reasonable measures have been taken or binding commitments are made to minimize the addition of contaminants to ground water and/or control the migration of contaminants in ground water;

(2) The ground water in question is confined to a shallow geologic unit which has little or no potential of being an Underground Source of Drinking Water, and discharges or will discharge to surface waters without contravening the surface water standards set forth in this regulation;

(3) The contaminant(s) in question occurs within the bounds of the property, and there is minimum possibility for ground water withdrawals (present or future) to create drawdown such that contaminants would flow off-site; and

(4) The contaminants or combination of contaminants in question are not dangerously toxic, mobile, or persistent.

b. [Reserved].

12. Site-specific numeric criteria for surface waters may be established by the Department to replace the numeric criteria of Sections E, G, and the appendix of this regulation or to add new numeric criteria not contained in this regulation. Establishment of such numeric criteria shall be subject to public participation and administrative procedures for adopting regulations. In addition, such site-specific numeric criteria shall not apply to tributary or downstream waters unless specifically described in the water classification listing R.61-69, Classified Waters.

13. In classifying and adopting standards for the waters of the State, the Department considers:

a. The size, depth, surface area covered, volume, flow direction, rate of flow, stream gradient and temperature of the water;

b. The character of the district bordering such water and its suitability for the uses and with a view to conserving it and encouraging the most appropriate use of the lands bordering on such water for residential, agricultural, industrial, or recreational purposes;

c. The uses which have been made, are being made, may be made or are desired to be made of such waters for transportation, domestic, and industrial consumption, irrigation, swimming, fishing, fish culture, fire prevention, sewage disposal or other uses;

d. The present quality of such waters; and

e. Information, about the four items above, from government agencies, interested groups, and the public.

D.ANTIDEGRADATION RULES.

1. Existing water uses and the level of water quality necessary to protect these existing uses shall be maintained and protected regardless of the water classification and consistent with the policies below.

a. A new activity or expansion of an existing activity shall not be allowed in Class ONRW, Class ORW, or Shellfish Harvesting Waters if it would exclude, through establishment of a prohibited area, an existing shellfish harvesting or culture use. A new activity or expansion of an existing activity which will result in a prohibited area may be allowed in Class SA or Class SB waters when determined to be appropriate by the Department and would not remove or impair an existing use.

b. Existing uses and water quality necessary to protect these uses are presently affected or may be affected by instream modifications or water withdrawals. The stream flows necessary to protect classified and existing uses and the water quality supporting these uses shall be maintained consistent with riparian rights to reasonable use of water.

c. Existing or classified ground water uses and the conditions necessary to protect those uses shall be maintained and protected.

2. Where surface water quality exceeds levels necessary to support propagation of fish, shellfish, and wildlife, and recreation in and on the water, that quality shall be maintained and protected unless the

Department finds, after intergovernmental coordination and public participation, that allowing lower water quality is necessary to important economic or social development in the areas where the waters are located. In allowing such lower water quality, water quality adequate to fully protect existing and classified uses shall be maintained. The highest statutory and regulatory requirements for all new and existing point sources shall be achieved and all cost-effective and reasonable best management practices for nonpoint source control shall be achieved within the State’s statutory authority and otherwise encouraged. In order to fulfill these goals, the Department shall consider (a) and (b) below when evaluating any proposed expansion or new discharge to waters of the State that will lower water quality to a measurable effect. This includes, but is not limited to, the new or increased loading of any pollutant or pollutant parameter in the effluent regardless of whether the discharge flow changes.

a. An alternatives analysis, conducted by the applicant, must demonstrate to the Department that none of the following applicable alternatives that would minimize or eliminate the lowering of water quality are economically and technologically reasonable:

(1) Water recycle or reuse;

(2) Use of other discharge locations;

(3) Connection to other wastewater treatment facilities;

(4) Use of land application;

(5) Product or raw material substitution;

(6) Any other treatment option or alternative.

b. After the alternatives analysis is completed, the Department shall evaluate whether a proposed discharge that will result in the lowering of water quality of a waterbody, and for which there are no economically or technologically reasonable alternatives, is necessary for important economic or social development. For this to be accomplished, several economic and social factors must be considered. If an evaluation of the economic and social factors reveals that affordable treatment options that, combined with any alternatives, would prevent the need for the lowering of water quality, the Department shall deny the request. Conformance of the proposed discharge with the applicable '208 Areawide Water Quality Management Plans may demonstrate importance to economic and social development as well as intergovernmental coordination and public participation. Activities requiring permits or certification by the Department shall provide for public participation through the Department’s existing public notification processes. Economic and social factors to be considered may include the following:

(1) Employment (increases, maintenance, or avoidance of reduction);

(2) Increased industrial production;

(3) Improved community tax base;

(4) Improved housing; and/or

(5) Correction of an environmental or public health problem.

3. The water quality of outstanding resource surface waters designated as Class ONRW or Class ORW shall be maintained and protected through application of the standards for these classifications as described in Section G.

4. Certain natural conditions may cause a depression of dissolved oxygen in surface waters while existing and classified uses are still maintained. The Department shall allow a dissolved oxygen depression in these naturally low dissolved oxygen waterbodies as prescribed below pursuant to the Act, Section 48-1-83, et seq., 1976 Code of Laws:

a. For purposes of section D of this regulation, the term "naturally low dissolved oxygen waterbody" is a waterbody that, between and including the months of March and October, has naturally low dissolved oxygen levels at some time and for which limits during those months shall be set based on a critical condition analysis. The term does not include the months of November through February unless low dissolved oxygen levels are known to exist during those months in the waterbody. For a naturally low dissolved oxygen waterbody, the quality of the surface waters shall not be cumulatively lowered more than 0.1 mg/l for dissolved oxygen from point sources and other activities; or

b. Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable water quality standard established for that waterbody, the minimum acceptable concentration is 90 percent of the natural condition. Under these circumstances, an anthropogenic dissolved oxygen depression greater than 0.1 mg/l shall not be allowed unless it is demonstrated that resident aquatic species shall not be adversely affected pursuant to Section 48-1-83. The Department may modify permit conditions to require appropriate instream biological monitoring.

c. The dissolved oxygen concentrations shall not be cumulatively lowered more than the deficit described above utilizing a daily average unless it can be demonstrated that resident aquatic species shall not be adversely affected by an alternate averaging period.

E. GENERAL RULES AND STANDARDS APPLICABLE TO ALL WATERS.

1. The General Assembly of South Carolina in the Act has declared the following policy: "It is declared to be the public policy of the State to maintain reasonable standards of purity of the air and water resources of the State, consistent with the public health, safety and welfare of its citizens, maximum employment, the industrial development of the State, the propagation and protection of terrestrial and marine fauna and flora, and the protection of physical property and other resources. It is further declared that to secure these purposes and the enforcement of the provisions of this Act, the Department of Health and Environmental Control shall have authority to abate, control and prevent pollution."

2. The classes and standards described in Section G and H of this regulation implement the above State policy by protecting the waters of South Carolina. Consistent with the above policy, the Department adopts the following general standards in items 3-17 for all waters of South Carolina.

3. No waters of the State shall be used for the sole or principal purpose of transporting or treating wastes.

4. a. Any discharge into waters of the State must be permitted by the Department and receive a degree of treatment and/or control which shall produce an effluent which is consistent with the Act, the Clean Water Act (P.L. 92-500, 95-217, 97-117, 100-4), this regulation, and related regulations. No permit issued by the Department shall be interpreted as creating any vested right in any person. Additionally, any discharge into waters of the State containing sanitary wastes shall be effectively disinfected as necessary to meet the appropriate standards of this regulation. The Department may require best management practices (BMPs)

for control of stormwater runoff as part of the requirements of an NPDES permit, a State construction permit, or a State 401 Water Quality Certification.

b. When not specifically covered by permit reporting requirements, any unauthorized discharge into waters of the State which may cause or contribute to an excursion of a water quality standard must be reported by the responsible party to the Department orally within 24 hours of becoming aware of such conditions. Further, written notification must be provided to the Department (Bureau of Water) within five (5) days of becoming aware of such conditions and the written notice must include the following:

(1) A description of the discharge and cause;

(2) The duration of the discharge, including exact dates and times, and if not corrected, the time that the unauthorized discharge is expected to cease, and what steps are being taken to eliminate, minimize, and prevent recurrence of the discharge.

5. All ground waters and surface waters of the State shall at all times, regardless of flow, be free from:

a. Sewage, industrial waste, or other waste that will settle to form sludge deposits that are unsightly, putrescent, or odorous to such degree as to create a nuisance, or interfere with classified water uses or existing water uses;

b. Floating debris, oil, grease, scum, and other floating material attributable to sewage, industrial waste, or other waste in amounts sufficient to be unsightly to such a degree as to create a nuisance or interfere with classified water uses or existing water uses;

c. Sewage, industrial, or other waste which produce taste or odor or change the existing color or physical, chemical, or biological conditions in the receiving waters or aquifers to such a degree as to create a nuisance, or interfere with classified water uses (except classified uses within mixing zones as described in this regulation) or existing water uses; and,

d. High temperature, toxic, corrosive, or deleterious substances attributable to sewage, industrial waste, or other waste in concentrations or combinations which interfere with classified water uses (except classified uses within mixing zones as described in this regulation), existing water uses, or which are harmful to human, animal, plant or aquatic life.

6. Waters where classified uses are not being attained can be reclassified for protection of an attainable use and standards designated for that use where:

a. Natural conditions prevent the attainment of the use; or

b. Natural, ephemeral, intermittent, low flow conditions, or water levels prevent the attainment of the use; or

c. Human caused conditions or sources prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

d. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use; or

e. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, preclude attainment of aquatic life protection uses; or

f. Controls more stringent than those required by Sections 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.

7. Before the Department may grant a variance for any water of the State, there must be a demonstration that one of the following factors for reclassifying uses has been satisfied:

a. Natural conditions prevent the attainment of the use; or

b. Natural, ephemeral, intermittent, low flow conditions, or water levels prevent the attainment of the use; or

c. Human caused conditions or sources prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

d. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use; or

e. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, preclude attainment of aquatic life protection uses; or

f. Controls more stringent than those required by Sections 301(b) and 306 of the Clean Water Act would result in adverse social and economic impact, disproportionate to the benefits to the public health, safety or welfare as a result of maintaining the standard.

8. If the demonstration necessary under Section E.7 above has been satisfied, the Department may then grant a variance provided the following apply:

a. The variance is granted to an individual discharger for a specific pollutant(s) or parameter(s) and does not otherwise modify water quality standards; and

b. The variance identifies and justifies the criterion that shall apply during the existence of the variance; and

c. The variance is established as close to the underlying criterion as is possible and upon expiration of the variance, the underlying criterion shall become the effective water quality standard for the waterbody; and

d. The variance is reviewed every three years, at a minimum, and extended only where the conditions for granting the variance still apply; and

e. The variance does not exempt the discharger from compliance with any applicable technology or other water quality-based permit effluent limitations; and

f. The variance does not affect permit effluent limitations for other dischargers.

9. Prior to removing any uses or granting a variance, notice and an opportunity for a public hearing shall be provided.

10. Discharge of fill into waters of the State is not allowed unless the activity is consistent with Department regulations and will result in enhancement of classified uses with no significant degradation to the aquatic ecosystem or water quality.

11. In order to protect and maintain lakes and other waters of the State, consideration needs to be given to the control of nutrients reaching the waters of the State. Therefore, the Department shall control nutrients as prescribed below.

a. Discharges of nutrients from all sources, including point and nonpoint, to waters of the State shall be prohibited or limited if the discharge would result in or if the waters experience growths of microscopic or macroscopic vegetation such that the water quality standards would be violated or the existing or classified uses of the waters would be impaired. Loading of nutrients shall be addressed on an individual basis as necessary to ensure compliance with the narrative and numeric criteria.

b. Numeric nutrient criteria for lakes are based on an ecoregional approach which takes into account the geographic location of the lakes within the State and are listed below. These numeric criteria are applicable to lakes of 40 acres or more. Lakes of less than 40 acres will continue to be protected by the narrative criteria.

(1) For the Blue Ridge Mountains ecoregion of the State, total phosphorus shall not exceed 0.02 mg/l, chlorophyll a shall not exceed 10 ug/l, and total nitrogen shall not exceed 0.35 mg/l.

(2) For the Piedmont and Southeastern Plains ecoregions of the State, total phosphorus shall not exceed 0.06 mg/l, chlorophyll a shall not exceed 40 ug/l, and total nitrogen shall not exceed 1.50 mg/l.

(3) For the Middle Atlantic Coastal Plains ecoregion of the State, total phosphorus shall not exceed 0.09 mg/l, chlorophyll a shall not exceed 40 ug/l, and total nitrogen shall not exceed 1.50 mg/l.

c. In evaluating the effects of nutrients upon the quality of lakes and other waters of the State, the Department may consider, but not be limited to, such factors as the hydrology and morphometry of the waterbody, the existing and projected trophic state, characteristics of the loadings, and other control mechanisms in order to protect the existing and classified uses of the waters.

d. The Department shall take appropriate action, to include, but not limited to: establishing numeric effluent limitations in permits, establishing Total Maximum Daily Loads, establishing waste load allocations, and establishing load allocations for nutrients to ensure that the lakes attain and maintain the above narrative and numeric criteria and other applicable water quality standards.

e. The criteria specific to lakes shall be applicable to all portions of the lake. For this purpose, the Department shall define the applicable area to be that area covered when measured at full pool elevation.

12. a. The water temperature of all Freshwaters which are free flowing shall not be increased more than 5oF (2.8°C) above natural temperature conditions and shall not exceed a maximum of 90°F (32.2°C) as a result of the discharge of heated liquids unless a different site-specific temperature standard as provided for in C.12. has been established, a mixing zone as provided in C.10. has been established, or a Section 316(a) determination under the Federal Clean Water Act has been completed.

b. The weekly average water temperature of all Shellfish Harvesting, Class SA and Class SB waters shall not exceed 4°F (2.2°C) above natural conditions during the fall, winter or spring, and shall not exceed 1.5°F (0.8°C) above natural conditions during the summer as a result of the discharge of heated liquids unless a different site-specific temperature standard as provided for in C.12. has been established, a mixing zone as provided for in C.10 has been established, or a Section 316(a) determination under the Federal Clean Water Act has been completed.

c. The weekly average water temperature of all Freshwaters which are lakes shall not be increased more than 5°F (2.8°C) above natural conditions and shall not exceed 90°F (32.2°C) as a result of the discharge of heated liquids unless a different site-specific temperature standard as provided for in C.12. has been established, a mixing zone as provided in C.10. has been established, or a Section 316(a) determination under the Federal Clean Water Act has been completed.

13. Numeric criteria based on organoleptic data (prevention of undesirable taste and odor) are adopted herein. Those substances and their criteria are listed in the appendix. For those substances which have aquatic life and/or human health numeric criteria and organoleptic numeric criteria, the most stringent of the three shall be used for derivation of permit effluent limitations.

14. Numeric criteria for the protection and maintenance of all classes of surface waters are adopted herein and are listed in Sections E, G, and the appendix. Footnotes that further describe the application of these numeric criteria are included in the appendix.

a. Application of numeric criteria to protect aquatic life.

(1) The stated CMC value shall be used as an acute toxicity number for calculating permit effluent limitations.

(2) The stated CCC value shall be used as a chronic toxicity number for calculating permit effluent limitations.

(3) If metals concentrations for numeric criteria are hardness-dependent, the CMC and CCC concentrations shall be based on 25 milligrams/liter (mg/l) hardness (as expressed as $CaCO_3$) if the ambient hardness is less than 25 mg/l. Concentrations of hardness less than 400 mg/l maybe based on the actual mixed stream hardness if it is greater than 25 mg/l and less than 400 mg/l and 400 mg/l if the ambient hardness is greater than 400 mg/l.

(4) If separate numeric criteria are given for fresh and salt waters, they shall be applied as appropriate. In transitional tidal and estuarine areas, the Department shall apply the more stringent of the criteria to protect the existing and classified uses of the waters of the State.

(5) The Department shall review new or revised EPA criteria for adoption by South Carolina when published in final form.

(6) If the State develops site-specific criteria for any substances for which EPA has developed national criteria, the site-specific criteria shall supersede the national criteria.

b. Application of numeric criteria to protect human health.

(1) If separate numeric criteria are given for organism consumption, water and organism consumption (W/O), and drinking water Maximum Contaminant Levels (MCLs), they shall be applied as appropriate.

The most stringent of the criteria shall be applied to protect the existing and classified uses of the waters of the State.

(2) The Department shall review new or revised EPA criteria for adoption by South Carolina when published in final form by EPA.

(3) If the State develops site-specific criteria for any substances for which EPA has developed national criteria, the site-specific criteria shall supersede the national criteria.

(4) Adoption of EPA human health criteria does not preclude the Department from considering health effects of other pollutants or from considering new or revised EPA criteria when developing effluent permit conditions.

c. Application of criteria for the derivation of permit effluent limitations.

(1) Numeric criteria for substances listed in Sections E, G, and the appendix shall be used by the Department to derive NPDES permit effluent limitations at the applicable critical flow conditions as determined by the Department unless an exception is provided below.

(2) When the derived permit effluent limitation based on aquatic life numeric criteria is below the practical quantitation limit for a substance, the derived permit effluent limitation shall include an accompanying statement in the permit that the practical quantitation limit using approved analytical methods shall be considered as being in compliance with the limit. Appropriate biological monitoring requirements shall be incorporated into the permit to determine compliance with appropriate water quality standards. Additionally, if naturally occurring instream concentration for a substance is higher than the derived permit effluent limitation, the Department may establish permit effluent limitations at a level higher than the derived limit, but no higher than the natural background concentration. In such cases, the Department may require biological instream monitoring and/or WET testing.

(3) When the derived permit effluent limitation based on human health numeric criteria is below the practical quantitation limit for a substance, the derived permit effluent limitation shall include an accompanying statement in the permit that the practical quantitation limit using approved analytical methods shall be considered as being in compliance with the limit. Additionally, if naturally occurring instream concentration for a substance is higher than the derived permit effluent limitation, the Department may establish permit effluent limitations at a level higher than the derived limit, but no higher than the natural background concentration.

(4) NPDES permit effluent limitations for metals shall normally be expressed on the permits as total recoverable metals, but the Department may utilize a federally- approved methodology to predict the dissolved fraction, partitioning coefficient, or the bioavailable portion of metals in calculating these limits.

(5) Except as provided herein, where application of MCLs or W/O numeric criteria using annual average flow for carcinogens, 7Q10 (or 30Q5 if provided by the applicant) for noncarcinogens, or comparable tidal condition as determined by the Department results in permit effluent limitations more stringent than limitations derived from other applicable human health (organism consumption only), aquatic life, or organoleptic numeric values; MCLs or W/O shall be used in establishing permit effluent limitations for human health protection. The Department may, after Notice of Intent included in a notice of a proposed NPDES permit in accordance with Regulation 61-9.124.10, determine that drinking water MCLs or W/O shall not apply to discharges to those waterbodies where there is: no potential to affect an existing or proposed drinking water source and no state-approved source water protection area. For purposes of this section, a proposed drinking water source is one for which a complete permit application, including plans

and specifications for the intake, is on file with the Department at the time of consideration of an NPDES permit application. for a discharge that will affect or has the potential to affect the drinking water source.

(6) Except as provided herein, where the Department may determine that an NPDES permitted discharge will not cause, have reasonable potential to cause, or contribute to an exceedence of the numeric criterion for turbidity under the following conditions:

i. The facility withdraws its surface intake water containing turbidity from the same body of water into which the discharge is made;

ii. The facility does not significantly concentrate or contribute additional turbidity to the discharged water;

iii. The facility does not alter the turbidity through chemical or physical means that would cause adverse water quality impacts to occur.

(7) Site-specific permit effluent limitations and alternate criteria less stringent than those derived in accordance with the above requirements may be derived where it is demonstrated that such limits and criteria shall maintain the existing and classified uses, adequate opportunity for public participation in such derivation process has occurred, and the effluent shall not cause criteria for human health to be exceeded. Where a site- specific permit effluent limitation and alternate criterion has been derived, such derivation shall be subject to EPA review as appropriate. Also, at a minimum, opportunity for input in derivation of a site-specific permit effluent limitation and alternate criterion shall be provided via public notice in NPDES permit notices.

(8) In order to protect recreational uses in freshwaters (including FW, and all types of Trout Waters) of the State, NPDES permit effluent limitations shall be specified as indicated below:

i. Monthly Average (*E. coli*)	126 MPN per 100 ml
ii. Daily Maximum (*E. coli*)	349 MPN per 100 ml (see c(12) below)
iii. Shellfish protection	Class SFH requirements for fecal coliform (see c(11)i. and c(11)ii. below) may be specified (in addition to the limits above) for the protection of downstream waters (regardless of their individual classification) with shellfish uses.
iv. Municipal separate storm sewer systems	For municipal separate storm sewer systems (as described in R.61-9.122.26.a.) compliance with the bacterial standards shall be determined in accordance with c(13) below.
v. Protection of upstream and/or downstream waters	Permit limitations may include (in addition to the requirements listed in c(8)i. and c(8)ii. above) one or more bacterial limitations for fecal coliform, *E. coli* and/or enterococci to protect both uses in the specific receiving water body and also to protect any upstream and/or downstream uses that may be required. If more than one bacterial limit is required, the conditions associated with each section below shall apply independently regardless of the water classification at the point of discharge.

vi. Class ORW or ONRW protection	For Class ORW or ONRW waters, the bacterial requirements shall be those applicable to the classification of the waterbody immediately prior to reclassification to either ORW or ONRW, including consideration of natural conditions. See G.5 and G.7 for prohibitions.

(9) In order to protect recreational uses in Class SA saltwaters of the State, NPDES permit effluent limitations shall be specified as indicated below:

i. Monthly Average (enterococci)	35 MPN per 100 ml
ii. Daily Maximum (enterococci)	104 MPN per 100 ml (see c(12) below)
iii. Shellfish protection	Class SFH requirements for fecal coliform (see c(11)i. and c(1)ii. below) may be specified (in addition to the limits above) for the protection of upstream and/or downstream waters (regardless of their individual classification) with shellfish uses.
iv. Municipal separate storm sewer systems	For municipal separate storm sewer systems (as described in R.61-9.122.26.a.) compliance with the bacterial standards shall be determined in accordance with c(13) below.
v. Protection of upstream and/or downstream waters	Permit limitations may include (in addition to the requirements listed in c(9)i. and c(9)ii. above) one or more bacterial limitations for fecal coliform, E. coli and /or enterococci to protect both uses in the specific receiving water body and also to protect any upstream or downstream uses that may be required. If more than one bacterial limit is required, the conditions associated with each section above or below shall apply independently regardless of the water classification at the point of discharge.
vi. Class ORW or ONRW protection	For Class ORW or ONRW waters, the bacterial requirements shall be those applicable to the classification of the waterbody immediately prior to reclassification to either ORW or ONRW, including consideration of natural conditions. See G.5 and G.7 for prohibitions.

(10) In order to protect recreational uses in Class SB saltwaters of the State, NPDES permit effluent limitations shall be specified as indicated below:

i. Monthly Average (enterococci)	35 MPN per 100 ml

ii. Daily Maximum (enterococci)	501 MPN per 100 ml (see c(12) below)
iii. Class SA recreational daily maximum and/or shellfish protection	Class SA daily maximum (see c(9)ii. above) recreational use requirements for enterococci and/or Class SFH requirements (see c(11)i. and c(11)ii. below) for fecal coliform may be specified (in addition to the limits above) for the protection of upstream and/or downstream waters (regardless of their individual classification).
iv. Municipal separate storm sewer systems	For municipal separate storm sewer systems (as described in R.61-9.122.26.a.) compliance with the bacterial standards shall be determined in accordance with c(13) below.
v. Protection of upstream and/or downstream waters	Permit limitations may include (in addition to the requirements listed in c(10)i. and c(10)ii. above) one or more bacterial limitations for fecal coliform, *E. coli* and /or enterococci to protect both uses in the specific receiving water body and also to protect any upstream or downstream uses that may be required. If more than one bacterial limit is required, the conditions associated with each section above or below shall apply independently regardless of the water classification at the point of discharge.
vi. Class ORW or ONRW protection	For Class ORW or ONRW waters, the bacterial requirements shall be those applicable

(11) In order to protect for the consumption of shellfish, for any discharge either directly or indirectly in Class SFH waters or in Class SA, Class SB, ORW or ONRW waters with existing and/or approved shellfish harvesting uses as described in Section C.7, including protection of shellfish upstream and/or downstream uses in all waters regardless of their classification, NPDES permit effluent limitations shall be specified as indicated below:

i. For protection of shellfish uses-Monthly Average (Fecal coliform)	14 MPN per 100 ml
ii. For protection of shellfish uses- Daily Maximum (Fecal coliform)	43 MPN per 100 ml (see c(12) below)
iii. For protection of recreational uses - Monthly Average (enterococci)	35 MPN per 100 ml

iv. For protection of recreational uses-Daily Maximum (enterococci)	104 MPN per 100 ml (see c(12) below)
v. Protection of upstream and/or downstream waters	Permit limitations may include (in addition to the requirements listed in c(11)i. through c(11)iv. above) one or more bacterial limitations for fecal coliform, *E. coli* and /or enterococci to protect both uses in the specific receiving water body and also to protect any upstream or downstream uses that may be required. If more than one bacterial limit is required, the conditions associated with each section above shall apply independently regardless of the water classification at the point of discharge.
vi. Municipal separate storm sewer systems	For municipal separate storm sewer systems (as described in R.61-9.122.26.a.) compliance with the bacterial standards shall be determined in accordance with c(13) below.

(12) Provided the permittee verifies in writing to the Department that conditions (12)i. through (12)iv. below have been met, the permittee would be in compliance with the daily maximum bacterial requirement. However, nothing in this regulation precludes the Department from taking action, depending on the individual circumstances to protect public health and/or the environment.

i. If the facility exceeds the permitted Daily Maximum bacterial limitation listed above (for E. coli, enterococci or fecal coliform) but two (2) additional samples collected within 48 hours of the original sample result do NOT exceed the required Daily Maximum limit; and

(A) For all waters not involving shellfish protection (regardless of the specific water classification), the individual bacterial sample result has not exceeded 800 MPN per 100ml, and for those waters involving shellfish protection, the individual bacterial sample result for fecal coliform has not exceeded 200 MPN per 100ml; and

(B) There is neither an existing Consent Order nor Administrative Order associated with the facilities operation of their disinfection system; and

(C) Either:

1. For facilities that routinely collect ten (10) bacterial samples per month (or 120 or more samples per calendar year), there were no more than four (4) total bacteria samples exceeding the daily maximum limit in the previous twelve (12 months); or

2. For facilities other than those listed in (C) 1. above (e.g. smaller facilities or those that do not routinely collect 10 samples or more per month), there was no more than one (1) bacterial sample exceeding the daily maximum limit in the previous twelve (12 months); and

ii. The permittee verifies that all disinfection equipment was fully functional, and the solids handling system was fully functional during that monitoring period; and

iii. Any additional bacterial sampling collected during the monthly monitoring period when the daily maximum exceedance occurred was reasonably distributed in time while maintaining representative sampling; and

iv. The permittee must provide sufficient laboratory data sensitivity (e.g., dilutions) to accurately represent the effluent bacterial concentration to utilize this procedure. Effluent bacterial results reported as greater than (>) do not meet this criteria, since the actual results are unknown.

(13) For waters of the State, where a permit has been issued pursuant to R.61-9.122.26 and R.61-9.122.34, the Department shall consider the permittee in compliance with the established bacterial (i.e., E. coli, enterococci, fecal coliform) criteria for recreational uses of the waterbody if the permittee is in compliance with their permit.

(14) TMDL(s), WLA(s), and LA(s) included in currently approved freshwater fecal coliform TMDL documents shall be converted to *E. coli* utilizing a translator equation established by the Department and shall be based upon existing targets included in approved freshwater fecal coliform bacteria TMDL documents.

(15) All effluent permit limitations which include WET shall require that the WET tests be conducted using *Ceriodaphnia dubia (C. dubia)*, except as stated. If the salinity of a discharge to a saline waterbody is high enough to be toxic to *C. dubia, Mysidopsis bahia (M. bahia)* shall be used. If the hardness of a waterbody is low enough to be toxic to *C. dubia*, then *Daphnia ambugua (D. ambigua)* may be used. Low salinity discharges to saltwater may be tested using either *C.dubia* or *M. bahia* with salinity adjustment, as determined by the Department. The Department may consider an alternative species if it can be demonstrated that the proposed species meets the requirements of 40 CFR 136.4 and 5., as approved by EPA. EPA test methods (40 CFR 136) for acute and chronic toxicity testing with freshwater organisms or marine and estuarine organisms must be followed. The Department may consider an alternative method if it can be demonstrated that the proposed method meets the requirements of 40 CFR 136, and is approved by EPA.

d. Evaluation of ambient water quality.

(1) If the numeric criterion for toxic pollutants is lower than the analytical detection limit, the criterion is not considered violated if the ambient concentration is below the detection limit and the instream indigenous biological community is not adversely impacted.

(2) If the ambient concentration is higher than the numeric criterion for toxic pollutants, the criterion is not considered violated if biological monitoring has demonstrated that the instream indigenous biological community is not adversely impacted.

(3) In order to appropriately evaluate the ambient water quality for the bioavailability of the dissolved portion of hardness dependent metals, the Department may utilize a federally- approved methodology to predict the dissolved fraction or partitioning coefficient in determining compliance with water quality standards established in this regulation.

(4) The assessment of fecal coliform for purposes of evaluating the shellfish harvesting use for South Carolina’s Shellfish Management Units is conducted in accordance with provisions of S.C. Regulation 61-47, Shellfish. R.61-47 also includes specific language describing the use of the allowable 10% exceedence value in the shellfish program.

(5) The assessment of enterococci for purposes of issuing swimming advisories for ocean beaches for recreational use will be based on the single sample maximum of 104/100 ml.

(6) The assessment of enterococci and *E. coli* for purposes of Section 303(d) listing determinations for recreational uses shall be based on the geometric mean with an allowable 10% exceedance, where sufficient data exists to calculate a geometric mean. In the absence of sufficient data to calculate a geometric mean, the assessment shall be based on the single sample maximum with an allowable 10% exceedance.

15. The Department may require biological or other monitoring in NPDES permits to further ascertain any bioaccumulative effects of pollutants. Such monitoring may include analyses of fish and shellfish, macroinvertebrates, macrophytes, and/or sediments in order to assess the accumulation of pollutants in tissues or sediments that:

a. May cause or have the potential to cause adverse impacts to the balanced indigenous aquatic community; and

b. May cause or have the potential to cause adverse impacts to human health and/or terrestrial flora and fauna.

16. The Department may consider other scientifically-defensible published data which are appropriate for use in developing permit limits and evaluating water quality for constituents for which EPA has not developed national criteria or South Carolina has no standards.

a. The Department shall apply a sensitivity factor to aquatic toxicity data unless, in the Department's judgment, the data represent a minimum of three appropriately sensitive species representing three taxonomic groups (plant, macroinvertebrate, and fish).

(1) If only an acute toxicity effect concentration for a number of species for a particular pollutant is given as an LC_{50}, the lowest concentration should be divided by an acute-to- chronic ratio (ACR) of 10 and a sensitivity factor of 3.3, for an acceptable instream concentration in order to protect against chronic toxicity effects.

(2) If a chronic toxicity effect concentration for a number of species for a particular pollutant is given as a no observed effect concentration (NOEC), the lowest concentration should be divided by a sensitivity factor of 3.3 in order to protect against chronic toxicity to the most sensitive species.

b. The Department must notify the permittee that other such data were used in developing permit limits and provide justification for their use.

17. Tests or analytical methods to determine compliance or non-compliance with standards shall be made in accordance with methods and procedures approved by the Department and the EPA. In making any tests or applying analytical methods to determine compliance or non- compliance with water quality standards, representative samples shall be collected in accordance with methods and procedures approved by the Department and the EPA. Consideration of representative sample methods shall include the following:

a. Surface water and ground water samples shall be collected so as to permit a realistic appraisal of quality and actual or potential damage to existing or classified water uses. For ground waters, consideration shall be given to, but shall not be limited to, depth to water table, flow direction, and velocity. For surface waters, time of day, flow, surface area, and depth shall be considered.

b. Biological assessment methods may be employed in appropriate situations to determine abnormal nutrient enrichment, trophic condition, LC_{50}, concentration of toxic substances, acceptable instream concentrations, or acceptable effluent concentrations for maintenance of a balanced indigenous aquatic community.

c. Temporal distribution of samples in tidally influenced waters shall cover the full range of tidal conditions.

d. Ambient toxicity tests used for screening purposes shall be conducted using *Ceriodaphnia dubia (C. dubia)*, except as stated. If salinity of a waterbody is high enough to be toxic to *C. dubia*, *Mysidopsis bahia (M. bahia)* will be used. If the hardness of a waterbody is low enough to be toxic to *C. dubia*, then *Daphnia ambigua (D. ambigua)* may be used. The Department may consider an alternative species if it can be demonstrated that the proposed species meets the requirements of 40 CFR.136.4 and 5, as approved by EPA. EPA test methods (40 CFR Part 136) for acute and chronic toxicity testing with freshwater organisms or marine and estuarine organisms must be followed. The Department may consider an alternative method if it can be demonstrated that the proposed method meets the requirements of 40 CFR.136, and is approved by EPA.

18. For the protection of human health, methylmercury concentration in fish or shellfish shall not exceed 0.3 mg/kg in wet weight of edible tissue.

a. NPDES permit implementation for methylmercury will require mercury monitoring, assessment and minimization for discharges that meet the following conditions;

(1) The receiving stream is impaired for methylmercury in fish or shellfish tissue, and;

(2) The discharge or proposed discharge has consistently quantifiable levels of mercury.

b. The need for a total mercury effluent limit, for the protection of aquatic life and/or human health, pursuant to R.61-9.122.44(d), shall be based on a reasonable potential analysis of the discharge compared to the mercury standards for ambient waters.

19. The assessment of methylmercury in fish or shellfish for purposes of Section 303(d) listing determinations shall be based on the Department’s Fish Consumption Advisories.

F. NARRATIVE BIOLOGICAL CRITERIA.

1. Narrative biological criteria are contained in this regulation and are described throughout the sections where applicable. The following are general statements regarding these narrative biological criteria.

a. Narrative biological criteria in Section A.4. describe the goals of the Department to maintain and improve all surface waters to a level that provides for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. These narrative criteria are determined by the Department based on the condition of the waters of the State by measurements of physical, chemical, and biological characteristics of the waters according to their classified uses.

b. Section C.10. describes narrative biological criteria relative to surface water mixing zones and specifies requirements necessary for the protection and propagation of a balanced indigenous aquatic community.

c. Narrative biological criteria shall be consistent with the objective of maintaining and improving all surface waters to a level that provides for the survival and propagation of a balanced indigenous aquatic community of fauna and flora attainable in waters of the State; and in all cases shall protect against degradation of the highest existing or classified uses or biological conditions in compliance with the antidegradation rules contained in this regulation. Section D.1.a. describes narrative biological criteria relative to activities in Outstanding National Resource Waters, Outstanding Resource Waters and Shellfish Harvesting Waters.

d. In order to determine the biological quality of the waters of the State, it is necessary that the biological component be assessed by comparison to a reference condition(s) based upon similar hydrologic and watershed characteristics that represent the optimum natural condition for that system. Such reference condition(s) or reaches of waterbodies shall be those observed to support the greatest variety and abundance of aquatic life in the region as is expected to be or would be with a minimal amount of disturbance from anthropogenic sources. Impacts from urbanization and agriculture should be minimal and natural vegetation should dominate the land cover. There should also be an appropriate diversity of substrate. Reference condition(s) shall be determined by consistent sampling and reliable measures of selected indicative communities of flora and fauna as established by the Department and may be used in conjunction with acceptable physical, chemical, and microbial water quality measurements and records judged to be appropriate for this purpose. Narrative biological criteria relative to activities in all waters are described in Section E.

e. In the Class Descriptions, Designations, and Specific Standards for Surface Waters Section, all water use classifications protect for a balanced indigenous aquatic community of fauna and flora. In addition, Trout Natural and Trout Put, Grow, and Take classifications protect for reproducing trout populations and stocked trout populations, respectively.

2. [Reserved].

G. CLASS DESCRIPTIONS, DESIGNATIONS, AND SPECIFIC STANDARDS FOR SURFACE WATERS.

1. All surface waters of the State, except as discussed in Section C., shall be identified within one of the classes described below. The Department may determine in accordance with Section 312 of the Clean Water Act that for some waterbodies (or portions of waterbodies), the designation of No Discharge Zone (NDZ) for Marine Sanitation Devices (MSDs) shall be enacted with application of the existing classified standards of the waterbody. Those waters classified by name shall be listed in Regulation 61-69 along with the NDZ designation, if applicable.

2. Where a surface water body is tributary to waters of a higher class, the quality of the water in the tributary shall be protected to maintain the standards of the higher classified receiving water.

3. For items not listed in each class, criteria published pursuant to Sections 304(a) and 307(a) of the Federal Clean Water Act or other documents shall be used as guides to determine conditions which protect water uses. Many of these criteria are listed in the appendix to this regulation. For consideration of natural conditions, refer to Sections: C.9., D.4., E.12., E.14.c.(2), E.14.c.(3), F.4.d., G.4., G.6., and G.9. For the following numeric criteria for turbidity (with the exception of Outstanding National Resource Waters, Outstanding Resource Waters, Trout waters, and Shellfish Harvesting Waters), compliance with these turbidity criteria may be considered to be met as long as the waterbody supports a balanced indigenous aquatic community when land management activities employ Best Management Practices (BMPs). For consideration, BMPs must be in full compliance with all specifications governing the proper design,

installation, operation and maintenance of such BMPs and all applicable permit conditions and requirements must be met.

4. **Outstanding National Resource Waters (ONRW)** are freshwaters or saltwaters which constitute an outstanding national recreational or ecological resource.

Quality Standards for Outstanding National Resource Waters

ITEMS	STANDARDS
a. Color, dissolved oxygen, fecal coliform enterococci, *E. coli*, pH, temperature, turbidity, and other parameters.	Water quality conditions shall be maintained and protected to the extent of the Department's statutory authority. Numeric and narrative criteria for Class ONRW shall be those applicable to the classification of the waterbody immediately prior to reclassification to Class ONRW, including consideration of natural conditions.

5. In order to maintain the existing quality of Class ONRW waters the following additional standards apply:

ITEMS	STANDARDS
a. Discharge from domestic, industrial, or agricultural waste treatment facilities; aquaculture; open water dredged spoil disposal.	None allowed.
b. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, concentrated aquatic animal production facilities, and uncontaminated groundwater from mining.	None allowed.
c. Dumping or disposal of garbage, cinders, ashes, oils, sludge, or other refuse.	None allowed.
d. Activities or discharges from waste treatment facilities in waters upstream or tributary to ONRW waters.	Allowed if there shall be no measurable impact on the downstream ONRW consistent with antidegradation rules.

6. Outstanding Resource Waters (ORW) are freshwaters or saltwaters which constitute an outstanding recreational or ecological resource or those freshwaters suitable as a source for drinking water supply purposes with treatment levels specified by the Department.

Quality Standards for Outstanding Resource Waters	
ITEMS	**STANDARDS**
a. Color, dissolved oxygen, fecal coliform enterococci, *E. coli*, pH, temperature, turbidity, and other parameters.	Water quality conditions shall be maintained and protected to the extent of the Department's statutory authority. Numeric and narrative criteria for Class ORW shall be those applicable to the classification of the waterbody immediately prior to reclassification to Class ORW, including consideration of natural conditions.

7. In order to maintain the existing quality of Class ORW waters the following additional standards apply:

ITEMS	STANDARDS
a. Discharge from domestic, industrial, agricultural waste treatment facilities; aquaculture; open water dredged spoil disposal.	None allowed.
b. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, concentrated aquatic animal production facilities, and uncontaminated groundwater from mining.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
c. Dumping or disposal of garbage, cinders, ashes, oils, sludge, or other refuse.	None allowed.
d. Activities or discharges from waste treatment facilities in waters upstream or tributary to ORW waters.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.

8. **Trout Waters**. The State recognizes three types of trout waters: Natural; Put, Grow, and Take; and Put and Take.

a. **Natural (TN)** are freshwaters suitable for supporting reproducing trout populations and a cold water balanced indigenous aquatic community of fauna and flora. Also suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.

b. **Put, Grow, and Take (TPGT)** are freshwaters suitable for supporting growth of stocked trout populations and a balanced indigenous aquatic community of fauna and flora. Also suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.

c. **Put and Take (TPT)** are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses. The standards of Freshwaters classification protect these uses.

9. The standards below protect the uses of Natural and Put, Grow, and Take trout waters.

Quality Standards for Trout Waters

ITEMS	**STANDARDS**
a. Garbage, cinders, ashes, oils, sludge, or other refuse	None allowed.
b. Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those given in a. above.	None alone or in combination with other substances or wastes in sufficient amounts to be injurious to reproducing trout populations in natural waters or stocked populations in put, grow, and take waters or in any manner adversely affecting the taste, color, odor, or sanitary condition thereof or impairing the waters for any other best usage as determined for the specific waters which are assigned to this class.
c. Toxic pollutants listed in the appendix.	As prescribed in Section E of this regulation.
d. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, concentrated aquatic animal production facilities, and uncontaminated groundwater from mining.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
e. Dissolved oxygen.	Not less than 6 mg/l.
f. *E. coli*	Not to exceed a geometric mean of 126/100 ml based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100 ml.

g. pH.	Between 6.0 and 8.0.
h. Temperature.	Not to vary from levels existing under natural conditions, unless determined that some other temperature shall protect the classified uses.
i. Turbidity.	Not to exceed 10 Nephelometric Turbidity Units (NTUs) or 10% above natural conditions, provided uses are maintained.

10. **Freshwaters (FW)** are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.

Quality Standards for Freshwaters	
ITEMS	**STANDARDS**
a. Garbage, cinders, ashes, oils, sludge, or other refuse	None allowed.
b. Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those given in a. above.	None alone or in combination with other substances or wastes in sufficient amounts to make the waters unsafe or unsuitable for primary contact recreation or to impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
c. Toxic pollutants listed in the appendix.	As prescribed in Section E of this regulation.
d. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, concentrated aquatic animal production facilities, and uncontaminated groundwater from mining.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
e. Dissolved oxygen.	Daily average not less than 5.0 mg/l with a low of 4.0 mg/1.
f. *E. coli*	Not to exceed a geometric mean of 126/100 ml based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100 ml.
g. pH.	Between 6.0 and 8.5.
h. Temperature.	As prescribed in E.12. of this regulation.

i. Turbidity. Except for Lakes. Lakes only.	Not to exceed 50 NTUs provided existing uses are maintained. Not to exceed 25 NTUs provided existing uses are maintained.

11. **Shellfish Harvesting Waters (SFH)** are tidal saltwaters protected for shellfish harvesting and uses listed in Class SA and Class SB. Suitable for primary and secondary contact recreation, crabbing, and fishing. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

Quality Standards for Shellfish Harvesting Waters	
ITEMS	**STANDARDS**
a. Garbage, cinders, ashes, oils, sludge, or other refuse	None allowed.
b. Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those given in a. above.	None alone or in combination with other substances or wastes in sufficient amounts to adversely affect the taste, color, odor, or sanitary condition of clams, mussels, or oysters for human consumption; or to impair the waters for any best usage as determined for the specific waters which are assigned to this class.
c. Toxic pollutants listed in the appendix.	As prescribed in Section E of this regulation.
d. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, and concentrated aquatic animal production facilities.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
e. Dissolved oxygen.	Daily average not less than 5.0 mg/l with a low of 4 mg/l.
f. Fecal coliform.	Not to exceed an MPN fecal coliform geometric mean of 14/100 ml; nor shall the samples exceed an MPN of 43/100 ml.
g. Enterococci.	Not to exceed a geometric mean of 35/100 ml based on at least four samples collected from a given sampling site over a 30 day period; nor shall a single sample maximum exceed 104/100 ml. Additionally, for beach monitoring and notification activities for CWA Section 406 only, samples shall not exceed a single sample maximum of 104/100 ml.

h. pH.	Shall not vary more than 3/10 of a pH unit above or below that of effluent-free waters in the same geological area having a similar total alkalinity and temperature, but not lower than 6.5 or above 8.5.
i. Temperature.	As prescribed in E.12. of this regulation.
j. Turbidity.	Not to exceed 25 (NTUs) provided existing uses are maintained.

k. The Department may designate prohibited areas where shellfish harvesting for market purposes or human consumption shall not be allowed, consistent with the antidegradation rule, Section D.1.a. of this regulation.

12. Class SA are tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption and uses listed in Class SB. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

Quality Standards for Class SA Waters	
ITEMS	**STANDARDS**
a. Garbage, cinders, ashes, oils, sludge, or other refuse.	None allowed.
b. Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those given in a. above.	None alone or in combination with other substances or wastes in sufficient amounts to make the waters unsafe or unsuitable for primary contact recreation or to impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
c. Toxic pollutants listed in the appendix.	As prescribed in Section E of this regulation.
d. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, and concentrated aquatic animal production facilities.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
e. Dissolved oxygen.	Daily average not less than 5.0 mg/1 with a low of 4.0 mg/1.

f. Enterococci.	Not to exceed a geometric mean of 35/100 ml based on at least four samples collected from a given sampling site over a 30 day period; nor shall a single sample maximum exceed 104/100 ml. Additionally, for beach monitoring and notification activities for CWA Section 406 only, samples shall not exceed a single sample maximum of 104/100 ml.
g. pH.	Shall not vary more than one-half of a pH unit above or below that of effluent-free waters in the same geological area having a similar total salinity, alkalinity and temperature, but not lower than 6.5 or above 8.5.
h. Temperature.	As prescribed in E.12. of this regulation.
i. Turbidity.	Not to exceed 25 NTUs provided existing uses are maintained.

j. The Department shall protect existing shellfish harvesting uses found in Class SA waters consistent with the antidegradation rule, Section D.1.a. of this regulation and shall establish permit limits in accordance with Section E.14.c(8), (9), (10), and (11) and Section G.11.f. of this regulation.

13. Class SB are tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption or human consumption. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

Quality Standards for Class SB Waters	
ITEMS	**STANDARDS**
a. Garbage, cinders, ashes, oils, sludge, or other refuse	None allowed.
b. Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those given in a. above.	None alone or in combination with other substances or wastes in sufficient amounts to make the waters unsafe or unsuitable for primary contact recreation or to impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
c. Toxic pollutants listed in the appendix.	As prescribed in Section E of this regulation.
d. Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, and concentrated aquatic animal production facilities.	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.

e. Dissolved oxygen.	Not less than 4.0 mg/1.
f. Enterococci.	Not to exceed a geometric mean of 35/100 ml based on at least four samples collected from a given sampling site over a 30 day period; nor shall a single sample maximum exceed 501/100 ml. Additionally, for beach monitoring and notification activities for CWA Section 406 only, samples shall not exceed a single sample maximum of 501/100 ml.
g. pH.	Shall not vary more than one-half of a pH unit above or below that of effluent-free waters in the same geological area having a similar total salinity, alkalinity and temperature, but not lower than 6.5 or above 8.5.
h. Temperature.	As prescribed in E.12. of this regulation.
i. Turbidity.	Not to exceed 25 NTUs provided existing uses are maintained.

j. The Department shall protect existing shellfish harvesting uses found in Class SB waters consistent with the antidegradation rule, Section D.1.a. of this regulation and shall establish permit limits in accordance with Section E.14.c(8), (9), (10), and (11) and Section G.11.f. of this regulation.

H. CLASS DESCRIPTIONS AND SPECIFIC STANDARDS FOR GROUND WATERS.

1. All ground waters of the State, except within mixing zones, shall be identified within one of the classes described below.

2. It is the policy of the Department to maintain the quality of ground water consistent with the highest potential uses. Most South Carolina ground water is presently suitable for drinking water without treatment and the State relies heavily upon ground water for drinking water. For this reason, all South Carolina ground water is classified Class GB effective on June 28, 1985.

3. The Department recognizes that Class GB may not be suitable for some ground water. Class GA is established for exceptionally valuable ground water and Class GC is established for ground water with little potential as an underground source of drinking water.

4. In keeping with this policy the Department declares that effective June 28, 1985, all ground waters of the State shall be protected to a quality consistent with the use associated with the classes described herein. Further, the Department may require the owner or operator of a contaminated site to restore the ground water quality to a level that maintains and supports the existing and classified uses (except classified uses within mixing zones, as described in this regulation). For purposes of this section, the term operator means any person in control of, or having responsibility for, the operation of on-site activities or property and owner means a person or a previous person who has assumed legal ownership of a property through the provisions of a contract of sale or other legally binding transfer of ownership. The term owner also means any person who owned, operated, or otherwise controlled activities at such site before the title or control of which was conveyed to a unit of State or local government due to bankruptcy, foreclosure, tax delinquency, abandonment, or similar means. However, nothing in this section shall be construed to supersede specific statutory or regulatory provision that relieves owners or operators of certain contaminated sites from liability for restoration of groundwater, including, without limitation, S.C. Code '44-2-80 (b) and (c). The term does not include a unit of State or local government which acquired ownership or control involuntarily through bankruptcy, tax delinquency, abandonment, or other circumstances in which the government involuntarily acquires title by virtue of its function as sovereign. The exclusion provided under this

paragraph shall not apply to any State or local government which has caused or contributed to the release or threatened release of a contaminant from the site, and such a State or local government shall be subject to these provisions in the same manner and to the same extent, both procedurally and substantively, as any nongovernmental entity.

5. A ground water monitoring program approved by the Department may be required for any existing or proposed disposal system or other activities to determine the ground water quality affected by such systems or activities. Such monitoring program may be required through the Department's permitting and certification programs.

6. Those ground waters which are classified Class GA or Class GC after petition and proper administrative procedures other than Class GB shall be described by location and listed in Regulation 61-69.

7. Class GA are those ground waters that are highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur and that are also characterized by either of the following two factors:

a. Irreplaceable, in that no reasonable alternative source of drinking water is available to substantial populations; or

b. Ecologically vital, in that the ground water provides the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat.

8. The standards below protect these ground waters:

Quality Standards for Class GA Ground Waters	
ITEMS	**STANDARDS**
a. Treated wastes, toxic wastes, deleterious substances, or constituents thereof.	None allowed.

9. **Class GB**. All ground waters of the State, unless classified otherwise, which meet the definition of underground sources of drinking water (USDW) as defined in Section B.

Quality Standards for Class GB Ground Waters	
ITEMS	**STANDARDS**
a. Inorganic chemicals.	Maximum contaminated levels as set forth in R.61-58, State Primary Drinking Water Regulations.
b. Organic chemicals.	Maximum contaminated levels as set forth in R.61-58, State Primary Drinking Water Regulations.
c. Man-made radionuclides, priority pollutant volatile organic compounds, herbicides, polychlorinated biphenyls, and other synthetic organic compounds not specified above, treated wastes, thermal wastes,	Not to exceed concentrations or amounts such as to interfere with the use actual or intended, as determined by the Department.

colored wastes or other wastes of constituents thereof.	

10. **Class GC** are those ground waters not considered potential sources of drinking water and of limited beneficial use, i.e., ground waters that exceed a concentration of 10,000 mg/l total dissolved solids or are otherwise contaminated beyond levels that allow cleanup using methods reasonably employed in public water system treatment. These ground waters also must not migrate to Class GA or Class GB ground waters or have a discharge to surface water that could cause degradation.

Quality Standards for Class GC Ground Waters	
ITEMS	**STANDARDS**
a. Treated wastes, toxic wastes, deleterious substances, or constituents thereof.	None which interfere with any existing use of an underground source of drinking water.

I. SEVERABILITY.

Should any section, paragraph, or other part of this regulation be declared invalid for any reason, the remainder shall not be affected.

APPENDIX: WATER QUALITY NUMERIC CRITERIA FOR THE PROTECTION OF AQUATIC LIFE AND HUMAN HEALTH

This appendix contains three charts (priority pollutants, nonpriority pollutants, and organoleptic effects) of numeric criteria for the protection of human health and aquatic life. The appendix also contains three attachments which address hardness conversions and application of ammonia criteria. Footnotes specific to each chart follow the chart. General footnotes pertaining to all are at the end of the charts prior to the attachments. The numeric criteria developed and published by EPA are hereby incorporated into this regulation. Please refer to the text of the regulation for other general information and specifications in applying these numeric criteria.

PRIORITY TOXIC POLLUTANTS

Priority Pollutant		CAS Number	Freshwater Aquatic Life		Saltwater Aquatic Life		Human Health			FR Cite/ Source
							For Consumption of:			
			CMC (µg/L)	CCC (µg/L)	CMC (µg/L)	CCC (µg/L)	Water & Organism (µg/L)	Organism Only (µg/L)	MCL (µg/L)	
1	Antimony	7440360					5.6 B, ee	640 B, ee	6 ee	65FR66443 SDWA
2	Arsenic	7440382	340 A, D, K	150 A, D, K	69 A, D, Y	36 A, D, Y	10 C	10 C	10 C	65FR31682 57FR60848 SDWA
3	Beryllium	7440417					J, ee	J, ee	4 ee	65FR31682 SDWA
4	Cadmium	7440439	0.53 D, E, K	0.10 D, E, K	43 D, Y	9.3 D, Y	J, ee	J, ee	5 ee	65FR31682 SDWA
5a	Chromium III	16065831	580 D, E, K	28 D, E, K			J, ee	J, ee	100 Total ee	EPA820/B-96-001 65FR31682 SDWA
5b	Chromium VI	18540299	16 D, K	11 D, K	1,100 D, Y	50 D, Y	J, ee	J, ee	100 Total ee	65FR31682 SDWA
6	Copper	7440508	3.8 D, E, K, Z, ll	2.9 D, E, K, Z, ll	5.8 D, Z, Y, cc	3.7 D, Z, Y, cc	1,300 T, ee			65FR31682
7	Lead	7439921	14 D, E, Y	0.54 D, E, Y	220 D, Y	8.5 D, Y				65FR31682
8	Mercury	7439976	1.6 D, K, dd	0.91 D, K, dd	2.1 D, bb, dd	1.1 D, bb, dd	0.050 B, ee	0.051 B, ee	2 ee	65FR31682 SDWA

9	Nickel	7440020	150 D, E, K	16 D, E, K	75 D, Y	8.3 D, Y	610 B, ee	4, 600 B, ee		65FR31682
10	Selenium	7782492	L, Q, S	5.0 S	290 D, aa	71 D, aa	170 Z, ee	4,200 ee	50 ee	65FR31682 65FR66443 SDWA
11	Silver	7440224	0.37 D, E, G		2.3 D, G					65FR31682
12	Thallium	7440280					0.24	0.47	2 ee	68FR75510 SDWA
13	Zinc	7440666	37 D, E, K	37 D, E, K	95 D, Y	86 D, Y	7,400 T, ee	26,000 T, ee		65FR31682 65FR66443
14	Cyanide	57125	22 K, P	5.2 K, P	1 P, Y	1 P, Y	140 ee, jj	140 ee, jj	200 ee	EPA820/B-96-001 57FR60848 68FR75510 SDWA
15	Asbestos	1332214							7 million fibers/L I, ee	57FR60848
16	2, 3, 7, 8-TCDD (Dioxin)	1746016						0.046 ppq O, C	30ppq O, C	State Standard SDWA
17	Acrolein	107028	3	3			6 ee, nn	9 ee, nn		74FR27535 74FR46587
18	Acrylonitrile	107131					0.051 B, C	0.25 B, C		65FR66443
19	Benzene	71432					2.2 B, C	51 B, C	5 C	IRIS 01/19/00 65FR66443 SDWA
20	Bromate	15541454							10 C	SDWA
21	Bromoform	75252					4.3 B, C	140 B, C	80 Total THMs C	65FR66443 SDWA
22	Bromoacetic acid	79083							60 Total HAA5 C,mm	SDWA
23	Carbon Tetrachloride	56235					0.23 B, C	1.6 B, C	5 C	65FR66443 SDWA
24	Chlorite	67481							100	SDWA

25	Chlorobenzene	108907			130 T, ee	1,600 T, ee	100 T, ee	68FR75510 SDWA
26	Chlorodibromomethane	124481			0.40 B, C	13 B, C	80 Total THMs C	65FR66443 SDWA
27	Chloroform	67663			5.7 B, C, hh	470 B, C, hh	80 Total THMs C	62FR42160 SDWA
28	Dibromoacetic acid	631641					60 Total HAA5 C, mm	SDWA
29	Dichloroacetic acid	79436					60 Total HAA5 C,mm	SDWA
30	Dichlorobromomethane	75274			0.55 B, C	17 B, C	80 Total THMs C	65FR66443 SDWA
31	1, 2-Dichloroethane	107062			0.38 B, C	37 B, C	5 C	65FR66443 SDWA
32	1, 1-Dichloroethylene	75354			330 ee	7,100 ee	7 C	68FR75510 SDWA
33	1, 2-Dichloropropane	78875			0.50 B, C	15 B, C	5 C	65FR66443 SDWA
34	1, 3-Dichloropropene	542756			0.34 ee	21 ee		68FR75510
35	Ethylbenzene	100414			530 ee	2,100 ee	700 ee	68FR75510 SDWA
36	Methyl Bromide	74839			47 B, ee	1,500 B, ee		65FR66443
37	Methylene Chloride	75092			4.6 B, C	590 B, C	5 C	65FR66443 SDWA
38	Monochloroacetic acid	79118					60 Total HAA5 C,mm	SDWA
39	1, 1, 2, 2-Tetrachloroethane	79345			0.17 B, C	4.0 B, C		65FR66443

40	Tetrachloroethylene	127184					0.69 C	3.3 C	5 C	65FR66443 SDWA
41	Toluene	108883					1,300 ee	15,000 ee	1000 ee	68FR75510 SDWA
42	1,2-Trans-Dichloroethylene	156605					140 ee	10,000 ee	100 ee	68FR75510 SDWA
43	Trichloroacetic acid	79039							60 Total HAA5 C,mm	SDWA
44	1, 1, 1-Trichloroethane	71556					J, ee	J, ee	200 ee	65FR31682 SDWA
45	1, 1, 2-Trichloroethane	79005					0.59 B, C	16 B, C	5 C	65FR66443 SDWA
46	Trichloroethylene	79016					2.5 C	30 C	5 C	65FR66443 SDWA
47	Vinyl Chloride	75014					0.025 kk	2.4 kk	2 C	68FR75510 SDWA
48	2-Chlorophenol	95578					81 B, T, ee	150 B, T, ee		65FR66443
49	2, 4-Dichlorophenol	120832					77 B, T, ee	290 B, T, ee		65FR66443
50	2, 4-Dimethylphenol	105679					380 B, T, ee	850 B, T, ee		65FR66443
51	2-Methyl- 4, 6-Dinitrophenol	534521					13 ee	280 ee		65FR66443
52	2, 4-Dinitrophenol	51285					69 B, ee	5,300 B, ee		65FR66443
53	Pentachlorophenol	87865	19 F, K	15 F, K	13 Y	7.9 Y	0.27 B, C	3.0 B, C, H	1 C	65FR31682 65FR66443 SDWA
54	Phenol	108952					10,000 T, ee, nn	860,000 T, ee, nn		74FR27535 74FR46587
55	2, 4, 6-Trichlorophenol	88062					1.4 B, C, T	2.4 B, C		65FR66443

56	Acenaphthene	83329					670 B, T, ee	990 B, T, ee		65FR66443
57	Anthracene	120127					8,300 B, ee	40,000 B, ee		65FR66443
58	Benzidine	92875					0.000086 B, C	0.00020 B, C		65FR66443
59	Benzo (a) Anthracene	56553					0.0038 B, C	0.018 B, C		65FR66443
60	Benzo (a) Pyrene	50328					0.0038 B, C	0.018 B, C	0.2 C	65FR66443 SDWA
61	Benzo (b) Fluoranthene	205992					0.0038 B, C	0.018 B, C		65FR66443
62	Benzo (k) Fluoranthene	207089					0.0038 B, C	0.018 B, C		65FR66443
63	Bis-2-Chloroethyl Ether	111444					0.030 B, C	0.53 B, C		65FR66443
64	Bis-2-Chloroisopropyl Ether	108601					1,400 B, ee	65,000 B, ee		65FR66443
65	Bi-s2-Ethylhexyl Phthalate (DEHP)	117817	V	V	V	V	1.2 B, C	2.2 B, C	6 C	65FR66443 SDWA
66	Butylbenzene Phthalate	85687	ii	ii	ii	ii	1,500 B, ee	1,900 B, ee		65FR66443
67	2-Chloronaphthalene	91587					1,000 B, ee	1,600 B, ee		65FR66443
68	Chrysene	218019					0.0038 B, C	0.018 B, C		65FR66443
69	Dibenzo(a,h)Anthracene	53703					0.0038 B, C	0.018 B, C		65FR66443

70	1, 2-Dichlorobenzene	95501					420 ee	1,300 ee	600 ee	68FR75510 SDWA
71	1, 3-Dichlorobenzene	541731					320 ee	960 ee		65FR66443
72	1, 4-Dichlorobenzene	106467					63 ee	190 ee	75 ee	68FR75510 SDWA
73	3, 3’-Dichlorobenzidine	91941					0.021 B, C	0.028 B, C		65FR66443
74	Diethyl Phthalate	84662	ii	ii	ii	ii	17,000 B, ee	44,000 B, ee		65FR66443
75	Dimethyl Phthalate	13113	ii	ii	ii	ii	270,000 B, ee	1,100,000 B, ee		64FR66443
76	Di-n-butyl Phthalate	84742	ii	ii	ii	ii	2,000 B, ee	4,500 B, ee		65FR66443
77	2, 4-Dinitrotoluene	121142					0.11 C	3.4 C		65FR66443
78	1, 2-Diphenylhydrazine	122667					0.036 B, C	0.20 B, C		65FR66443
79	Fluoranthene	206440					130 B, ee	140 B, ee		65FR66443
80	Fluorene	86737					1,100 B, ee	5,300 B, ee		65FR66443
81	Hexachlorobenzene	118741					0.00028 B, C	0.00029 B, C	1 C	65FR66443 SDWA
82	Hexachlorobutadiene	87683					0.44 B, C	18 B, C		65FR66443
83	Hexachlorocyclo-pentadiene	77474					40 T, ee	1100 T, ee	50 ee	68FR75510 SDWA
84	Hexachloroethane	67721					1.4 B, C	3.3 B, C		65FR66443
85	Indeno 1,2,3(cd) Pyrene	193395					0.0038 B, C	0.018 B, C		65FR66443

86	Isophorone	78591					35 B, C	960 B, C		65FR66443
87	Nitrobenzene	98953					17 B, ee	690 B, H, T, ee		65FR66443
88	N-Nitrosodimethylamine	62759					0.00069 B, C	3.0 B, C		65FR66443
89	N-Nitrosodi-n-Propylamine	621647					0.0050 B, C	0.51 B, C		65FR66443
90	N-Nitrosodiphenylamine	86306					3.3 B, C	6.0 B, C		65FR66443
91	Pyrene	129000					830 B, ee	4,000 B, ee		65FR66443
92	1, 2, 4-Trichlorobenzene	120821					35 ee	70 ee	70 ee	68FR75510 SDWA
93	Aldrin	309002	3.0 G, X		1.3 G, X		0.000049 B, C	0.000050 B, C		65FR31682 65FR66443
94	alpha-BHC	319846					0.0026 B, C	0.0049 B, C		65FR66443
95	beta-BHC	319857					0.0091 B, C	0.017 B, C		65FR66443
96	gamma-BHC (Lindane)	58899	0.95 K		0.16 G		0.98 ee	1.8 ee	0.2 C	65FR31682 68FR75510 SDWA
97	Chlordane	57749	2.4 G	0.0043 G, X	0.09 G	0.004 G, X	0.00080 B, C	0.00081 B, C	2 C	65FR31682 65FR66443 SDWA
98	4, 4’-DDT	50293	1.1 G, gg	0.001 G, X, gg	0.13 G, gg	0.001 G, X, gg	0.00022 B, C	0.00022 B, C		65FR31682 65FR66443
99	4, 4’-DDE	72559					0.00022 B, C	0.00022 B, C		65FR66443
100	4, 4’-DDD	72548					0.00031 B, C	0.00031 B, C		65FR66443

101	Dieldrin	60571	0.24 K	0.056 K, N	0.71 G	0.0019 G, X	0.000052 B, C	0.000054 B, C		65FR31682 65FR66443
102	alpha-Endosulfan	959988	0.22 G, W	0.056 G, W	0.034 G, W	0.0087 G, W	62 B, ee	89 B, ee		65FR31682 65FR66443
103	beta-Endosulfan	33213659	0.22 G, W	0.056 G, W	0.034 G, W	0.0087 G, W	62 B, ee	89 B, ee		65FR31682 65FR66443
104	Endosulfan Sulfate	1031078					62 B, ee	89 B, ee		65FR31682 65FR66443
105	Endrin	72208	0.086 K	0.036 K, N	0.037 G	0.0023 G, X	0.059 ee	0.060 ee	2 ee	68FR75510 SDWA
106	Endrin Aldehyde	7421934					0.29 B, ee	0.30 B, H, ee		65FR66443
107	Heptachlor	76448	0.52 G	0.0038 G, X	0.053 G	0.0036 G, X	0.000079 B, C	0.000079 B, C	0.4 C	65FR31682 65FR66443 SDWA
108	Heptachlor Epoxide	1024573	0.52 G, U	0.0038 G, U, X	0.053 G, U	0.0036 G, U, X	0.000039 B, C	0.000039B, C	0.2 C	65FR31682 65FR66443 SDWA
109	Polychlorinated Biphenyls PCBs	--		0.014 M, X		0.03 M, X	0.000064 B, C, M	0.000064 B, C, M	0.5 C	65FR31682 65FR66443 SDWA
110	Toxaphene	8001352	0.73	0.0002 X	0.21	0.0002 X	0.00028 B, C	0.00028 B, C	3 C	65FR31682 65FR66443 SDWA

Footnotes:

A This water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. In the arsenic criteria document (EPA 440/5-84-033, January 1985), Species Mean Acute Values are given for both arsenic (III) and arsenic (V) for five species and the ratios of the SMAVs for each species range from 0.6 to 1.7. Chronic values are available for both arsenic (III) and arsenic (V) for one species; for the fathead minnow, the chronic value for arsenic (V) is 0.29 times the chronic value for arsenic (III). No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive.

B This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

C This criterion is based on carcinogenicity of 10^{-6} risk. As prescribed in Section E of this regulation, application of this criterion for permit effluent limitations requires the use annual average flow or comparable tidal condition as determined by the Department.

D Freshwater and saltwater criteria for metals are expressed in terms of total recoverable metals. As allowed in Section E of this regulation, these criteria may be expressed as dissolved metal for the purposes of deriving permit effluent limitations. The dissolved metal water quality criteria value may be calculated by using these 304(a) aquatic life criteria expressed in terms of total recoverable metal, and multiplying it by a conversion factor (CF). The term "Conversion Factor" (CF) represents the conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. (Conversion Factors for saltwater CCCs are not currently available. Conversion factors derived for saltwater CMCs have been used for both saltwater CMCs and CCCs). See “Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria”, October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available from the Water Resource center, USEPA, 401 M St., SW, mail code RC4100, Washington, DC 20460; and 40CFR§131.36(b)(1). Conversion Factors can be found in Attachment 1 – Conversion Factors for Dissolved Metals.

E The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 25 mg/L as expressed as $CaCO_3$. Criteria values for other hardness may be calculated from the following: CMC (dissolved) = exp{m_A [ln(hardness)]+ b_A} (CF), or CCC (dissolved) = exp{m_C [ln (hardness)]+ b_C} (CF) and the parameters specified in Attachment 2 – Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent. As noted in footnote D above, the values in this appendix are expressed as total recoverable, the criterion may be calculated from the following: CMC (total) = exp{m_A [ln(hardness)]+ b_A}, or CCC (total) = exp{m_C [ln (hardness)]+ b_C}.

F Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: CMC = exp(1.005(pH)-4.869); CCC = exp(1.005(pH)-5.134). Values displayed in table correspond to a pH of 7.8.

G This criterion is based on 304(a) aquatic life criterion issued in 1980, and was issued in one of the following documents: Aldrin/Dieldrin (EPA 440/5-80-019), Chlordane (EPA 440/5-80-027), DDT (EPA 440/5-80-038), Endosulfan (EPA 440/5-80-046), Endrin (EPA 440/5-80-047), Heptachlor (440/5-80-052), Hexachlorocyclohexane (EPA 440/5-80-054), Silver (EPA 440/5-80-071). The Minimum Data Requirements and derivation procedures were different in the 1980 Guidelines than in the 1985 Guidelines. For example, a “CMC” derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

H No criterion for protection of human health from consumption of aquatic organisms excluding water was presented in the 1980 criteria document or in the *1986 Quality Criteria for Water*. Nevertheless, sufficient information was presented in the 1980 document to allow the calculation of a criterion, even though the results of such a calculation were not shown in the document.

I This criterion for asbestos is the Maximum Contaminant Level (MCL) developed under the Safe Drinking Water Act (SDWA) and the National Primary Drinking Water Regulation (NPDWR).

J EPA has not calculated a 304(a) human health criterion for this contaminant. The criterion is the Maximum Contaminant Level developed under the Safe Drinking Water Act (SDWA) and the National Primary Drinking Water Regulation (NPDWR).

K This criterion is based on a 304(a) aquatic life criterion that was issued in the *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water*, (EPA-820-B-96-001, September 1996). This value was derived using the GLI Guidelines (60FR15393-15399, March 23, 1995; 40CFR132 Appendix A); the difference between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. None of the decisions concerning the derivation of this criterion were affected by any considerations that are specific to the Great Lakes.

L The CMC = 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg /l and 12.82 µg /l, respectively.

M This criterion applies to total PCBs, (e.g., the sum of all congener or all isomer or homolog or Aroclor analyses.)

N The derivation of the CCC for this pollutant did not consider exposure through the diet, which is probably important for aquatic life occupying upper trophic levels.

O This state criterion is also based on a total fish consumption rate of 0.0175 kg/day.

P This water quality criterion is expressed asµg free cyanide (as CN)/L.

Q This value was announced (61FR58444-58449, November 14, 1996) as a proposed GLI 303 I aquatic life criterion

S This water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996 – CMC or 0.922 – CCC) that was used in the GLI to convert this to a value that is expressed in terms of dissolved metal.

T The organoleptic effect criterion is more stringent than the value for priority toxic pollutants.

U This value was derived from data for heptachlor and the criteria document provides insufficient data to estimate the relative toxicities of heptachlor and heptachlor epoxide.

V There is a full set of aquatic life toxicity data that show that DEHP is not toxic to aquatic organisms at or below its solubility limit.

W This value was derived from data for endosulfan and is most appropriately applied to the sum of alpha-endosulfan and beta-endosulfan.

X This criterion is based on a 304(a) aquatic life criterion issued in 1980 or 1986, and was issued in one of the following documents: Aldrin/Dieldrin (EPA440/5-80-019), Chlordane (EPA 440/5-80-027), DDT (EPA 440/5-80-038), Endrin (EPA 440/5-80-047), Heptachlor (EPA 440/5-80-052), Polychlorinated Biphenyls (EPA 440/5- 80-068), Toxaphene (EPA 440/5-86-006). This CCC is based on the Final Residue value procedure in the 1985 Guidelines. Since the publication of the Great Lakes Aquatic Life Criteria Guidelines in 1995 (60FR15393-15399, March 23, 1995), the EPA no longer uses the Final Residue value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria.

Y This water quality criterion is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85-227049, January 1985) and was issued in one of the following criteria documents: Arsenic (EPA 440/5-84-033), Cadmium (EPA 440/5-84-032), Chromium (EPA 440/5-84-029), Copper (EPA 440/5-84-031), Cyanide (EPA 440/5-84-028), Lead (EPA 440/5-84-027), Nickel (EPA 440/5-86-004), Pentachlorophenol (EPA 440/5-86-009), Toxaphene, (EPA 440/5-86-006), Zinc (EPA 440/5-87- 003).

Z When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of Water-Effect Ratios might be appropriate.

aa The selenium criteria document (EPA 440/5-87-006, September 1987) provides that if selenium is as toxic to saltwater fishes in the field as it is to freshwater fishes in the field, the status of the fish community should be monitored whenever the concentration of selenium exceeds 5.0 7g/L in salt water because the saltwater CCC does not take into account uptake via the food chain.

bb This water quality criterion was derived on page 43 of the mercury criteria document (EPA 440/5-84-026, January 1985). The saltwater CCC of 0.025 ug/L given on page 23 of the criteria document is based on the Final Residue value procedure in the 1985 Guidelines. Since the publication of the Great Lakes Aquatic Life criteria Guidelines in 1995 (60FR15393-15399, March 23, 1995), the EPA no longer uses the Final Residue value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria.

cc This water quality criterion was derived in *Ambient Water Quality Criteria Saltwater Copper Addendum* (Draft, April 14, 1995) and was promulgated in the Interim Final National Toxics Rule (60FR22228-222237, May 4, 1995).

dd This water quality criterion was derived from data for inorganic mercury (II), but is applied here to total mercury. If a substantial portion of the mercury in the water column is methylmercury, this criterion will probably be under protective. In addition, even though inorganic mercury is converted to methylmercury and methylmercury bioaccumulates to a great extent, this criterion does not account for uptake via the food chain because sufficient data were not available when the criterion was derived.

ee This criterion is a noncarcinogen. As prescribed in Section E of this regulation, application of this criterion for determining permit effluent limitations requires the use of 7Q10 or comparable tidal condition as determined by the Department.

gg This criterion applies to DDT and its metabolites (i.e., the total concentration of DDT and its metabolites should not exceed this value).

hh Although a new RfD is available in IRIS, the surface water criteria will not be revised until the National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) is completed, since public comment on the relative source contribution (RSC) for chloroform is anticipated.

ii Although EPA has not published a completed criteria document for phthalate, it is EPA’s understanding that sufficient data exist to allow calculation of aquatic life criteria.

jj This recommended water quality criterion is expressed as total cyanide, even though the IRIS RfD the EPA used to derive the criterion is based on free cyanide. The multiple forms of cyanide that are present in ambient water have significant differences in toxicity due to their abilities to liberate the CN-moiety. Some complex cyanides require even more extreme conditions than refluxing with sulfuric acid to liberate the CN-moiety. Thus, these complex cyanides are expected to have little or no ‘bioavailalbility’ to humans. If a substantial fraction of the cyanide present in a water body is present in a complexed form (e.g.,$FE_4[FE(CN)_6]_3$), this criterion may be overly conservative.

kk This recommended water quality criterion was derived using the cancer slope factor of 1.4 (Linear multi-stage model (LMS) exposure from birth).

ll Freshwater copper criteria may be calculated utilizing the procedures identified in EPA-822-R-07-001.

mm HAA5 means five haloacetic acids (monochloracitic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid and dibromoaccetic acid).

nn This criterion has been revised to reflect the EPA’s cancer slope factor (CSF) or reference dose (RfD), as contained in the Integrated Risk Information System (IRIS) as of (Final FR Notice June 10, 2009). The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

NON PRIORITY POLLUTANTS

Non Priority Pollutant		CAS Number	Freshwater Aquatic Life		Saltwater Aquatic Life		Human Health			FR Cite/Source
							For Consumption of:			
			CMC (µg/L)	CCC (µg/L)	CMC (µg/L)	CCC (µg/L)	Water & Organism (µg/L)	Organism Only (µg/L)	MCL (µg/L)	
1	Alachlor								2 M	SDWA

2	Ammonia	7664417	CRITERIA ARE pH AND TEMPERATURE DEPENDENT - SEE DOCUMENT FOR DETAILS C							EPA822-R99-014 EPA440/5-88-004
3	Aesthetic Qualities		NARRATIVE STATEMENT AND NUMERIC CRITERIA – SEE TEXT							Gold Book
4	Atrazine								3 M	SDWA
5	Bacteria		FOR PRIMARY CONTACT RECREATION AND SHELLFISH USES – SEE TEXT							Gold Book
6	Barium	7440393					1,000 A, L		2,000 L	Gold Book
7	Carbofuran	1563662							40 L	SDWA
8	Chlorine	7782505	19	11	13	7.5			G	Gold Book SDWA
9	Chlorophenoxy Herbicide 2, 4, 5, -TP	93721					10 A, L		50 L	Gold Book SDWA
10	Chlorophenoxy Herbicide 2, 4-D	94757					100 A, L		70 L	Gold Book SDWA
11	Chlorophyll *a*		NARRATIVE STATEMENT AND NUMERIC CRITERIA – SEE TEXT							State Standard
12	Chloropyrifos	2921882	0.083 F	0.041 F	0.011 F	0.0056 F				Gold Book
13	Color		NARRATIVE STATEMENT – SEE TEXT							State Standard
14	Dalapon	75990							200 L	SDWA
15	Demeton	8065483		0.1 E		0.1 E				Gold Book
16	1,2-Dibromo-3-chloropropane (DBCP)	96128							0.2 M	SDWA
17	Di(2-ethylhexyl) adipate	103231							400 L	SDWA
18	Dinoseb	88857							7 L	SDWA

19	Dinitrophenols	25550587					69 L	5,300 L		65FR66443
20	Nonylphenol	1044051	28	6.6	7.0	1.7				71FR9337
21	Diquat	85007							20 L	SDWA
22	Endothall	145733							100 L	SDWA
23	Ether, Bis Chloromethyl	542881					0.00010 D, M	0.00029 D, M		65FR66443
24	Cis-1, 2-dichloroethylene	156592							70 L	SDWA
25	Ethylene dibromide								0.05 M	SDWA
26	Fluoride	7681494							4000 L	SDWA
27	Glyphosate	1071836							700 L	SDWA
28	Guthion	86500		0.01 E		0.01 E				Gold Book
29	Hexachlorocyclo-hexane-Technical	319868					0.0123 L	0.0414 L		Gold Book
30	Malathion	121755		0.1 E		0.1 E				Gold Book
31	Methoxychlor	72435		0.03 E		0.03 E	100 A, L		40 L	Gold Book SDWA
32	Mirex	2385855		0.001 E		0.001 E				Gold Book
33	Nitrates	14797558					10, 000 L		10, 000 L	SDWA Gold Book

34	Nitrites	14797650							1,000 L	SDWA
35	Nitrogen, Total		NARRATIVE STATEMENT AND NUMERIC CRITERIA - SEE TEXT							State Standard
36	Nitrosamines						0.0008 L	1.24 L		Gold Book
37	Nitrosodibutylamine, N	924163					0.0063 A, M	0.22 A, M		65FR66443
38	Nitrosodiethylamine, N	55185					0.0008 A, M	1.24 A, M		Gold Book
39	Nitrosopyrrolidine, N	930552					0.016 M	34 M		65FR66443
40	Oil and Grease		NARRATIVE STATEMENT – SEE TEXT							Gold Book
41	Oxamyl	23135220							200 L	SDWA
42	Oxygen, Dissolved	7782447	WARMWATER, COLDWATER, AND EXCEPTIONS FOR NATURAL CONDITIONS - SEE TEXT K							Gold Book State Standard
43	Diazinon	333415	0.17	0.17	0.82	0.82				71FR9336
44	Parathion	56382	0.065 H	0.013 H						Gold Book
45	Pentachlorobenzene	608935					1.4 E	1.5 E		65FR66443
46	pH		SEE TEXT I							Gold Book State Standard
47	Phosphorus, Total		NARRATIVE STATEMENT AND NUMERIC CRITERIA - SEE TEXT							State Standard
48	Picloram	1918021							500 L	SDWA
49	Salinity		NARRATIVE STATEMENT - SEE TEXT							Gold Book
50	Simazine	122349							4 L	SDWA

51	Solids,Suspended,and Turbidity		NARRATIVE STATEMENT AND NUMERIC CRITERIA - SEE TEXT							Gold Book State Standard
52	Styrene	100425							100 L	SDWA
53	Sulfide-Hydrogen Sulfide	7783064		2.0 E		2.0 E				Gold Book
54	Tainting Substances		NARRATIVE STATEMENT - SEE TEXT							Gold Book
55	Temperature		SPECIES DEPENDENT CRITERIA - SEE TEXT J							Red Book
56	1, 2, 4, 5-Tetrachlorobenzene	95943					0.97 D	1.1 D		65FR66443
57	Tributyltin (TBT)	688733	0.46	0.063	0.37	0.010				EPA 822-F-00-008
58	2, 4, 5-Trichlorophenol	95954					1,800 B, D	3,600 B, D		65FR66443
59	Xylenes, Total								10, 000 L	SDWA
60	Uranium								30	SDWA
61	Beta particles and photon emitters								4 Millirems/ yr	SDWA
62	Gross alpha particle activity								15 picocuries per liter (pCi/l)	SDWA
63	Radium 226 and Radium 228 (combined)								5 pCi/l	SDWA

Footnotes:

A This human health criterion is the same as originally published in the Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value is now published in the Gold Book.

B The organoleptic effect criterion is more stringent than the value presented in the non priority pollutants table.

C According to the procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, except possibly where a very sensitive species is important at a site, freshwater aquatic life should be protected if both conditions specified in Attachment 3 - Calculation of Freshwater Ammonia Criterion are satisfied.

D This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of April 8, 1998. The fish tissue bioconcentration factor (BCF) used to derive the original criterion was retained in each case.

E The derivation of this value is presented in the Red Book (EPA 440/9-76-023, July, 1976).

F This value is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85-227049, January 1985) and was issued in the following criteria document: Chloropyrifos (EPA 440/5-86-005).

G A more stringent Maximum Residual Disinfection Level (MRDL) has been issued by EPA under the Safe Drinking Water Act. Refer to S.C. Regulation 61-58, *State Primary Drinking Water Regulations*.

H This value is based on a 304(a) aquatic life criterion that was issued in the *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water* (EPA-820-B-96-001). This value was derived using the GLI Guidelines (60FR15393-15399, March 23, 1995; 40CFR132 Appendix A); the differences between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. No decision concerning this criterion was affected by any considerations that are specific to the Great Lakes.

I South Carolina has established some site-specific standards for pH. These site-specific standards are listed in S.C. Regulation 61-69, *Classified Waters*.

J U.S. EPA, 1976, Quality Criteria for Water 1976.

K South Carolina has established numeric criteria in Section G for waters of the State based on the protection of warmwater and coldwater species. For the exception to be used for waters of the State that do not meet the numeric criteria established for the waterbody due to natural conditions, South Carolina has specified the allowable deficit in Section D.4. and used the following document as a source. U.S. EPA, 1986, Ambient Water Quality Criteria for Dissolved Oxygen, EPA 440/5-86-003, National Technical Information Service, Springfield, VA. South Carolina has established some site-specific standards for DO. These site-specific standards are listed in S.C. Regulation 61-69, *Classified Waters*.

L This criterion is a noncarcinogen. As prescribed in Section E of this regulation, application of this criterion for determining permit effluent limitations requires the use of 7Q10 or comparable tidal condition as determined by the Department

M This criterion is based on an added carcinogenicity risk. As prescribed in Section E of this regulation, application of this criterion for permit effluent limitations requires the use annual average flow or comparable tidal condition as determined by the Department.

ORGANOLEPTIC EFFECTS

Pollutant		CAS Number	Organoleptic Effect Criteria (µg/L)	FR Cite/Source
1	Acenaphthene	83329	20	Gold Book
2	Chlorobenzene	108907	20	Gold Book
3	3-Chlorophenol		0.1	Gold Book
4	4-Chlorophenol	106489	0.1	Gold Book
5	2, 3-Dichlorophenol		0.04	Gold Book

6	2, 5-Dichlorophenol		0.5	Gold Book
7	2, 6-Dichlorophenol		0.2	Gold Book
8	3, 4-Dichlorophenol		0.3	Gold Book
9	2, 4, 5-Trichlorophenol	95954	1	Gold Book
10	2, 4, 6-Trichlorophenol	88062	2	Gold Book
11	2, 3, 4, 6-Tetrachlorophenol		1	Gold Book
12	2-Methyl-4-Chlorophenol		1,800	Gold Book
13	3-Methyl-4-Chlorophenol	59507	3,000	Gold Book
14	3-Methyl-6-Chlorophenol		20	Gold Book
15	2-Chlorophenol	95578	0.1	Gold Book
16	Copper	7440508	1,000	Gold Book
17	2, 4-Dichlorophenol	120832	0.3	Gold Book
18	2, 4-Dimethylphenol	105679	400	Gold Book
19	Hexachlorocyclopentadiene	77474	1	Gold Book
20	Nitrobenzene	98953	30	Gold Book
21	Pentachlorophenol	87865	30	Gold Book
22	Phenol	108952	300	Gold Book
23	Zinc	7440666	5,000	45FR79341

Footnote:

These criteria are based on organoleptic (taste and odor) effects. Because of variations in chemical nomenclature systems, this listing of pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. Also listed are the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

WATER QUALITY CRITERIA ADDITIONAL NOTES

1. Criteria Maximum Concentration and Criterion Continuous Concentration

The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CMC and CCC are just two of the six parts of a aquatic life criterion; the other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedence, and chronic frequency of allowed exceedence.

2. Criteria for Priority Pollutants, Non Priority Pollutants and Organoleptic Effects

This appendix lists all priority toxic pollutants and some nonpriority toxic pollutants, and both human health effect and organoleptic effect criteria issued pursuant to CWA §304(a), the SDWA, and the NPDWR. Blank spaces indicate that EPA has no CWA §304(a) criteria recommendations. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A of 40CFR Part 423.

3. Human Health Risk

The human health criteria for the priority and non priority pollutants are based on carcinogenicity of 10^{-6} risk.

4. Water Quality Criteria published pursuant to Section 304(a) or Section 303(c) of the CWA

Many of the values in the appendix were published in the California Toxics Rule. Although such values were published pursuant to Section 303(c) of the CWA, they represent the EPA's most recent calculation of water quality criteria.

5. Calculation of Dissolved Metals Criteria

The 304(a) criteria for metals are shown as total recoverable metals. As allowed in Section E of this regulation, these criteria may be expressed as dissolved metals. Dissolved metals criteria may be calculated in one of two ways (please refer to Attachments). For freshwater metals criteria that are hardness-dependent, the dissolved metal criteria may be calculated using a hardness of 25 mg/l as expressed as $CaCO_3$. Saltwater and freshwater metals' criteria that are not hardness-dependent are calculated by multiplying the total recoverable criteria before rounding by the appropriate conversion factors. The final metals' criteria in the table are rounded to two significant figures. Information regarding the calculation of hardness dependent conversion factors are included in the footnotes.

6. Chemical Abstract Services Number

The Chemical Abstract Services number (CAS) for each pollutant is provided (where available).

7. Gold Book Reference

The Gold Book reference listed in the appendix refers to the May 1, 1986 EPA publication EPA 440/5-86-001.

8. Federal Register Reference

The FR listed in the appendix refers to the appropriate *Federal Register* listing. and source refers to the origin of the value. Many of the numeric values contained in this appendix have been modified, revised, or altered and therefore, the source as listed may not be the same as it appears in this table. Also, South Carolina may have selected to use a different value or may have promulgated a different value in its previous iterations of this regulation, so differences from these sources should be expected.

9. Maximum Contaminant Levels

The appendix includes Maximum Contaminant Levels (MCLs) developed under the Safe Drinking Water Act (SDWA) and the National Primary Drinking Water Regulation (NPDWR).

10. Organoleptic Effects

The appendix contains 304(a) criteria for pollutants with toxicity-based criteria as well as non-toxicity based criteria. The basis for the non-toxicity based criteria are organoleptic effects (e.g., taste and odor) which would make water and edible aquatic life unpalatable but not toxic to humans. The table includes criteria for organoleptic effects for 23 pollutants. Pollutants with organoleptic effect criteria more stringent than the criteria based on toxicity (e.g., included in both the priority and non-priority pollutant tables) are footnoted as such.

11. Category Criteria

In the 1980 criteria documents, certain water quality criteria were published for categories of pollutants rather than for individual pollutants within that category. Subsequently, in a series of separate actions, the EPA derived criteria for specific pollutants within a category. Therefore, in this appendix South Carolina is replacing criteria representing categories with individual pollutant criteria (e.g., 1, 3-dichlorobenzene, 1, 4-dichlorobenzene and 1, 2-dichlorobenzene).

12. Specific Chemical Calculations

A. Selenium

(1) Human Health

In the 1980 Selenium document, a criterion for the protection of human health from consumption of water and organisms was calculated based on a BCF of 6.0 l/kg and a maximum water-related contribution of 35 Φg Se/day. Subsequently, the EPA Office of Health and Environmental Assessment issued an errata notice (February 23, 1982), revising the BCF for selenium to 4.8 L/kg. In 1988, EPA issued an addendum (ECAO-CIN-668) revising the human health criteria for selenium. Later in the final National Toxic Rule (NTR, 57 FR 60848), EPA withdrew previously published selenium human health criteria, pending EPA review of new epidemiological data.

This appendix includes human health criteria for selenium, calculated using a BCF of 4.8 L/kg along with the current IRIS RfD of 0.005 mg/kg/day. South Carolina included these water quality criteria in the appendix because the data necessary for calculating a criteria in accordance with EPA’s 1980 human health methodology are available.

(2) Aquatic Life

This appendix contains aquatic life criteria for selenium that are the same as those published in the CTR. In the CTR, EPA proposed an acute criterion for selenium based on the criterion proposed for selenium in the Water Quality Guidance for the Great Lakes System (61FR584440. The GLI and CTR proposals take into account data showing that selenium’s two prevalent oxidation state in water, selenite and selenate, present differing potentials for aquatic toxicity, as well as new data indication that various forms of selenium are additive. The new approach produces a different selenium acute criterion concentration, or CMC, depending upon the relative proportions of selenite, selenate, and other forms of selenium that are present. EPA is currently undertaking a reassessment of selenium, and expects the 304(a) criterion for selenium will be revised based on the final reassessment (63FR26186). However, until such time as revised water quality criteria for selenium are published by the EPA, the water quality criteria in this appendix are EPA’s current 304(a) criteria.

B. Chromium (III)

The aquatic life water quality criteria for chromium (III) included in the appendix are based on the values presented in the document titled: *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water*.

C. PCBs

In this appendix, South Carolina is publishing aquatic life and human health criteria based on total PCBs rather than individual arochlors.

Attachment 1 - Conversion Factors for Dissolved Metals

Metal	Conversion Factor freshwater CMC	Conversion Factor freshwater CCC	Conversion Factor saltwater CMC	Conversion Factor saltwater CCC
Arsenic	1.000	1.000	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]	0.994	0.994
Chromium III	0.316	0.860	--	--
Chromium VI	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]	0.951	0.951
Mercury	0.85	0.85	0.85	0.85
Nickel	0.998	0.997	0.990	0.990
Selenium	--	--	0.998	0.998
Silver	0.85	--	0.85	--
Zinc	0.978	0.986	0.946	0.946

Attachment 2 - Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent

Chemical	m_A	b_A	m_C	b_C	Freshwater Conversion Factors (CF)	
					Acute	Chronic
Cadmium	1.0166	-3.924	0.7409	-4.719	1.136672-[ln (hardness)(0.041838)]	1.101672-[ln (hardness)(0.041838)]
Chromium III	0.8190	3.7256	0.8190	0.6848	0.316	0.860
Copper	0.9422	-1.700	0.8545	-1.702	0.960	0.960
Lead	1.273	-1.460	1.273	-4.705	1.46203-[ln (hardness)(0.145712)]	1.46203-[ln (hardness)(0.145712)]
Nickel	0.8460	2.255	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.52	--	--	0.85	--
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

Attachment 3 - Calculation of Freshwater Ammonia Criterion

1. The one-hour average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every three years on the average, the CMC calculated using the following equation:

$$CMC = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$$

In situations where salmonids are absent, the CMC may be calculated using the following equation:

$$CMC = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$$

2. The thirty-day average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every three years on the average, the CCC calculated using the following equations:

When fish early life stages (ELS) are present:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) \times \min(2.85, 1.45x10^{0.028\times(25-T)})$$

When fish early life stages are absent:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) \times 1.45 \times 10^{0.028\times(25-\max(T,7))}$$

and the highest four-day average within the 30-day period does not exceed 2.5 times the CCC.

In the absence of information substantiating that ELS are absent, the ELS present equation will be used