



EPA-600/R-09/151
December 2009

Characterization of Coal Combustion Residues from Electric Utilities – Leaching and Characterization Data



Characterization of Coal Combustion Residues from Electric Utilities – Leaching and Characterization Data

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Contract No. EP-C-09-027

Work Assignment No. 0-7

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ACKNOWLEDGMENTS

Authors are grateful to the input provided by G. Helms, U.S. EPA, Office of Solid Waste and Emergency Response (Washington, D.C.) in helping with the research design and application of improved leaching test methods to provide better characterization data for fly ash and other coal combustion residues.

Overall project planning and integration was carried out jointly by D.S. Kosson and F. Sanchez (Vanderbilt University), and P. Kariher (ARCADIS).

R. Delapp and D. McGill of Vanderbilt University were responsible for the chemical analyses of the leachate samples except for mercury analysis. All other laboratory testing including physical and chemical analysis, sample digestion, and leaching tests of fly ash and other coal combustion residues was conducted by ARCADIS. Technical assistance was provided by A. Garrabrants of Vanderbilt University. Solid phase chromium analysis by X-ray Absorption Fine Structure was carried out under the direction of N.D. Hutson (U.S. EPA). Database management and data presentation technical assistance was provided by L.H. Turner (Turner Technology, LLC) and P. Seignette (Energy Research Centre of the Netherlands).

K. Ladwig and the Electric Power Research Institute (EPRI) are gratefully acknowledged for assistance in obtaining coal combustion residue samples and providing information from the EPRI database on coal combustion residues.

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 these 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 Roadmap¹ 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 used². 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

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 research⁵, 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 thallium⁶. 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).

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>.

Characterization of Coal Combustion Residues III

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 exposure⁷.

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

⁷DWEL 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 models⁸. 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.

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>.

Characterization of Coal Combustion Residues III

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

¹¹U.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 modeling¹².

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.

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).

Characterization of Coal Combustion Residues III

Table ES-2. Leach results for $5.4 \leq \text{pH} \leq 12.4$ and at “own pH¹³” from evaluation of thirty-four fly ashes.

	Hg	Sb	As	Ba	B	Cd	Cr	Co	Pb	Mo	Se	Tl
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 $5.4 \leq \text{pH} \leq 12.4$ and at “own pH” from evaluation of twenty FGD gypsums.

	Hg	Sb	As	Ba	B	Cd	Cr	Co	Pb	Mo	Se	Tl
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.

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 SO₂ 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

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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 SO₂ 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 (CaSO₄•H₂O). 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 SO₂ 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 (CaSO₃•½H₂O). In natural oxidation systems, the by-product is a mixture of CaSO₃•½H₂O and CaSO₄•H₂O. 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 managed¹⁴.” 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.

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

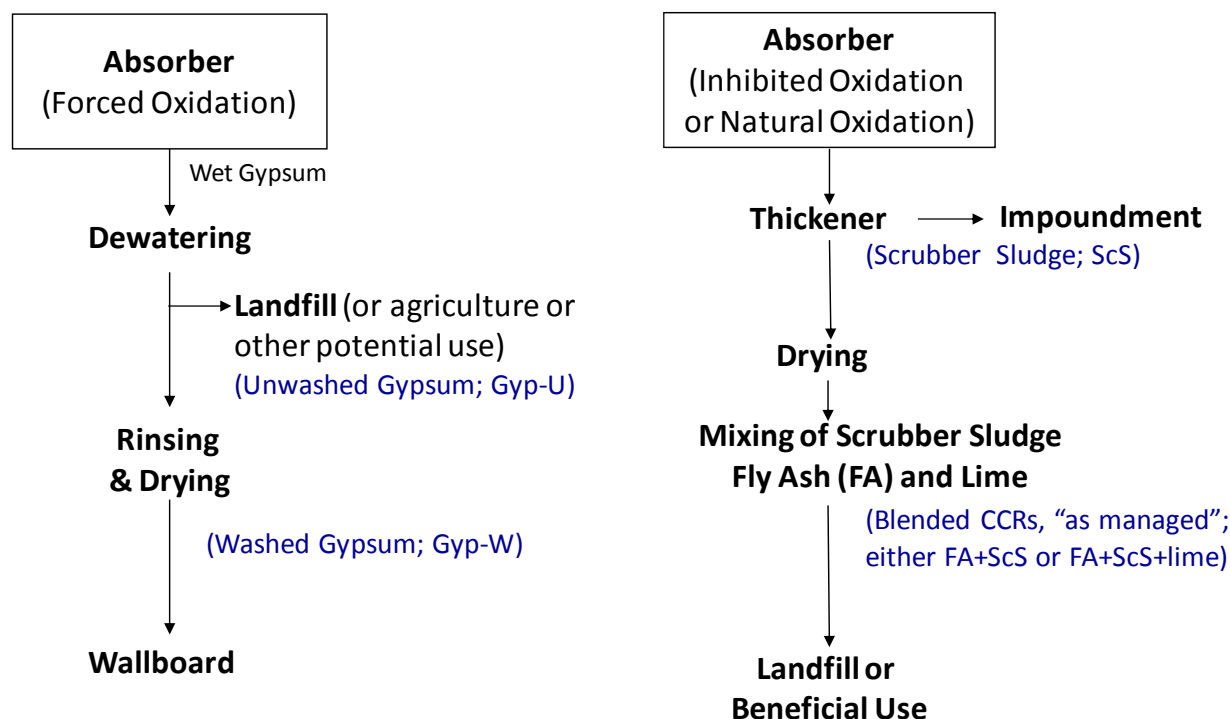


Figure 1. Flow diagram describing processing and nomenclature of FGD scrubber residues and samples included in this study.

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—has 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

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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 equilibrium¹⁵ 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.

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 wastes¹⁶ 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

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

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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 regulations¹⁷ will necessitate the addition of new air pollution control devices for NO_x and SO₂ 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) 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
Bitu- minous	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- bitu- minous	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.

¹⁷On 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, SO₂, 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 SO₂ 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 SO₂ control requirements, additional post-combustion NO_x control and flue gas desulfurization (FGD) systems for SO₂ 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).

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

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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 SO₂ 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 addition¹⁹. 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.

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).

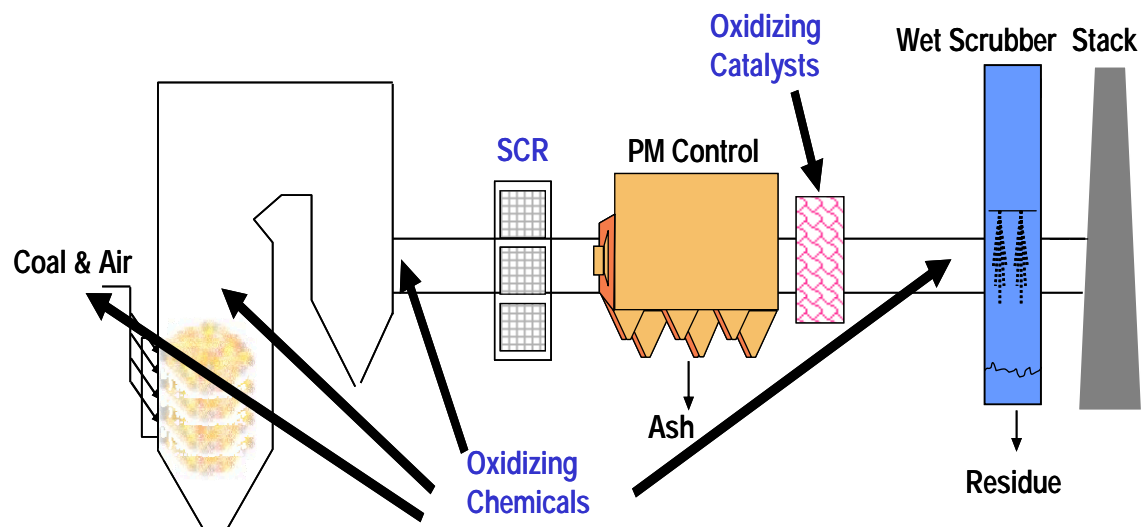


Figure 2. Illustration of available technology for multi-pollutant control at coal-fired power plants.

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 (COHPACTM). 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 COHPACTM and when combined with sorbent injection is referred to as Toxic Emission Control (TOXECONTM). 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™ option; or
- Injection of powdered sorbent between ESP fields (TOXECON-II™ approach).

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

- Injection rate of the sorbent measured in lb/MMacf²⁰;
- Flue gas conditions, including temperature and concentrations of HCl and sulfur trioxide (SO₃), 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.

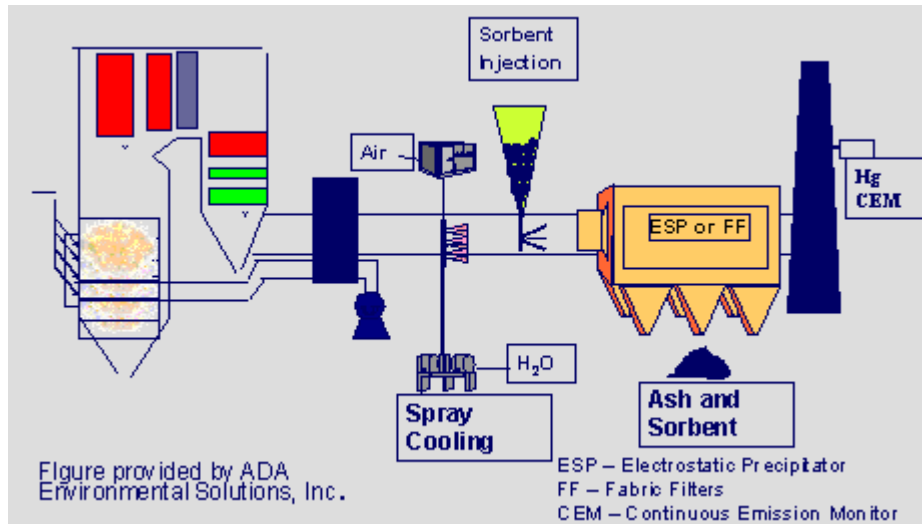


Figure 3. Coal-fired boiler with sorbent injection and spray cooling (Senior et al., 2003).

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.

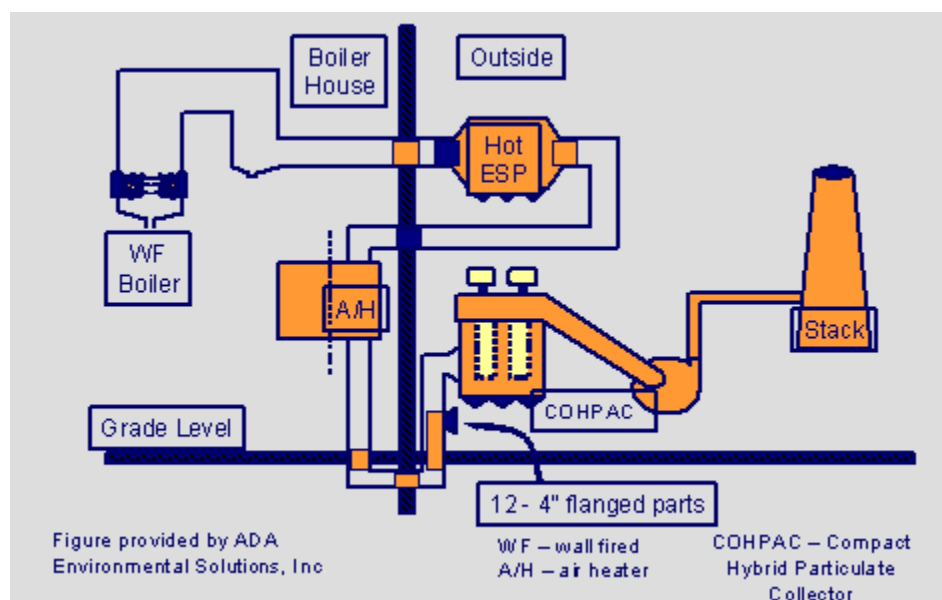


Figure 4. Flow diagram for power plant with a hot ESP, carbon injection, and a compact hybrid particulate collector (Senior et al., 2003).

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 gas²¹, the number of active sites²² 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;

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

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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 °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.

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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 Totals	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).

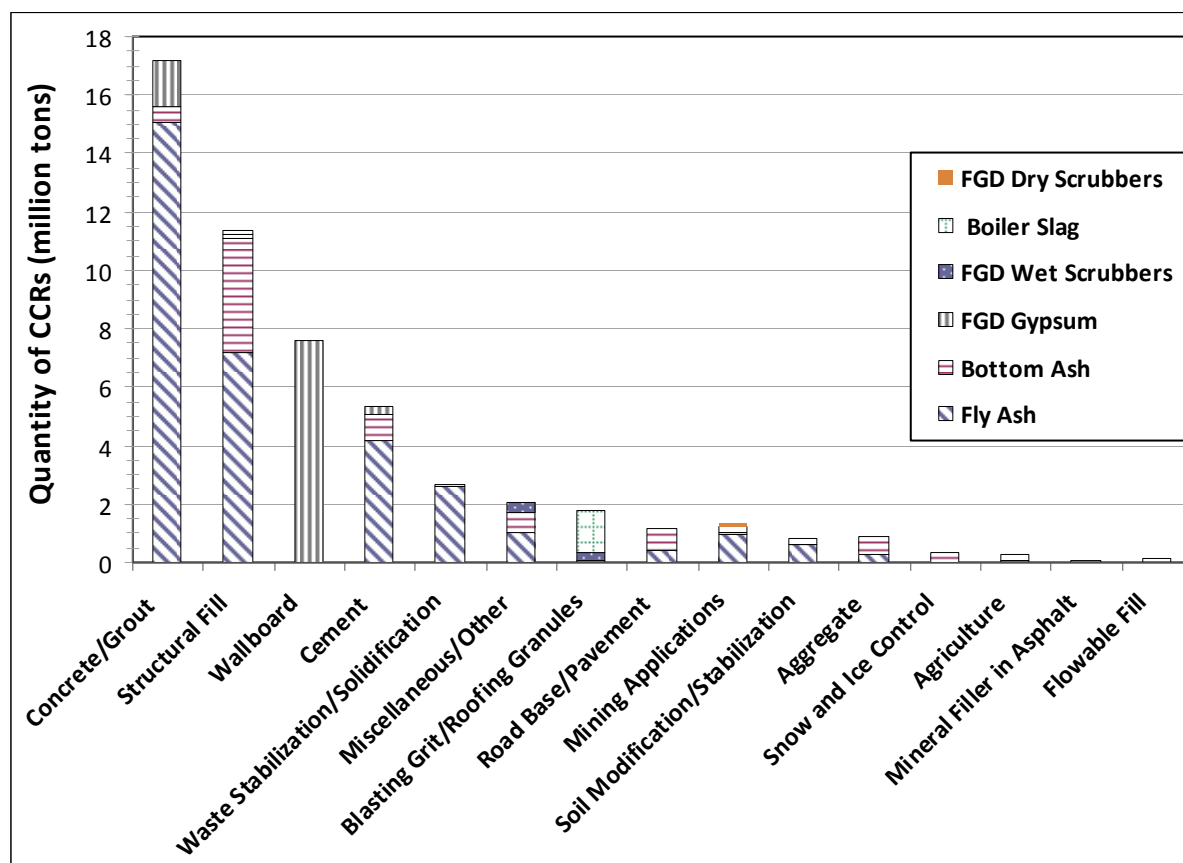


Figure 5. Uses of CCRs based on 2006 industry statistics (ACAA, 2007).

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.

Characterization of Coal Combustion Residues III

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 monofilled²³ 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

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 leaching²⁵.

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;

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.

Characterization of Coal Combustion Residues III

- 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 conservative²⁸ 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.

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 Ratio) 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.* lignite²⁹), 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).

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.

Characterization of Coal Combustion Residues III

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								
¹ C	Low S Bit	None	HS-ESP + ACI + COHPAC	None	None	GAT			DGD					
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 Appalachian	SOFA ⁴	HS-ESP	None	None	LAB								
¹ L	Southern Appalachian	SOFA	Br-ACI + HS-ESP	None	None	LAT			KGD					
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						

Characterization of Coal Combustion Residues III

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)

³BP – 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.

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

⁵Facility 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.

Characterization of Coal Combustion Residues III

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
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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
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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
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Characterization of Coal Combustion Residues III

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
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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
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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
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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

Characterization of Coal Combustion Residues III

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
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Gypsum, unwashed and washed

Bituminous, Low S

Facility U	UAU	Southern Appalachian	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None
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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
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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
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Characterization of Coal Combustion Residues III

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
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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
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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
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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
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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 1313³⁰ 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 appropriate³¹ 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

³⁰Preliminary 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 1314³² 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 °C for at least one hour in the sample preparation manifold prior to analysis with N₂ 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 $\pm 1\%$ and have a precision of $\pm 1\%$.

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 °C, 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 °C. 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 $\mu\text{g}/\text{cm}^2$ 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/HNO₃ 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.

Characterization of Coal Combustion Residues III

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.

Characterization of Coal Combustion Residues III

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	Detection Limit,
	Limit mg/kg	wt % 2 σ (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 matrix³³ and verified by the analysis of calibration standards near the calculated MDL according to (EPA, 2004). The MDL then was determined by multiplying the

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 5×10^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 $0.025 \mu\text{g/L}$ was 0.00069. Therefore, the MDL was set equal to the instrument detection limit of $0.001 \mu\text{g/L}$ times the minimum dilution factor from sample preparation (3.59) to result in an MDL of $0.0036 \mu\text{g/L}$. The ML was set to 10 times the instrument detection limit and rounded to the nearest integer value as above. The resulting ML was $0.01 \mu\text{g/L}$.

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

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.

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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%

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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 pH³⁵” 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

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).

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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 fulfilled³⁷.

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 surface³⁸. This observation has been supported by the observation of mercury dimer formation during sorption (Munro et al., 2001) and the occurrence

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 °C (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.

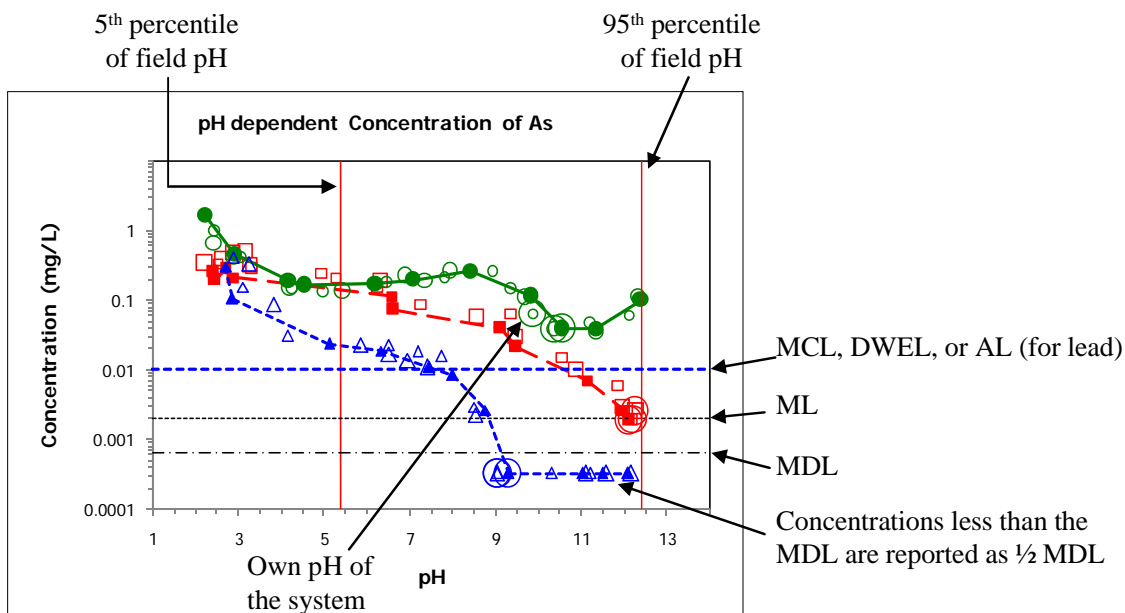


Figure 6. An example of eluate concentrations as a function of pH from SR002.1. Different colors, symbols and line types are used to represent different data sets. In this example figure, green, red, and blue indicate different CCR samples and open symbols are used to represent replicate data.

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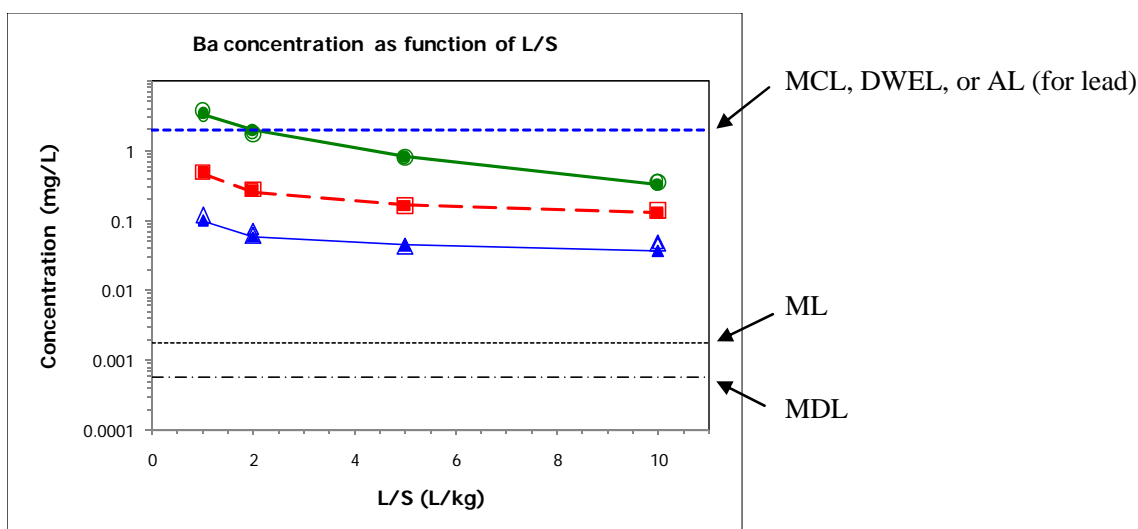


Figure 7. An example of eluate concentrations as a function of LS ratio from SR003.1.

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).

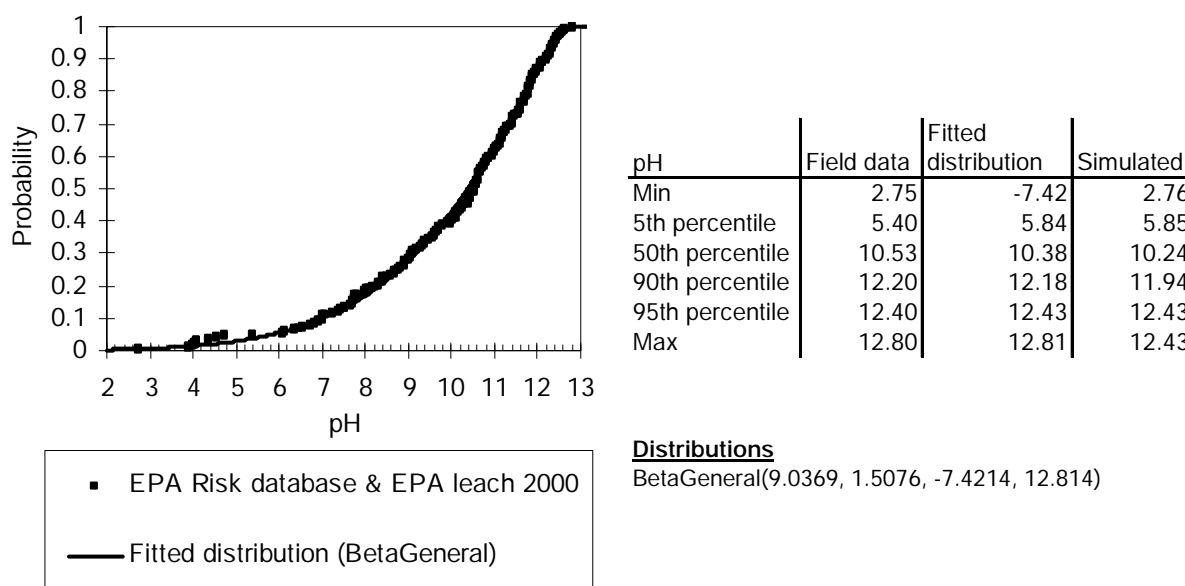


Figure 8. Probability distributions for field pH. Summary statistics for the field data and the probability distribution are provided to the right of the graph (EPA, 2000; EPA, 2007b; EPRI, 2006).

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

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 $\mu\text{g/g}$, and in scrubber sludges 80-3,000 $\mu\text{g/g}$. 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 $\mu\text{g/g}$, 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 $\mu\text{g/g}$.

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

Chromium (Cr) (Figure 14). Cr content in fly ash was 70-200 $\mu\text{g/g}$, and 1-20 $\mu\text{g/g}$ 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 $\mu\text{g/g}$ compared to 9-20 $\mu\text{g/g}$ for other samples).

Mercury (Hg) (Figure 15 and Figure 16). Hg content in all CCRs was from 0.01-20 $\mu\text{g/g}$ 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 $\mu\text{g/g}$, with one exception in fly ash at 80 $\mu\text{g/g}$ (Facility U, sample UFA). Mo content in gypsum was 1-10 $\mu\text{g/g}$. 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 $\mu\text{g/g}$, 0.4-10 $\mu\text{g/g}$ in gypsum and 2-30 $\mu\text{g/g}$ 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 $\mu\text{g/g}$ and 0.15-8 $\mu\text{g/g}$ 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 $\mu\text{g/g}$ with two samples with approximately 200 $\mu\text{g/g}$ (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 $\mu\text{g/g}$ 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

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calcium had acidic own pH values (typically $4 < \text{pH} < 5$) compared to samples with medium and high calcium content that had alkali own pH values (typically $\text{pH} > 10$). 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.

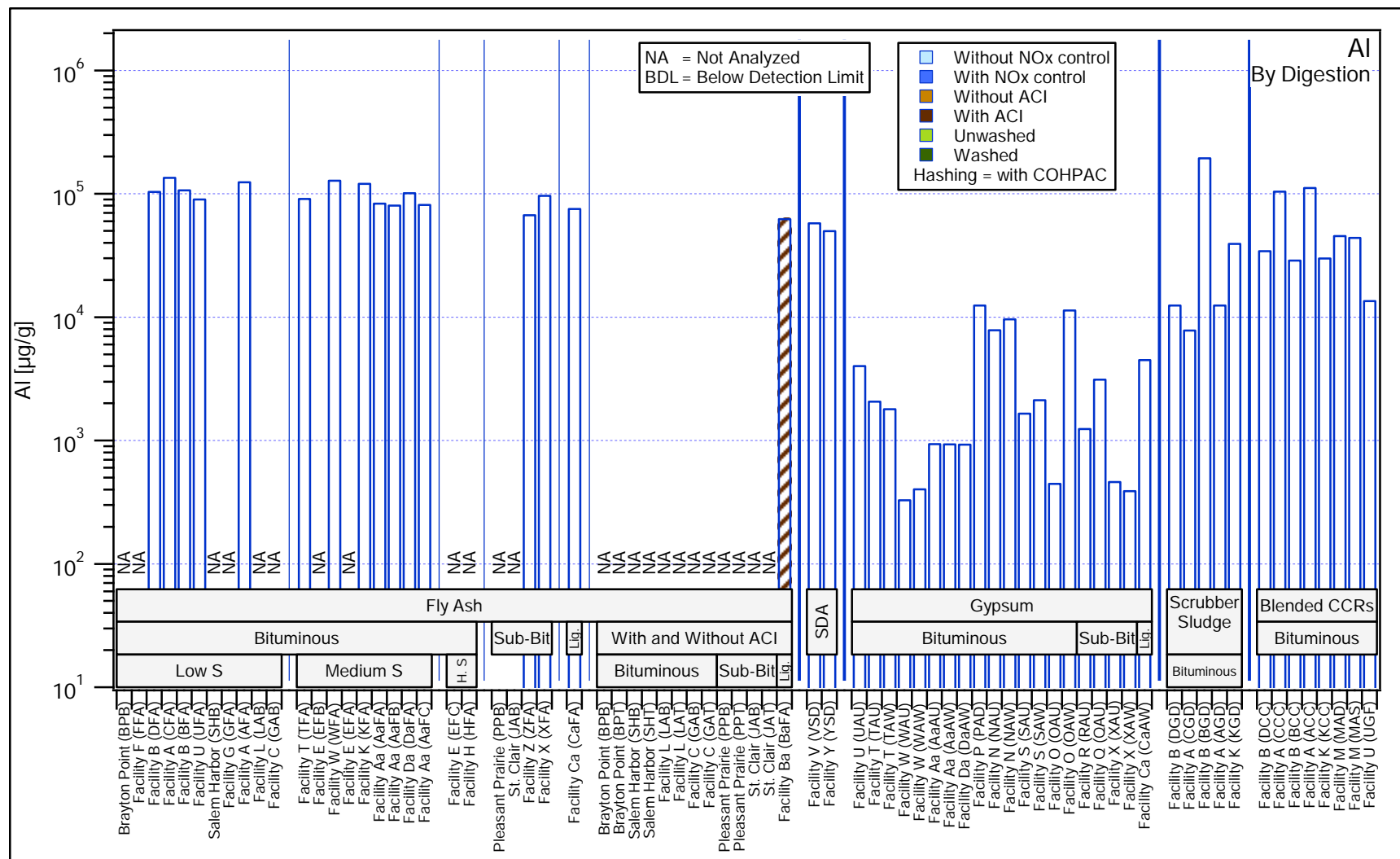


Figure 9. Aluminum. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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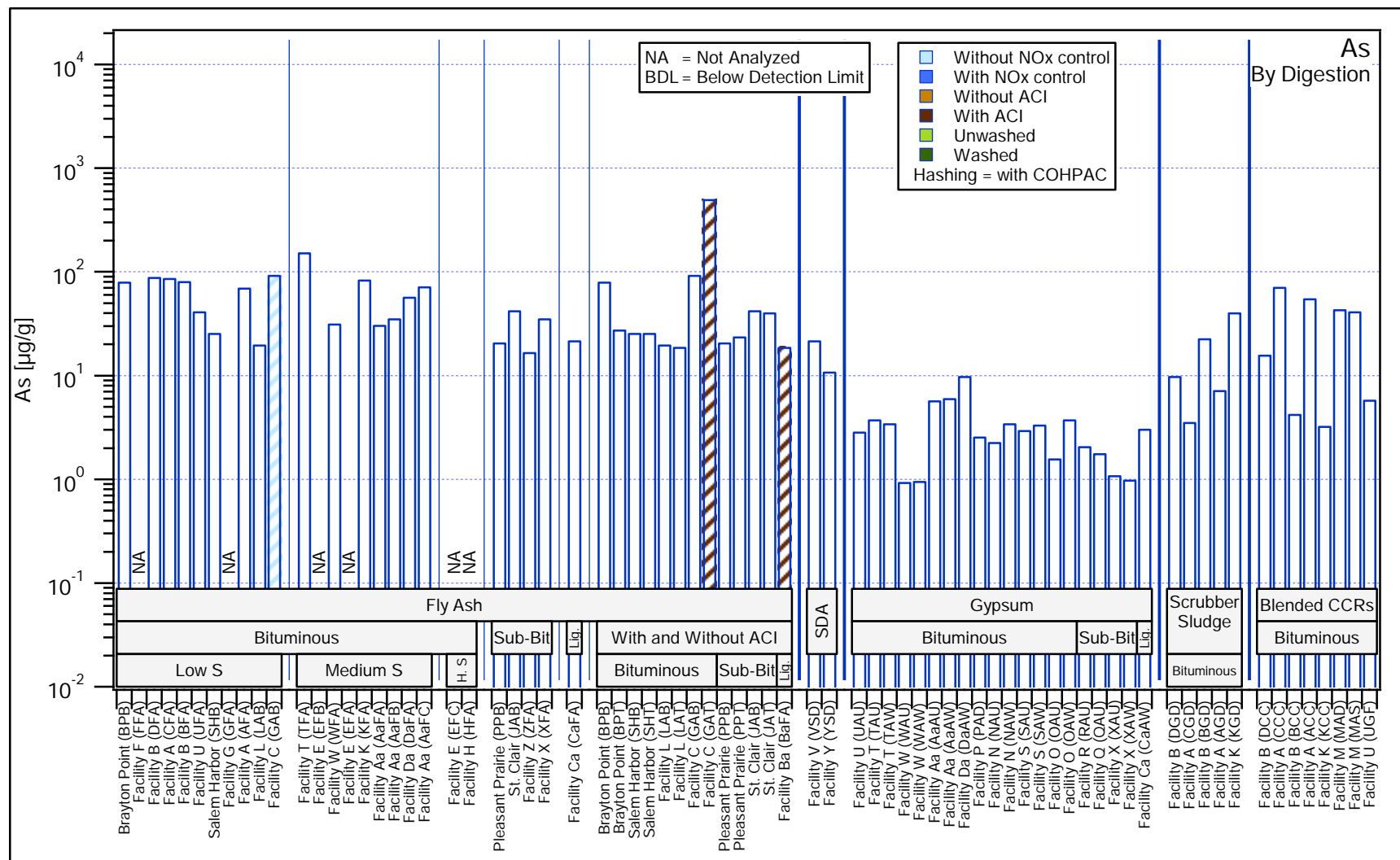


Figure 10. Arsenic. Comparison of total elemental content by digestion (Methods 3052 and 6020).

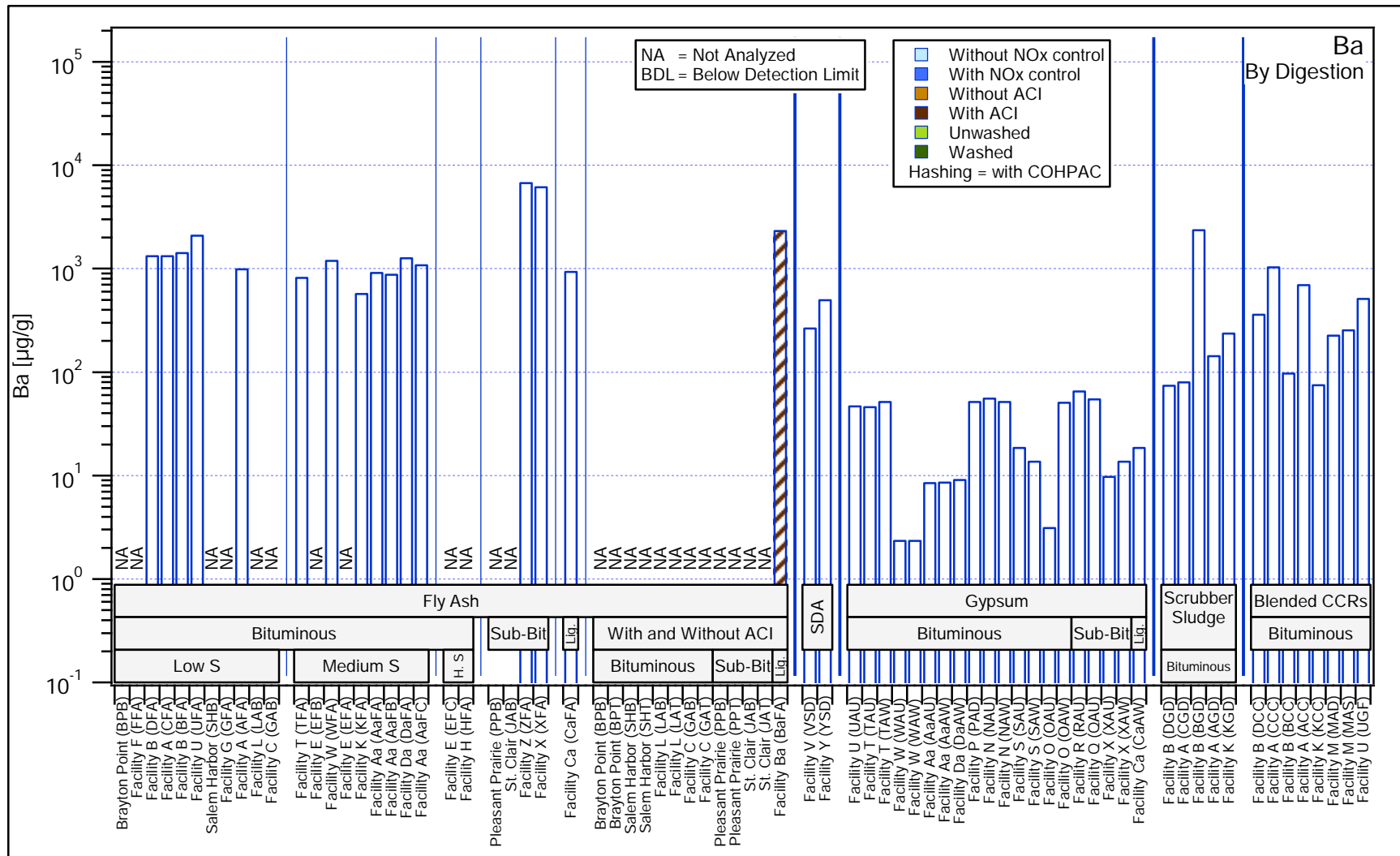


Figure 11. Barium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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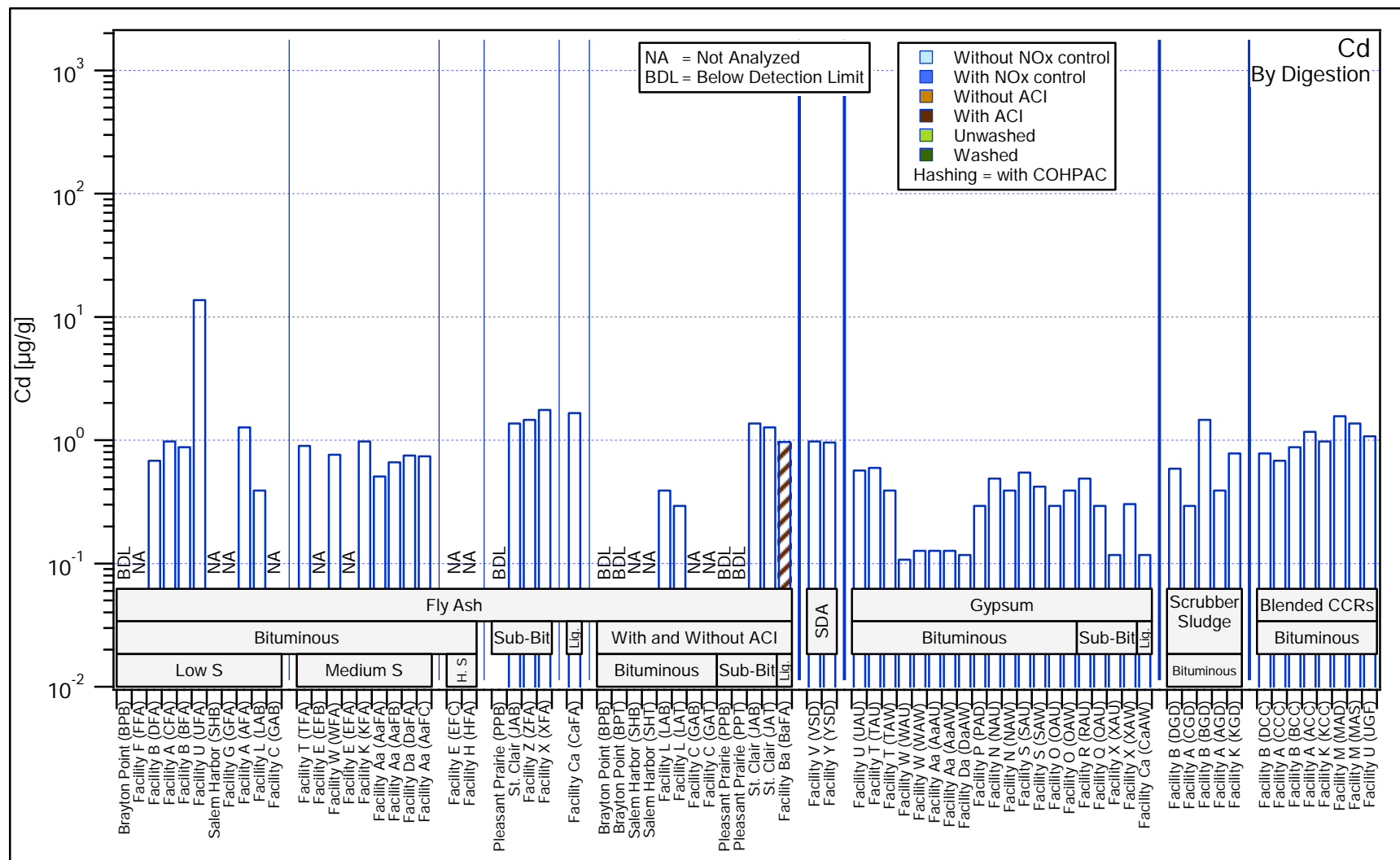


Figure 12. Cadmium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

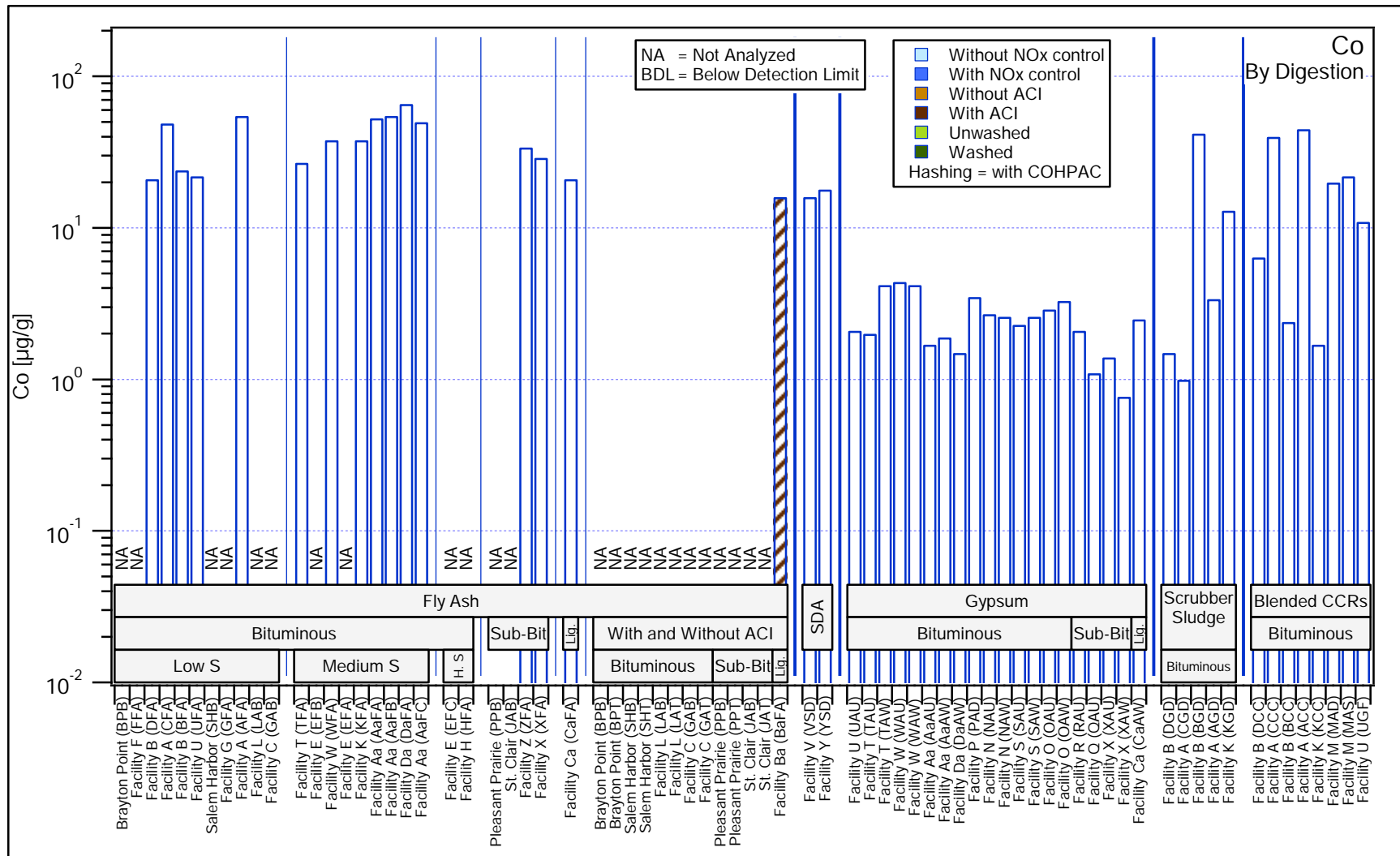


Figure 13. Cobalt. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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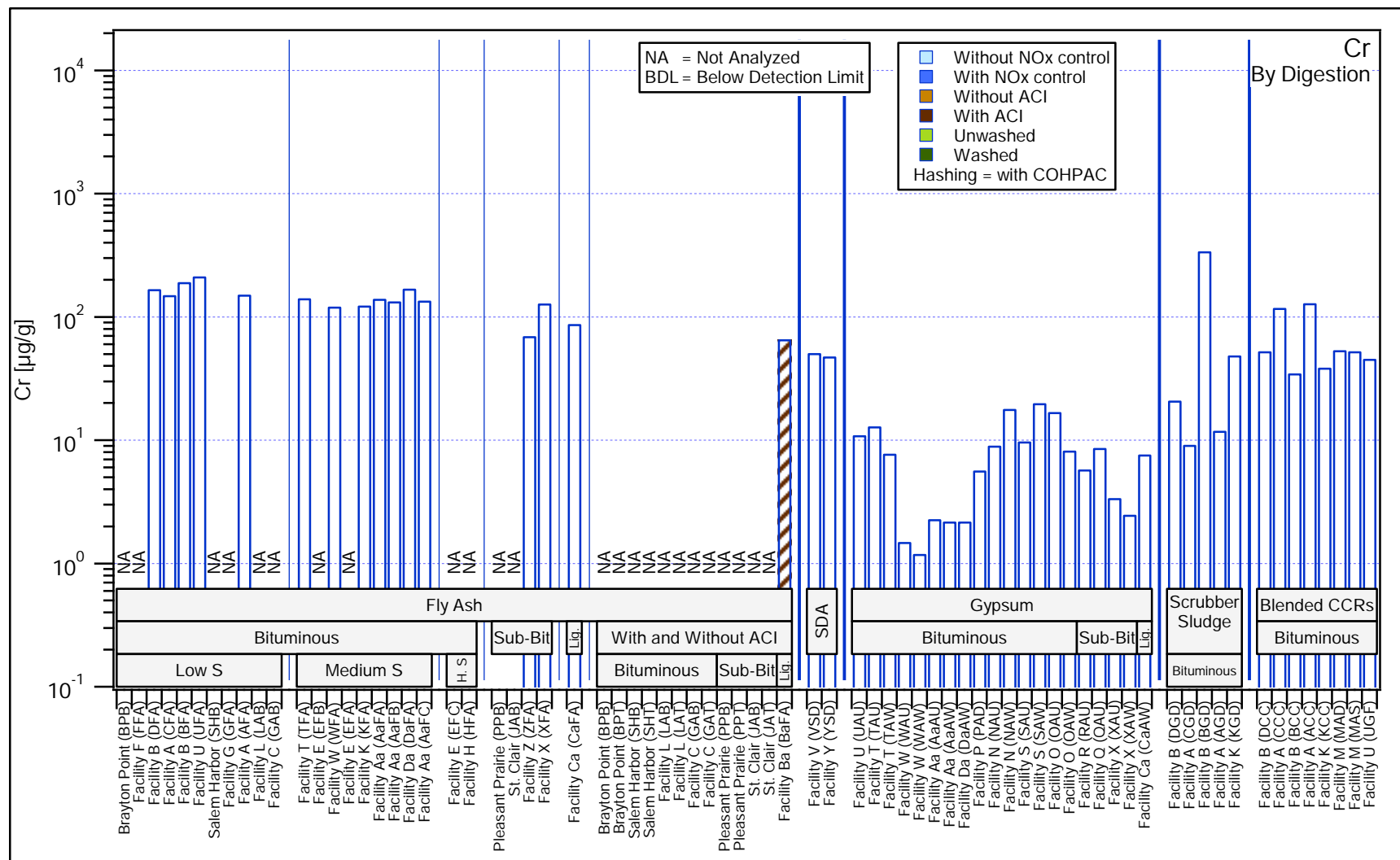


Figure 14. Chromium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

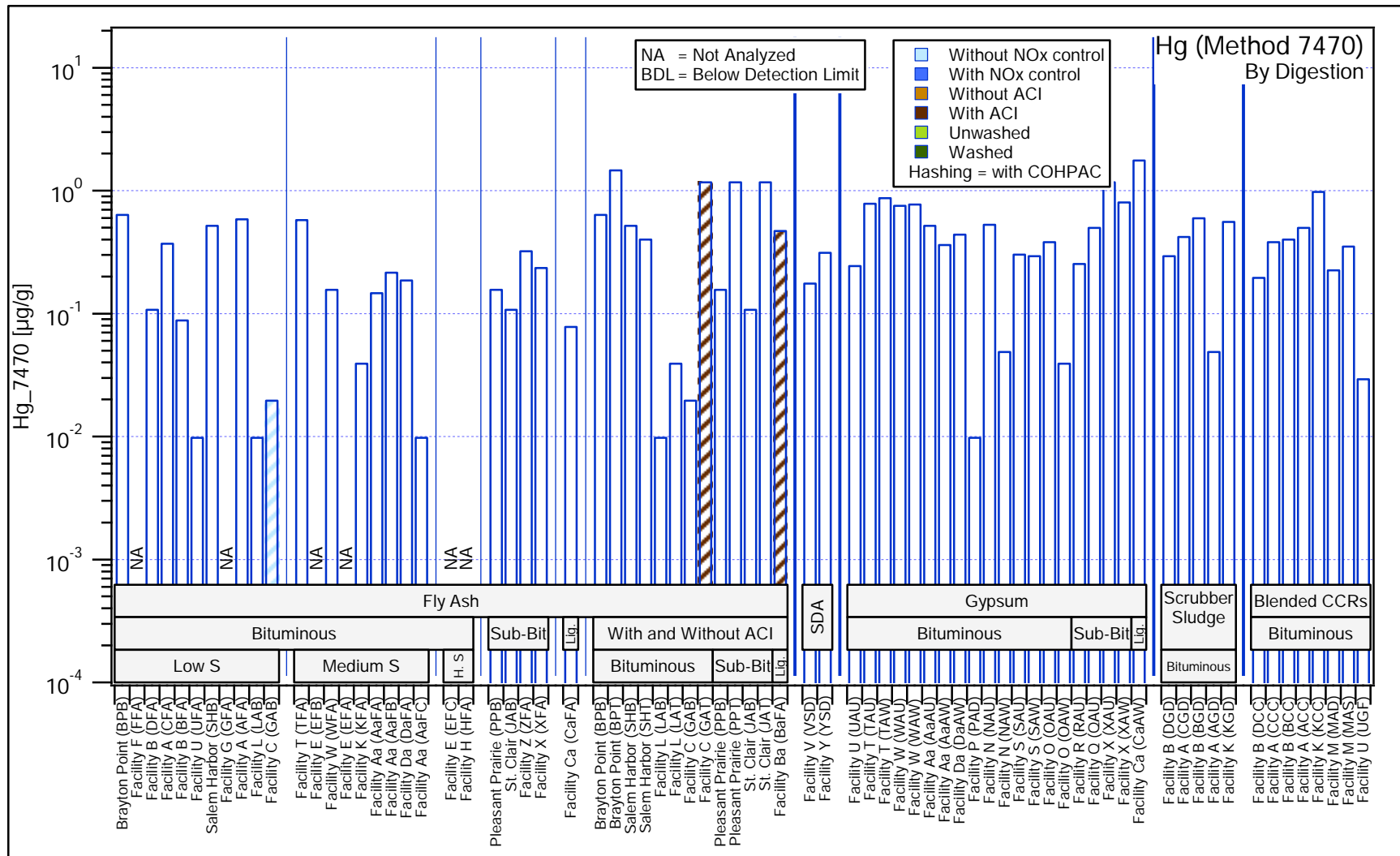


Figure 15. Mercury. Comparison of total elemental content by digestion (Method 7470).

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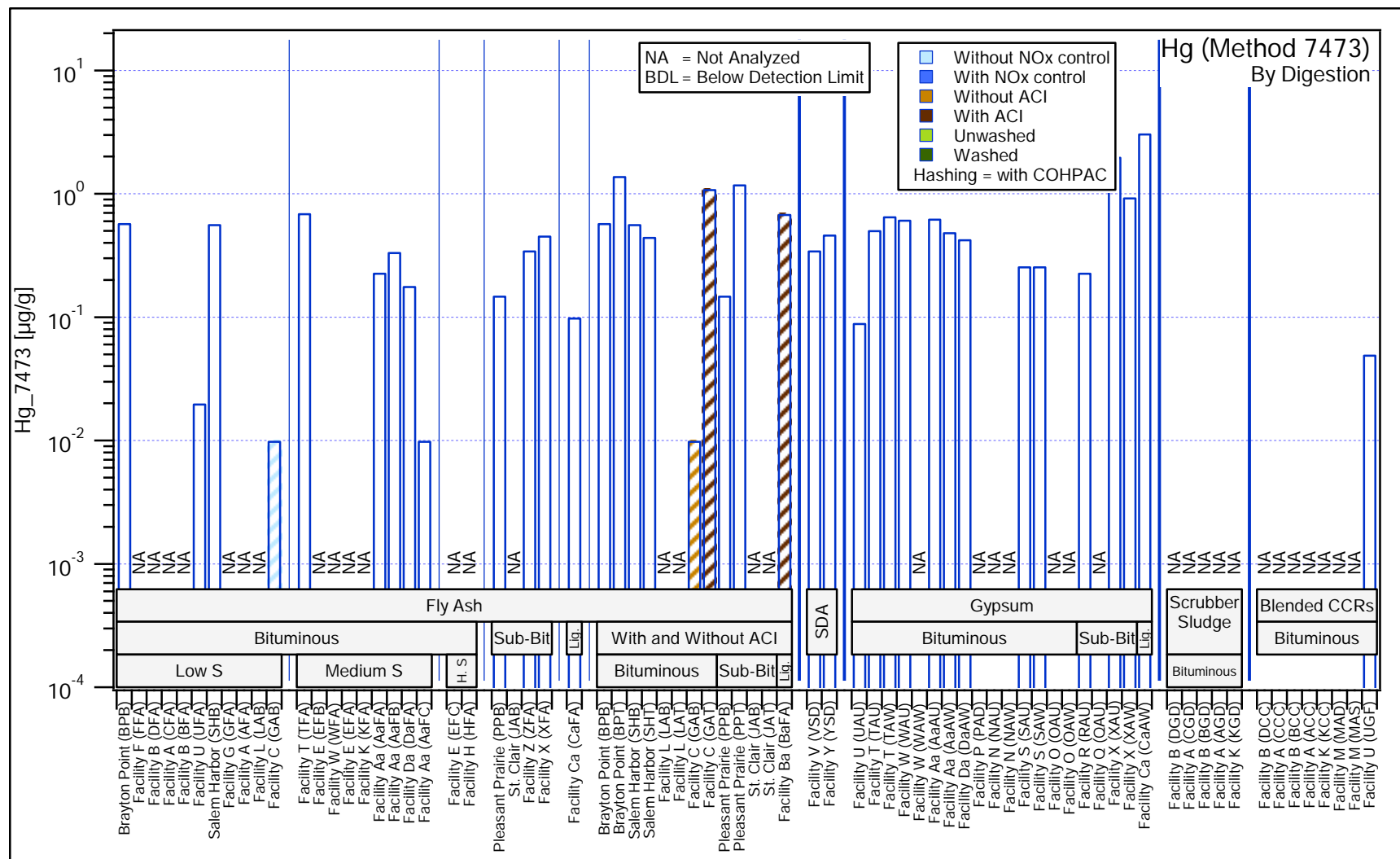


Figure 16. Mercury. Comparison of total elemental content by digestion (Method 7473).

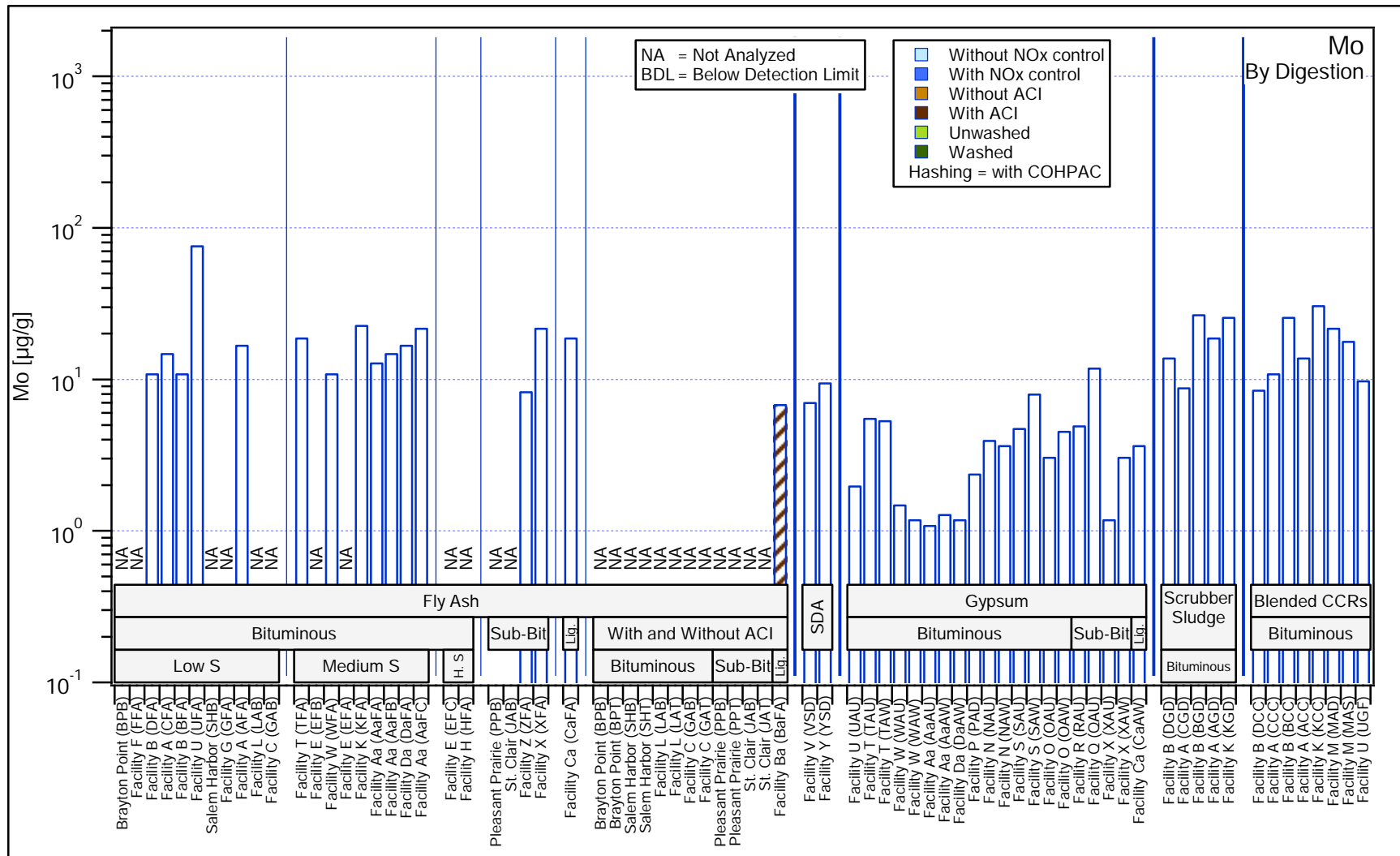


Figure 17. Molybdenum. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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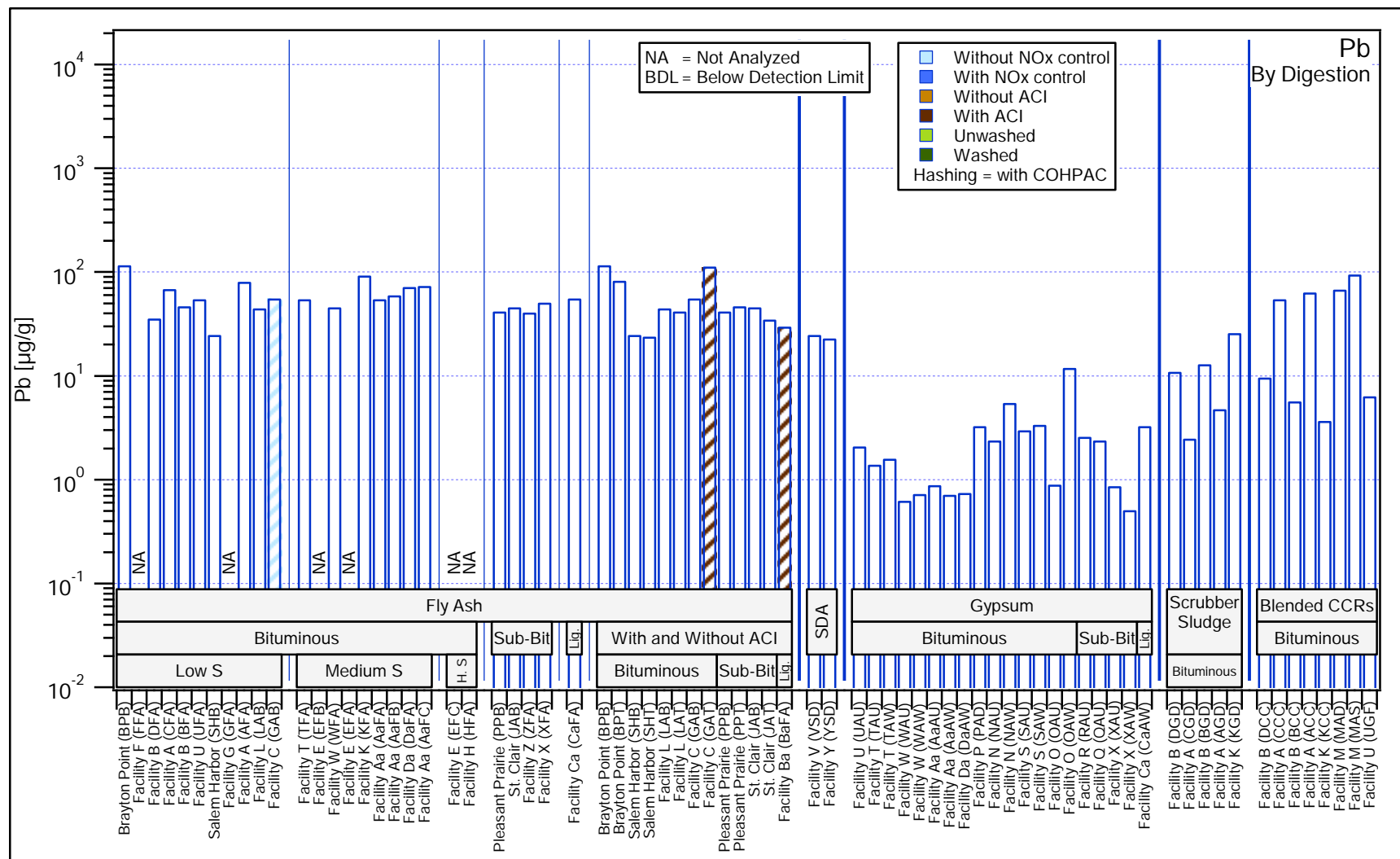


Figure 18. Lead. Comparison of total elemental content by digestion (Methods 3052 and 6020).

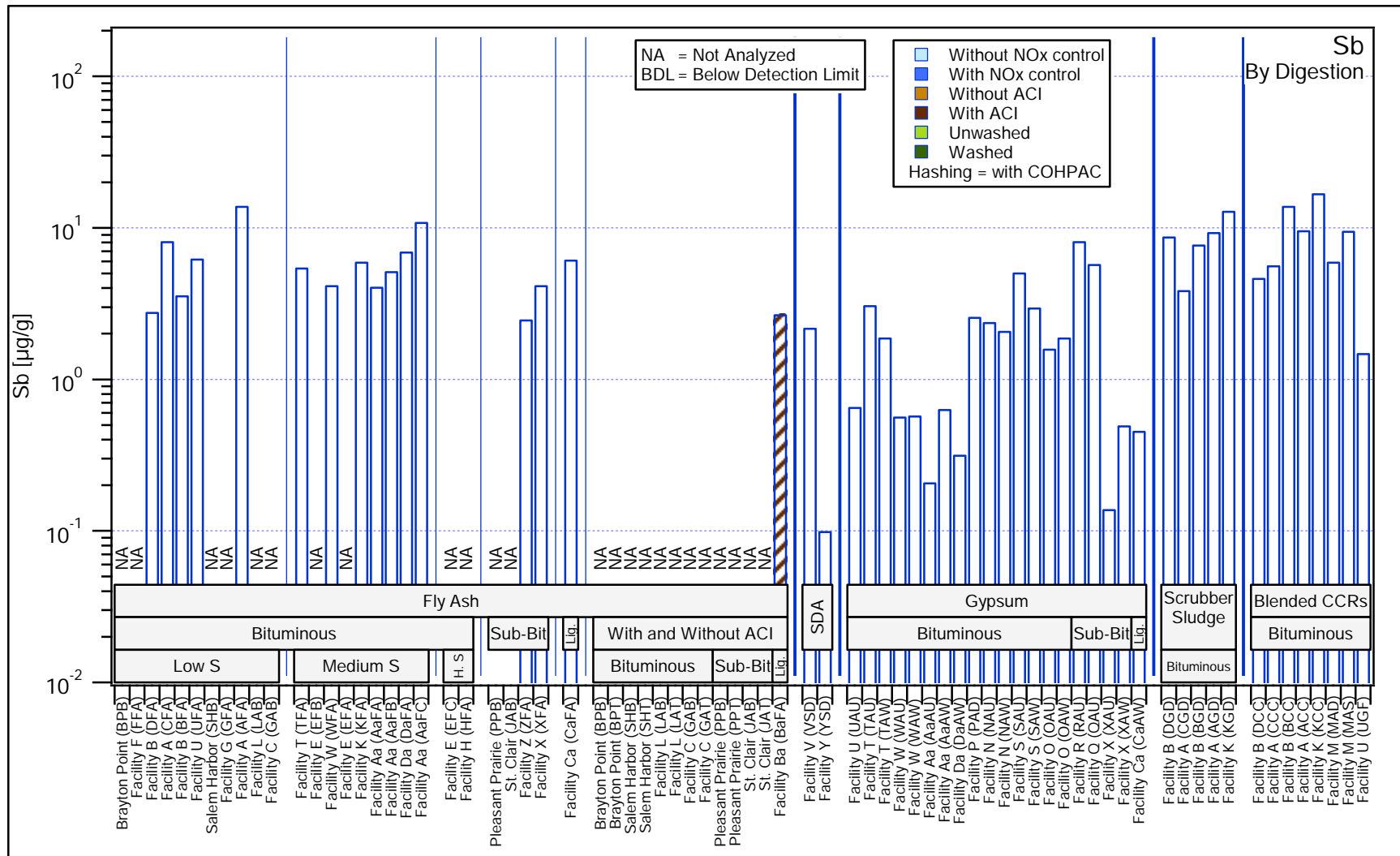


Figure 19. Antimony. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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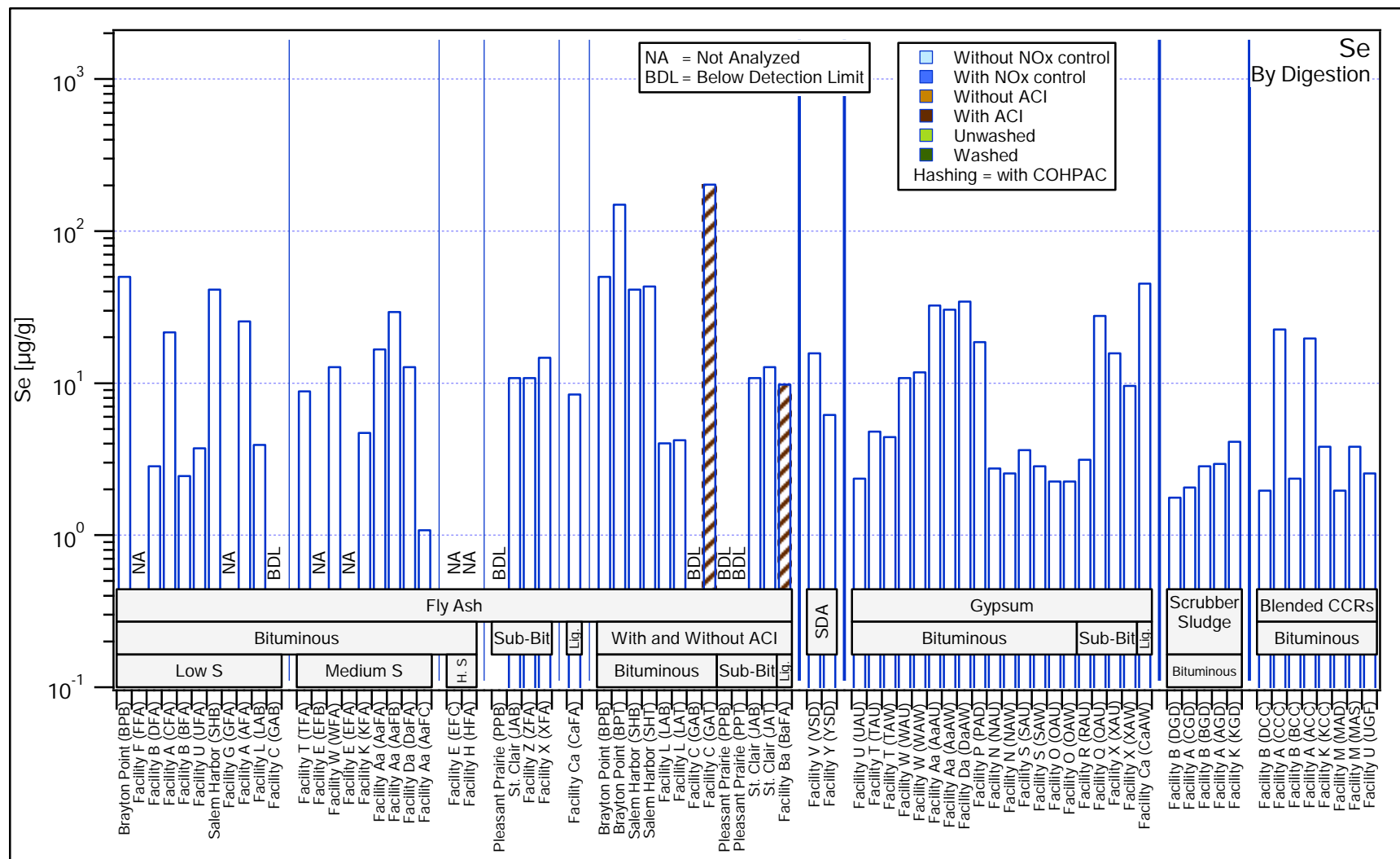


Figure 20. Selenium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

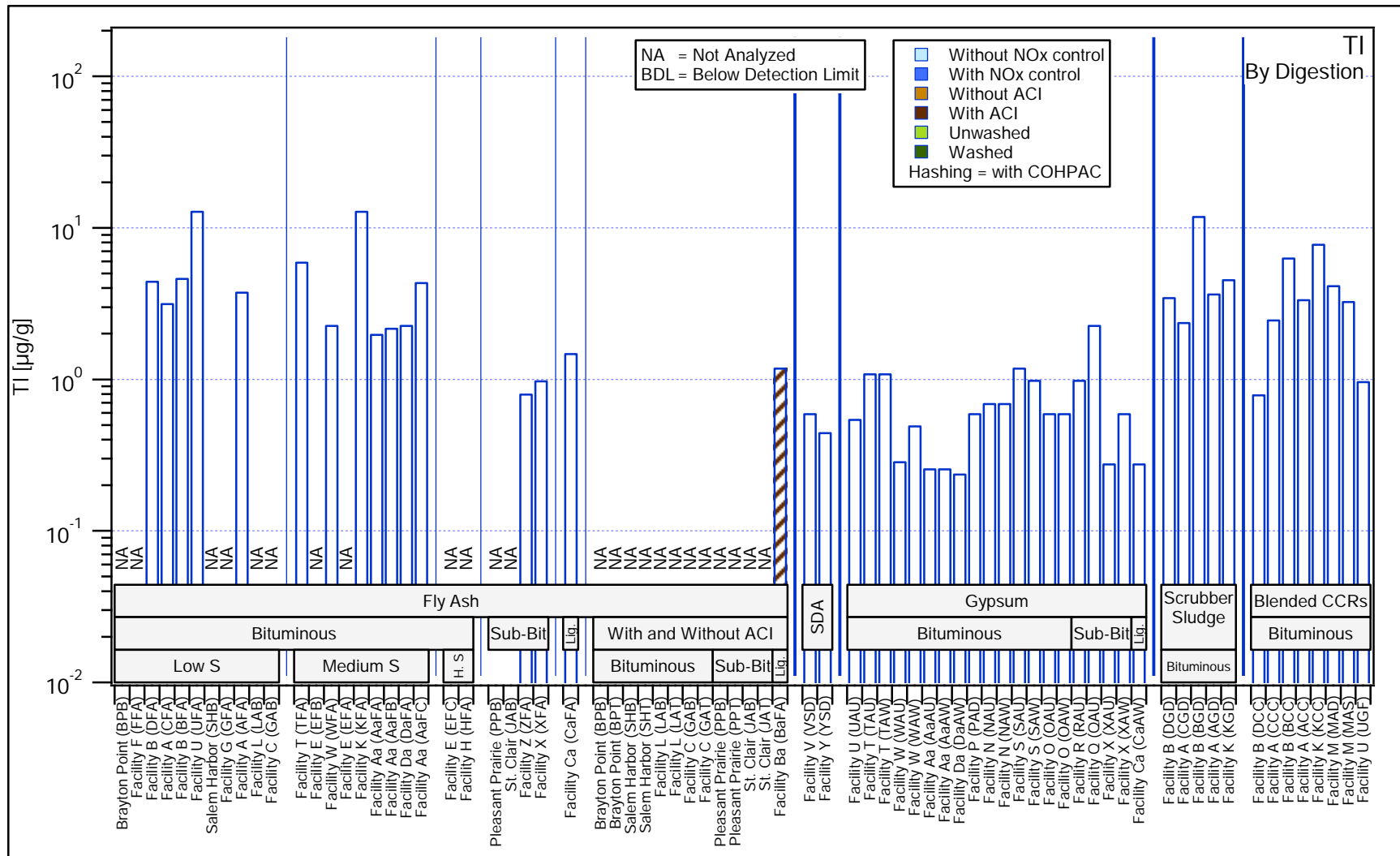


Figure 21. Thallium. Comparison of total elemental content by digestion (Methods 3052 and 6020).

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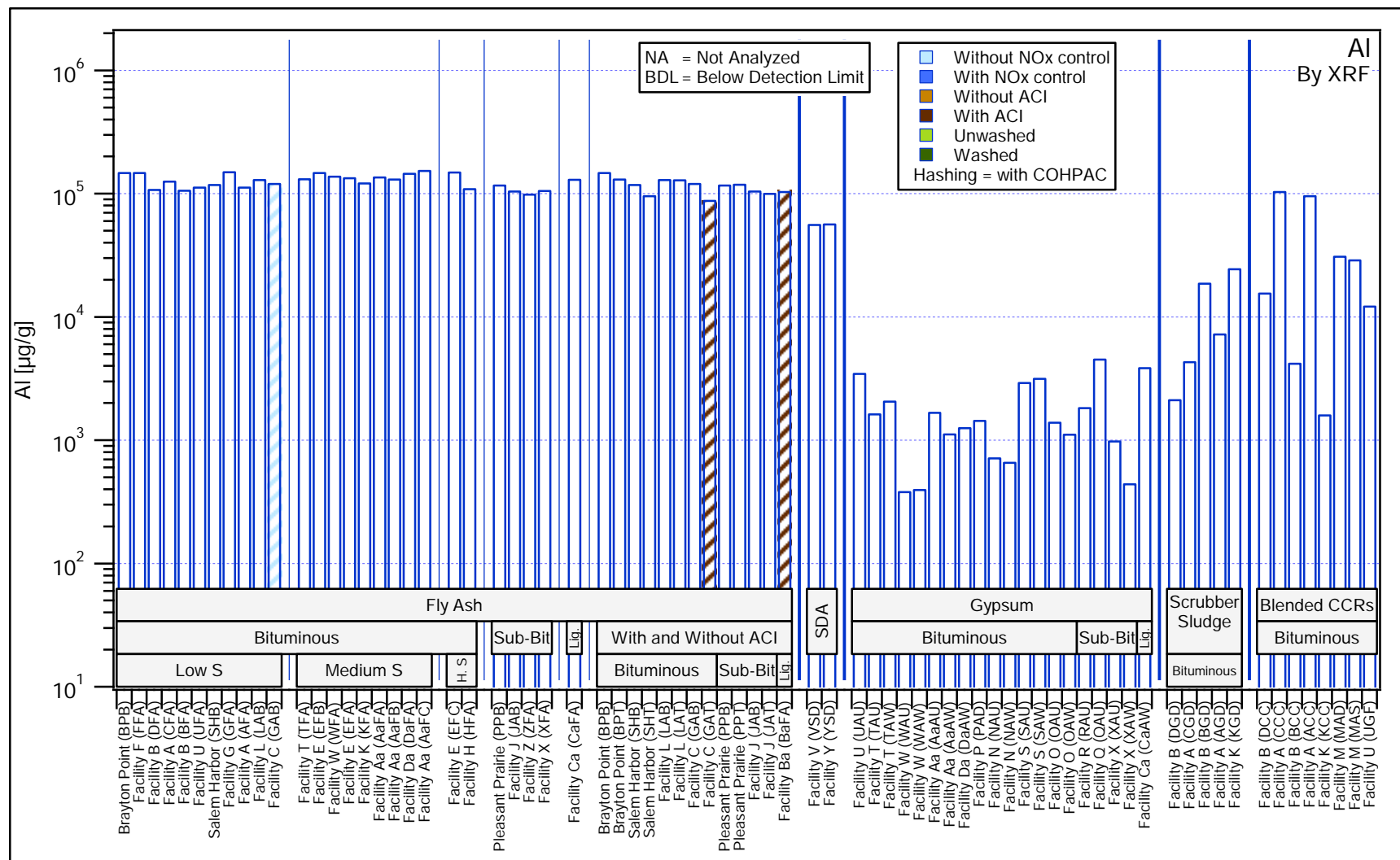


Figure 22. Aluminum. Comparison of total elemental content by XRF.

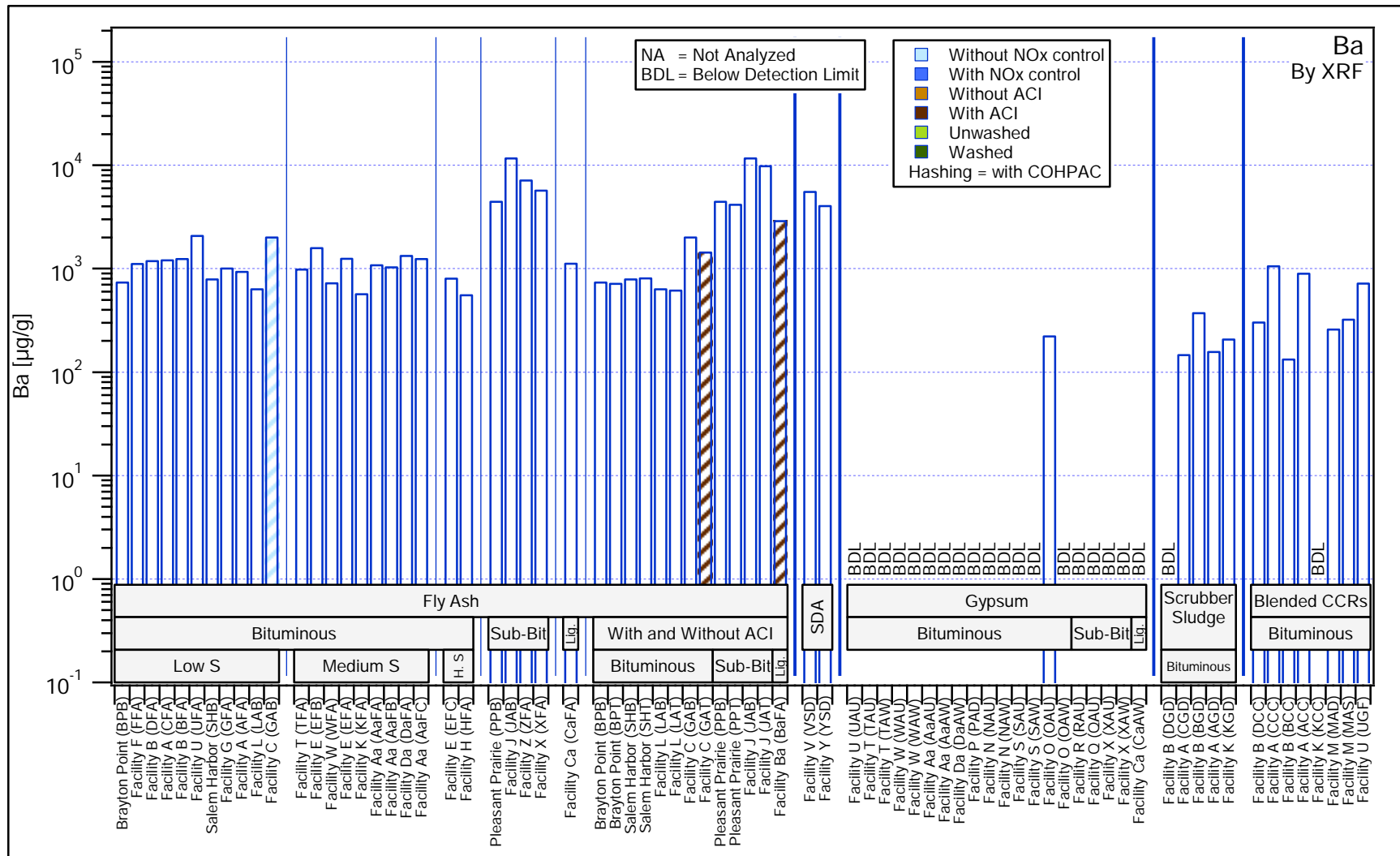


Figure 23. Barium. Comparison of total elemental content by XRF.

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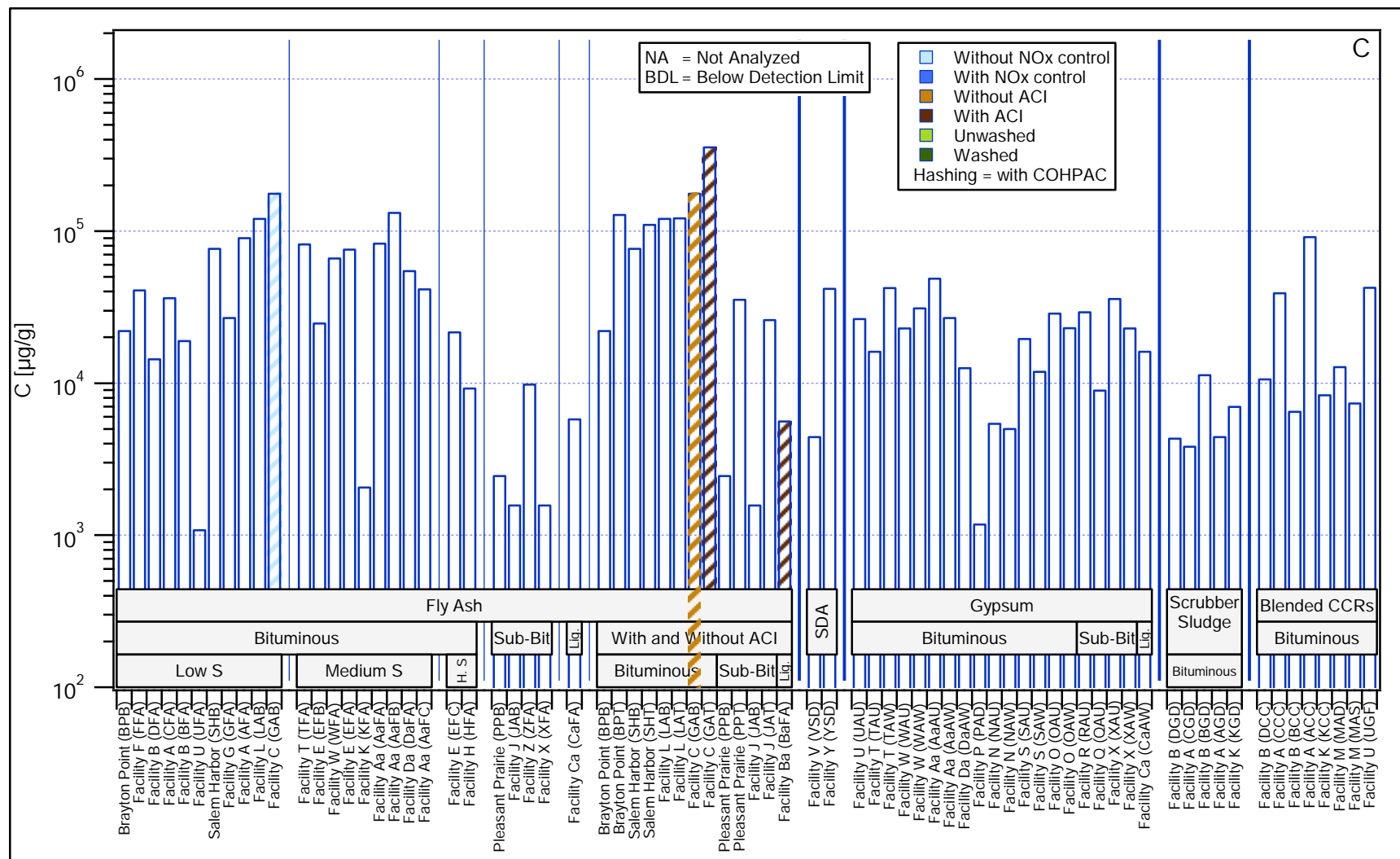


Figure 24. Carbon. Comparison of total elemental content.

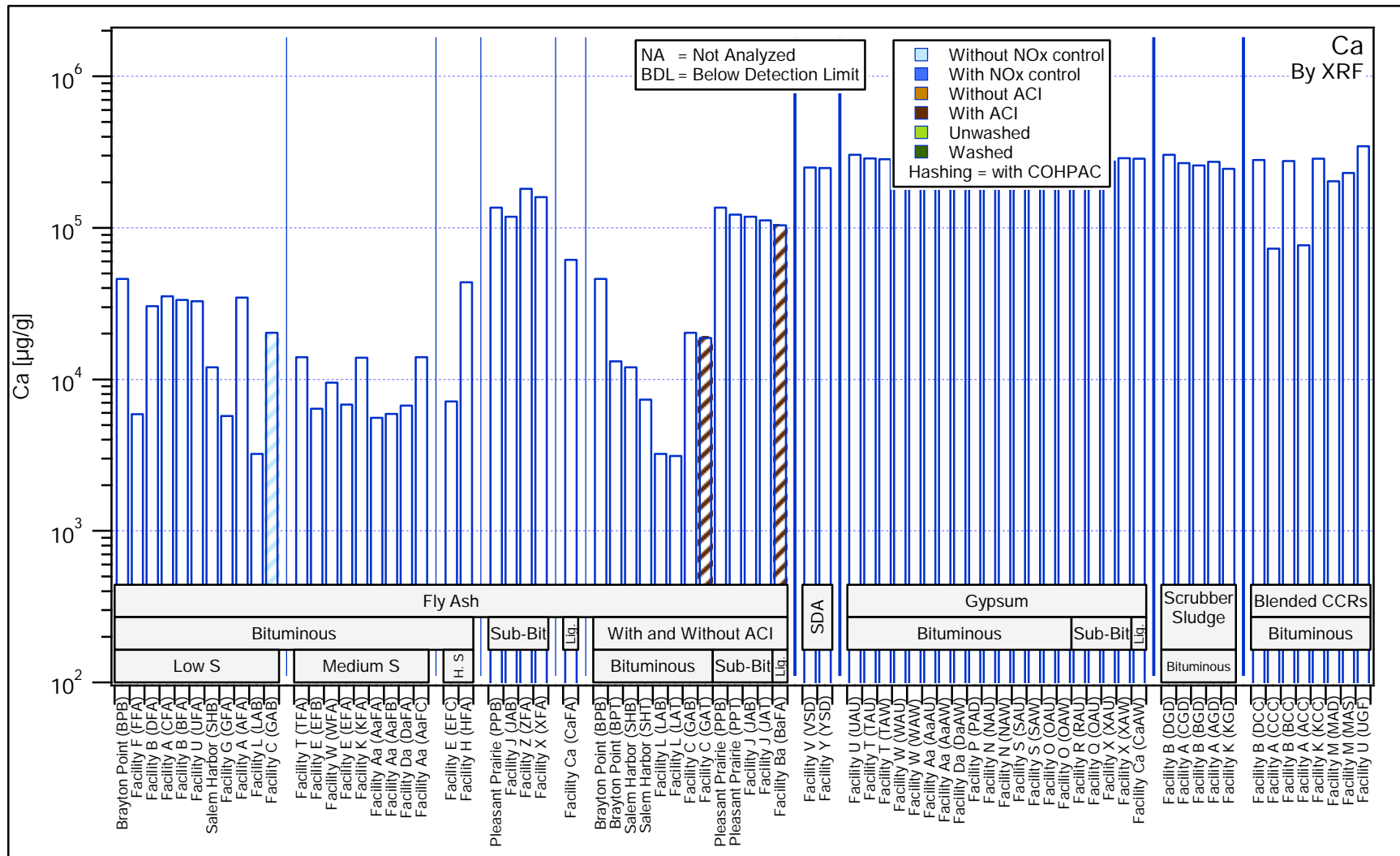


Figure 25. Calcium. Comparison of total elemental content by XRF.

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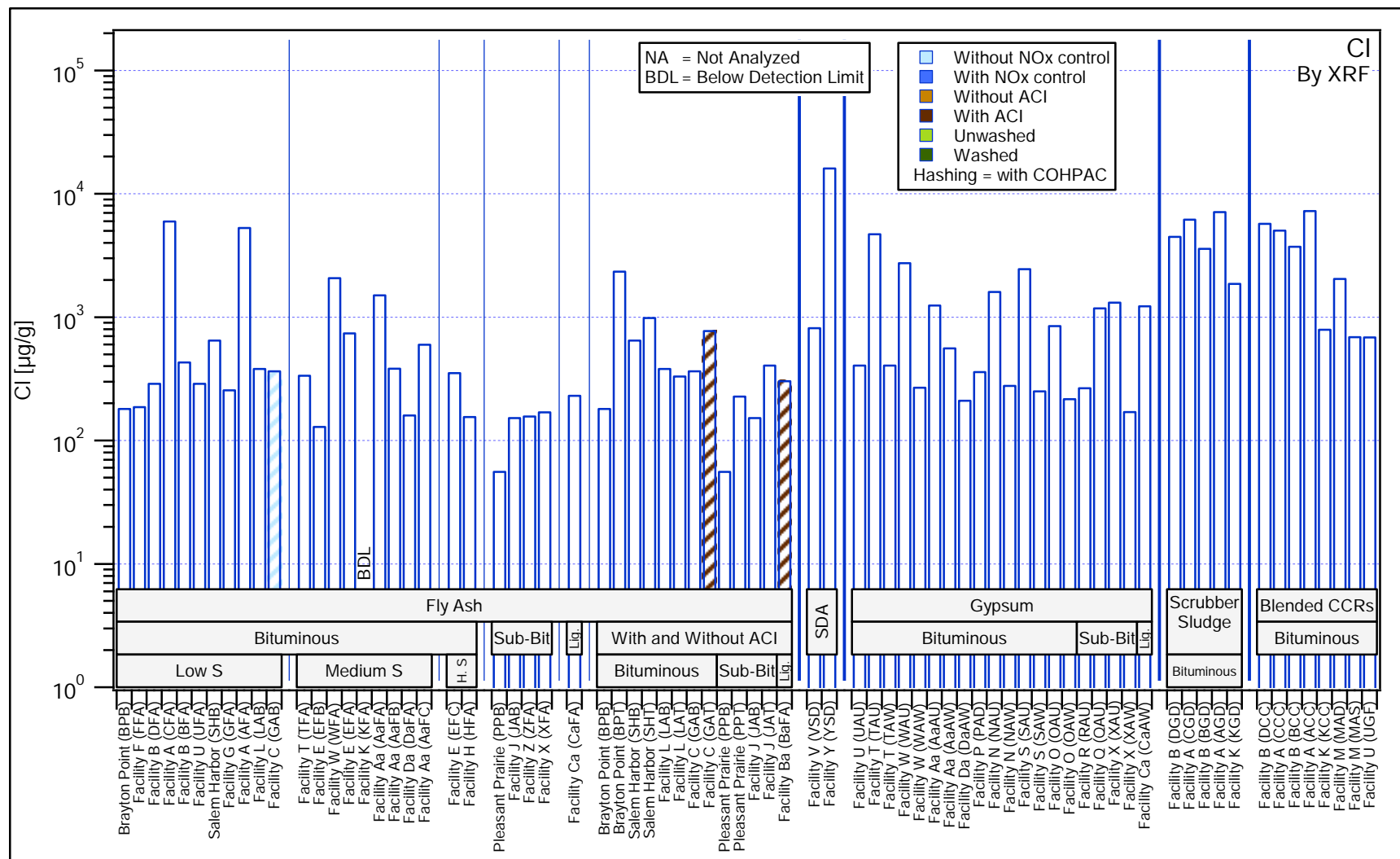


Figure 26. Chloride. Comparison of total elemental content by XRF.

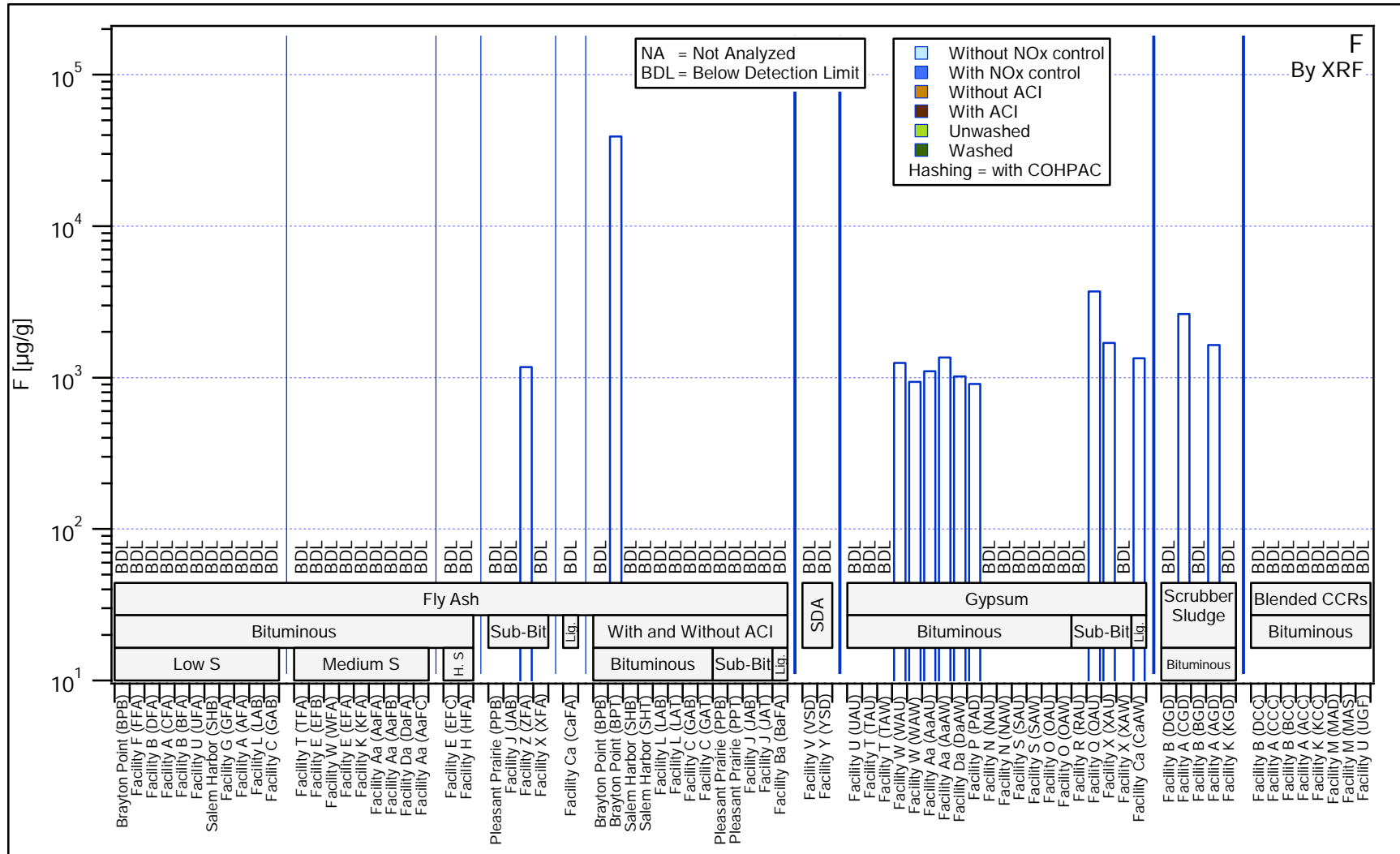


Figure 27. Fluoride. Comparison of total elemental content by XRF.

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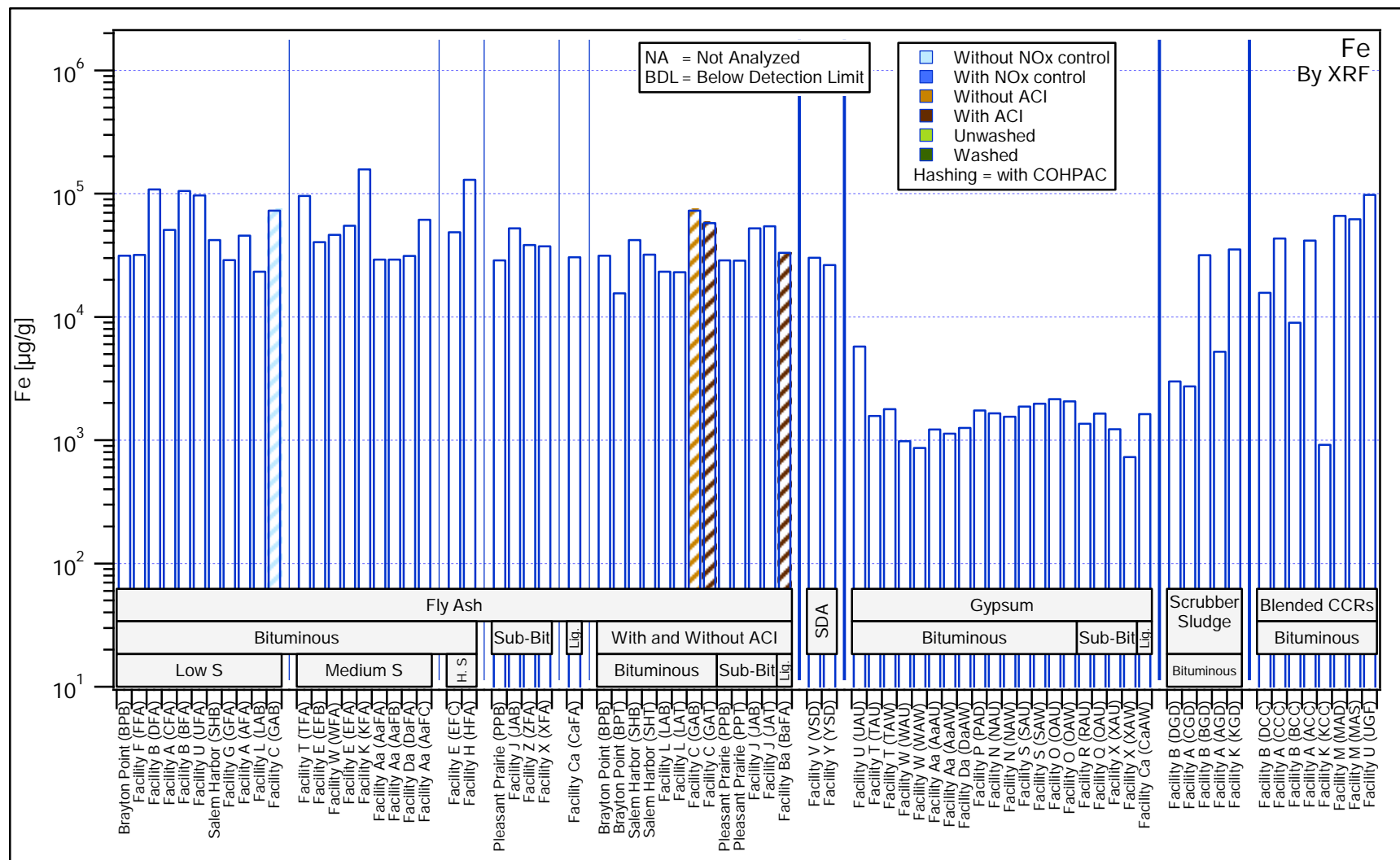


Figure 28. Iron. Comparison of total elemental content by XRF.

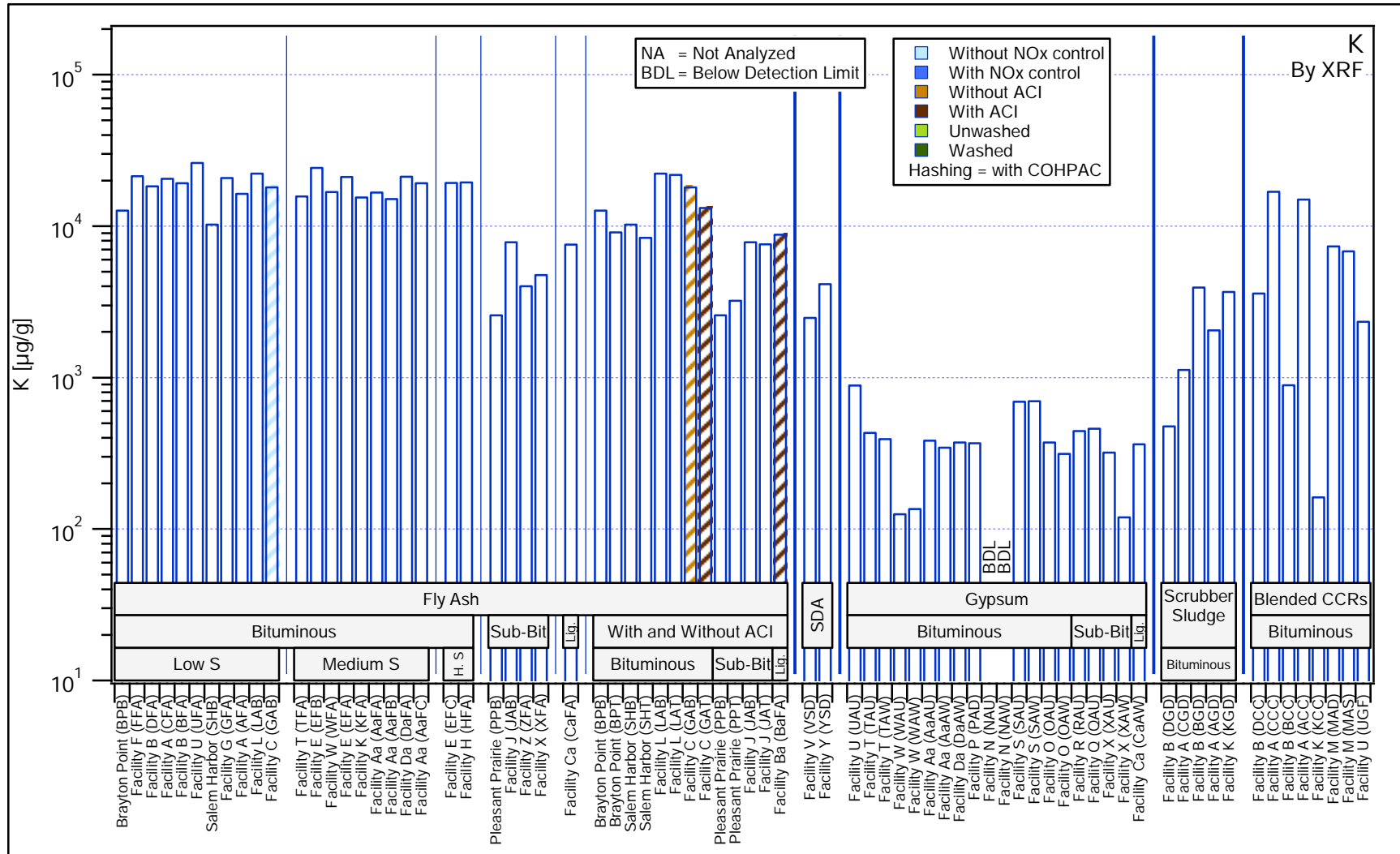


Figure 29. Potassium. Comparison of total elemental content by XRF.

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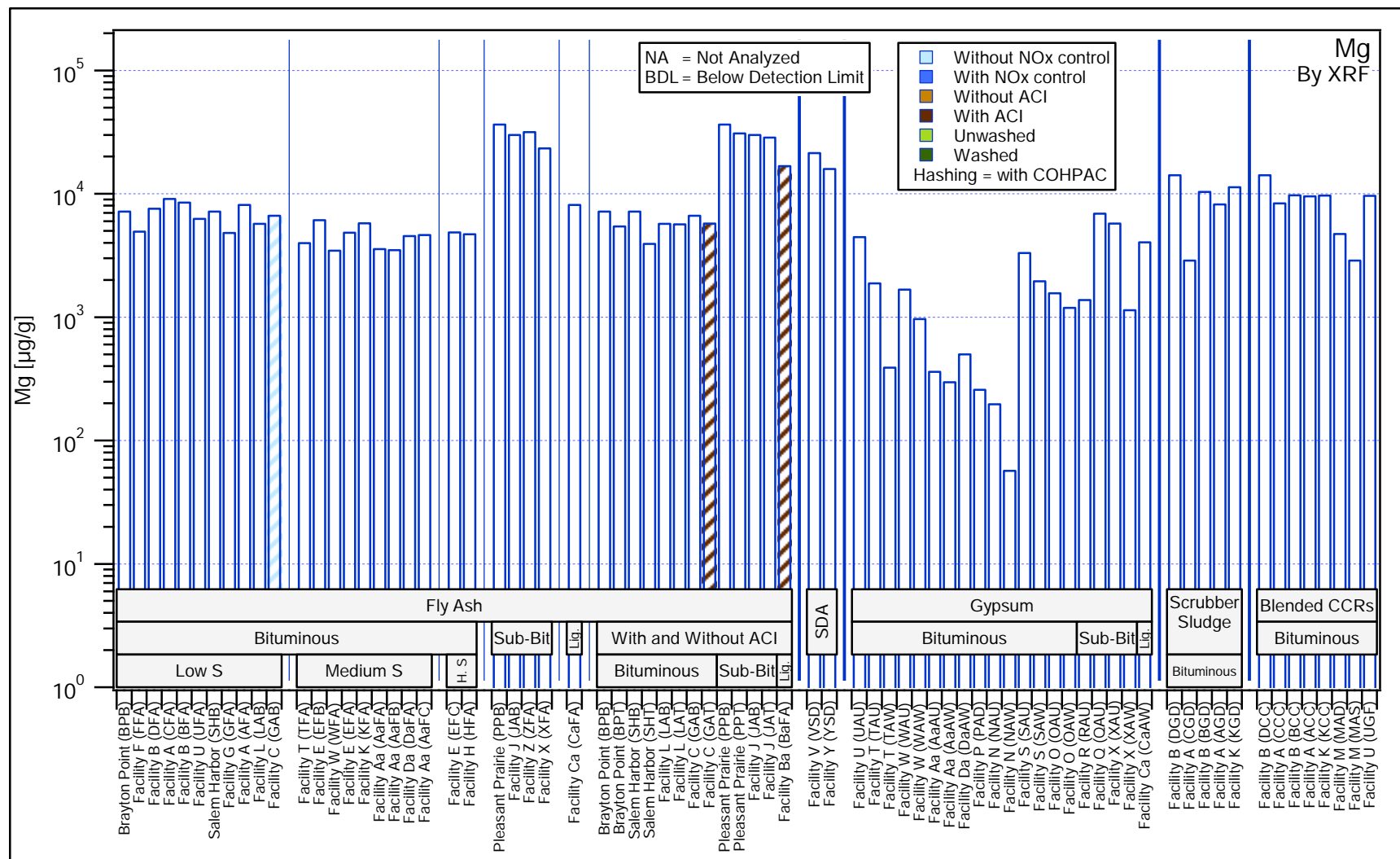


Figure 30. Magnesium. Comparison of total elemental content by XRF.

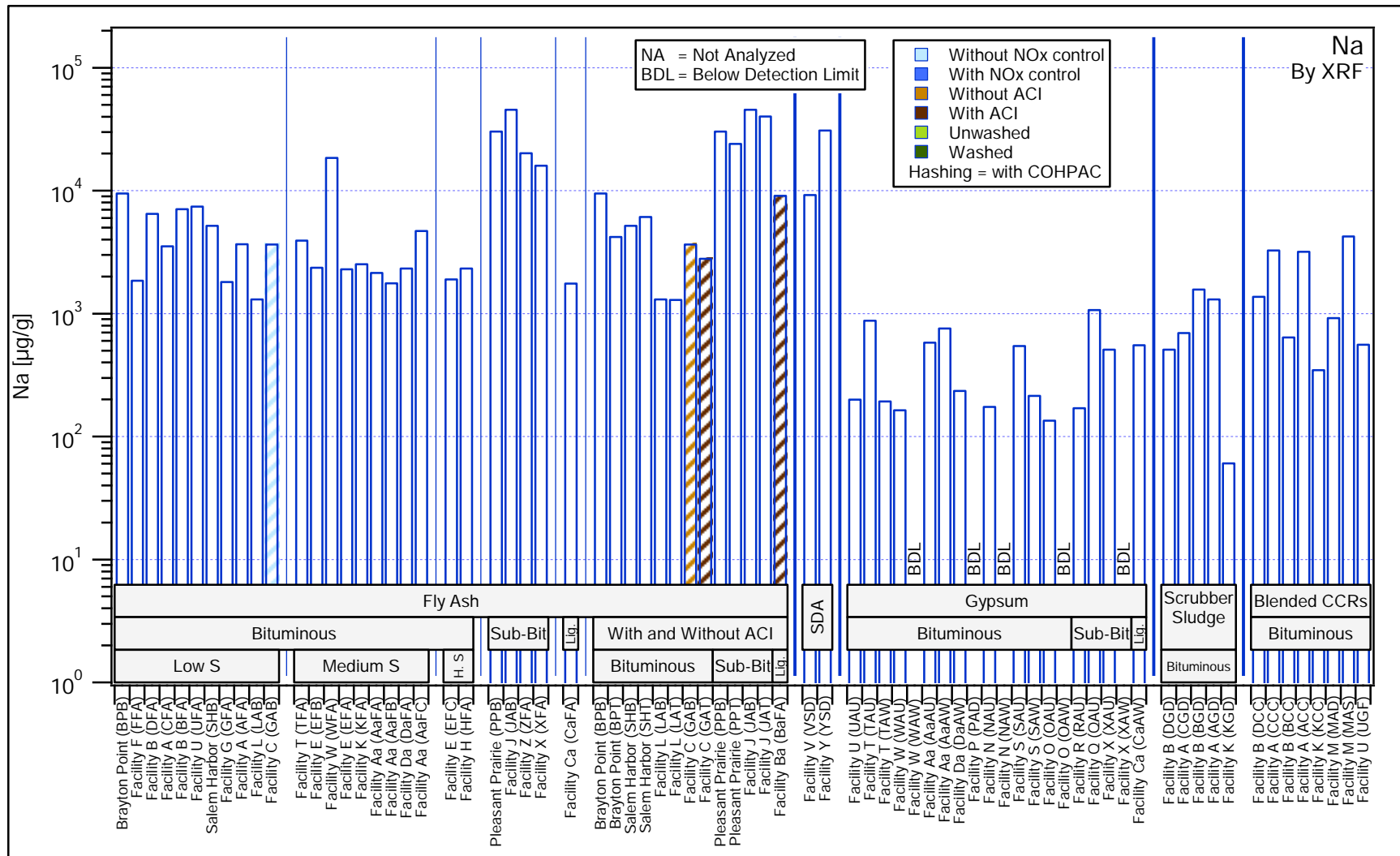


Figure 31. Sodium. Comparison of total elemental content by XRF.

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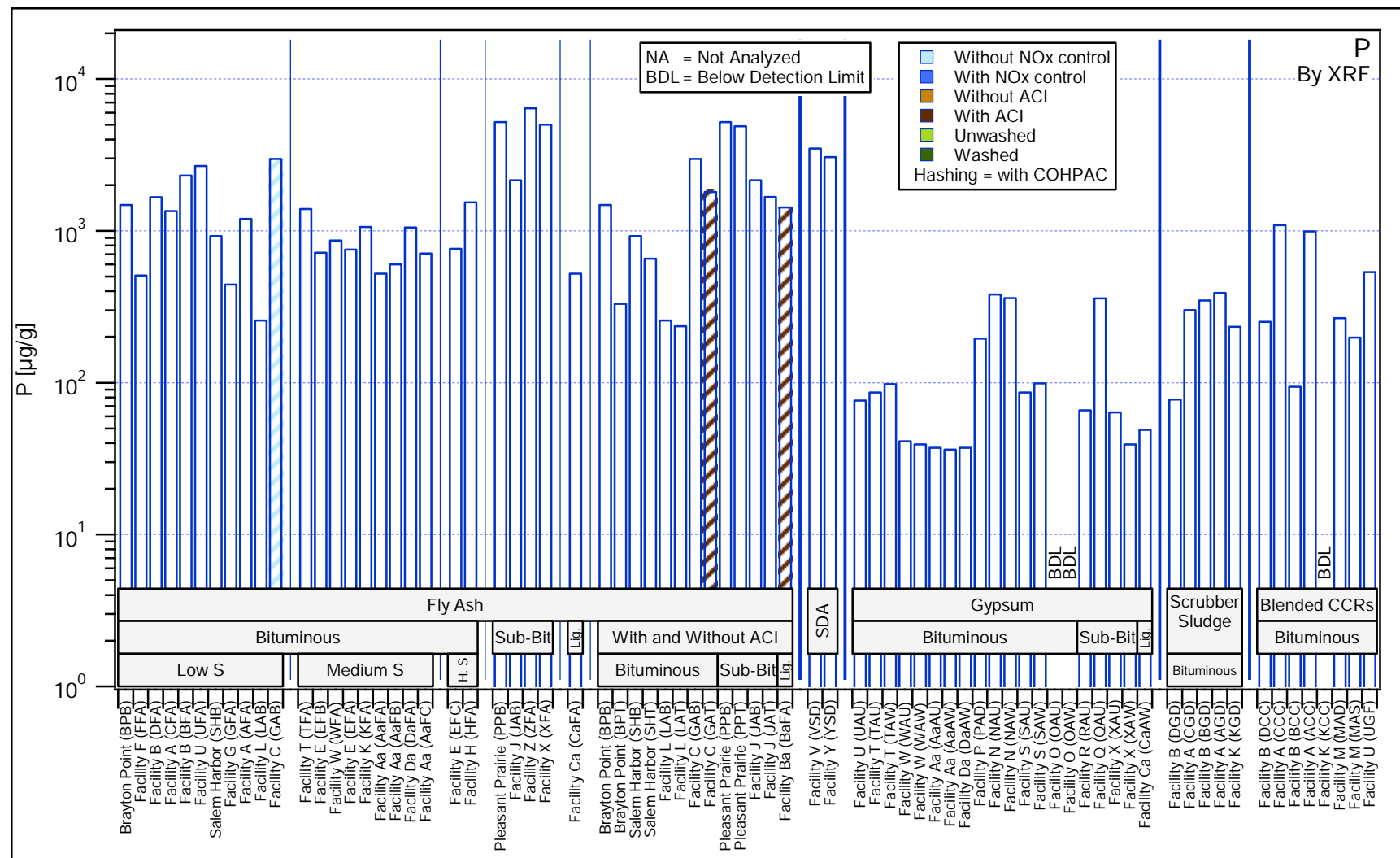


Figure 32. Phosphorous. Comparison of total elemental content by XRF.

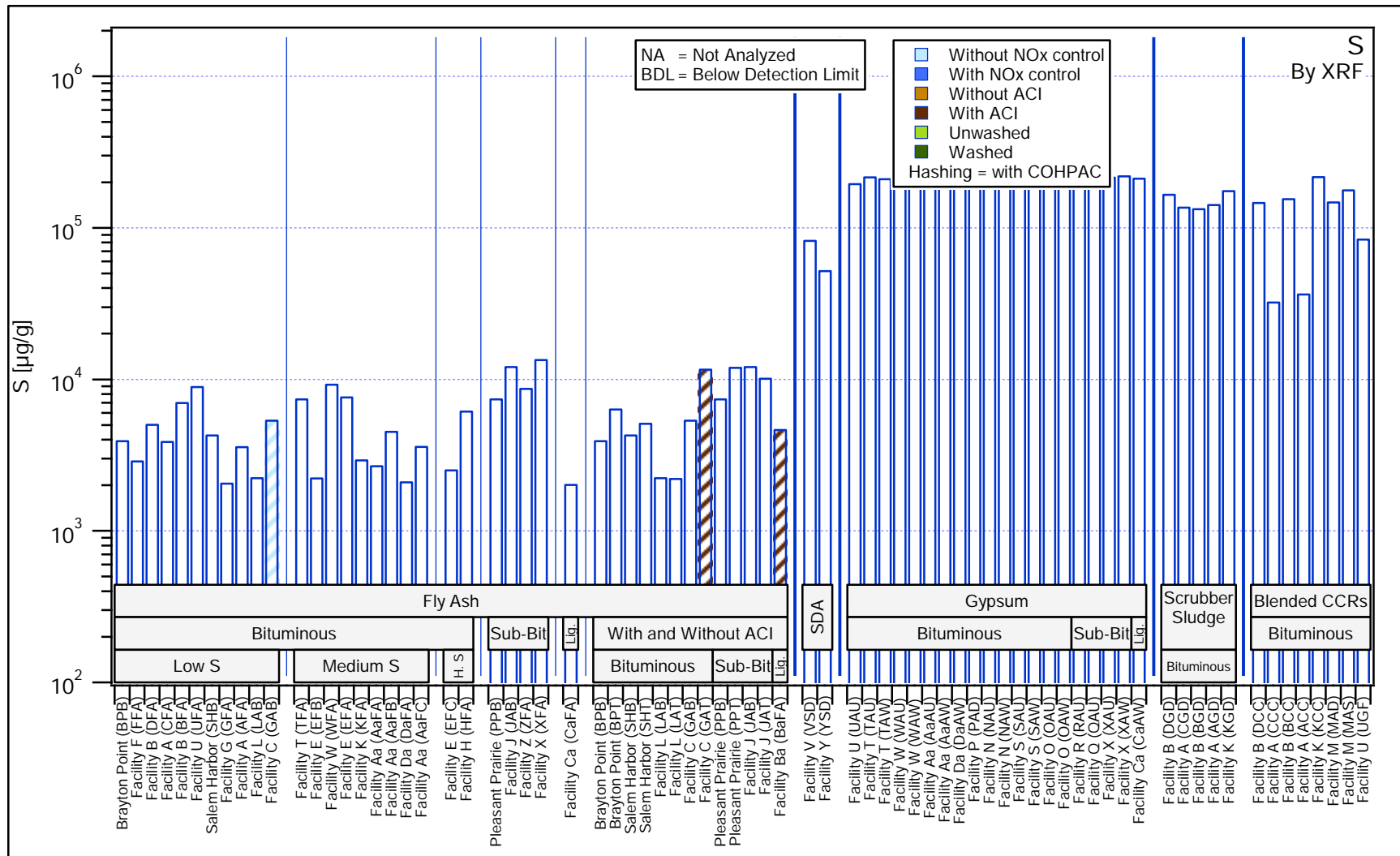


Figure 33. Sulfur. Comparison of total elemental content by XRF.

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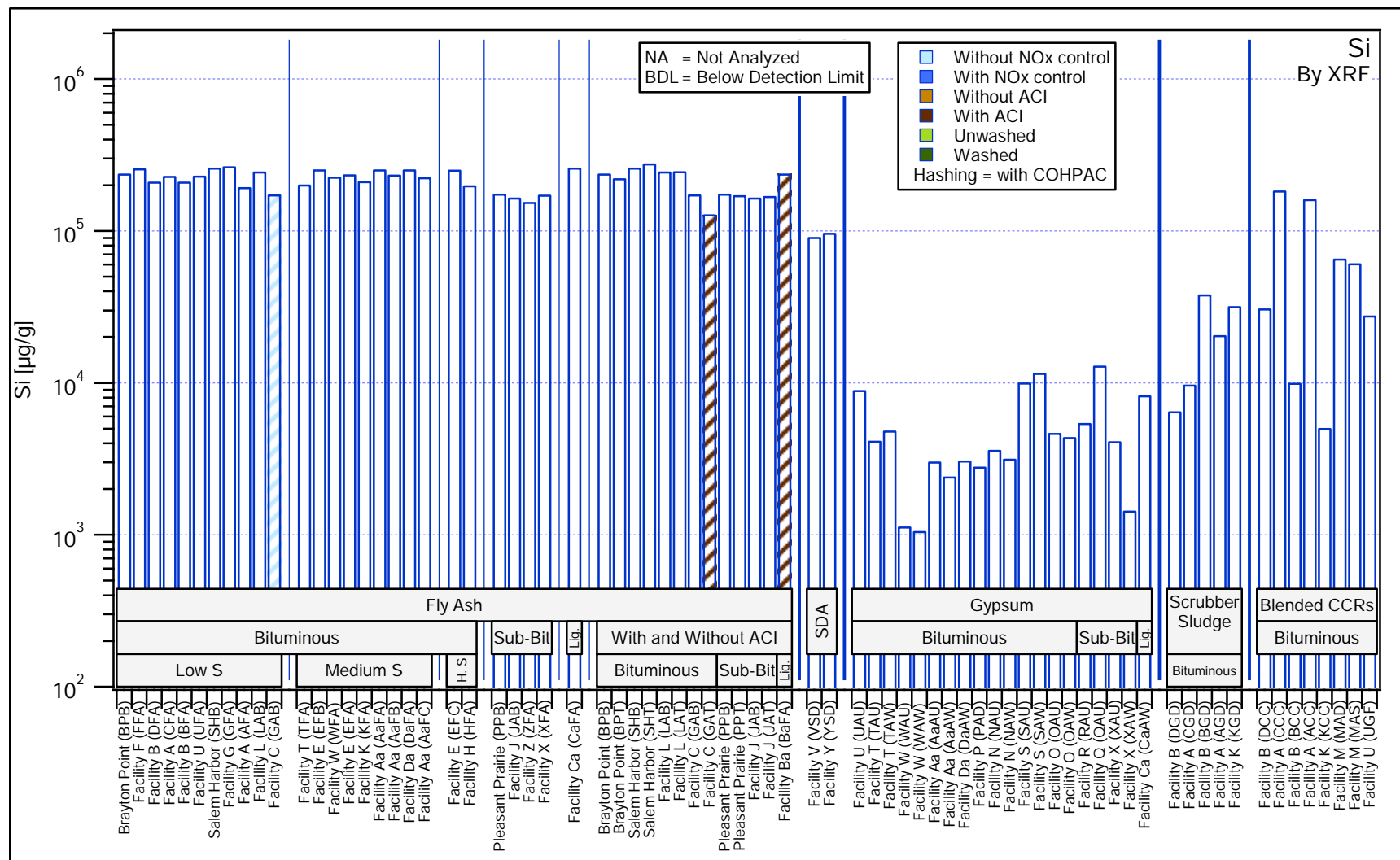


Figure 34. Silicon. Comparison of total elemental content by XRF.

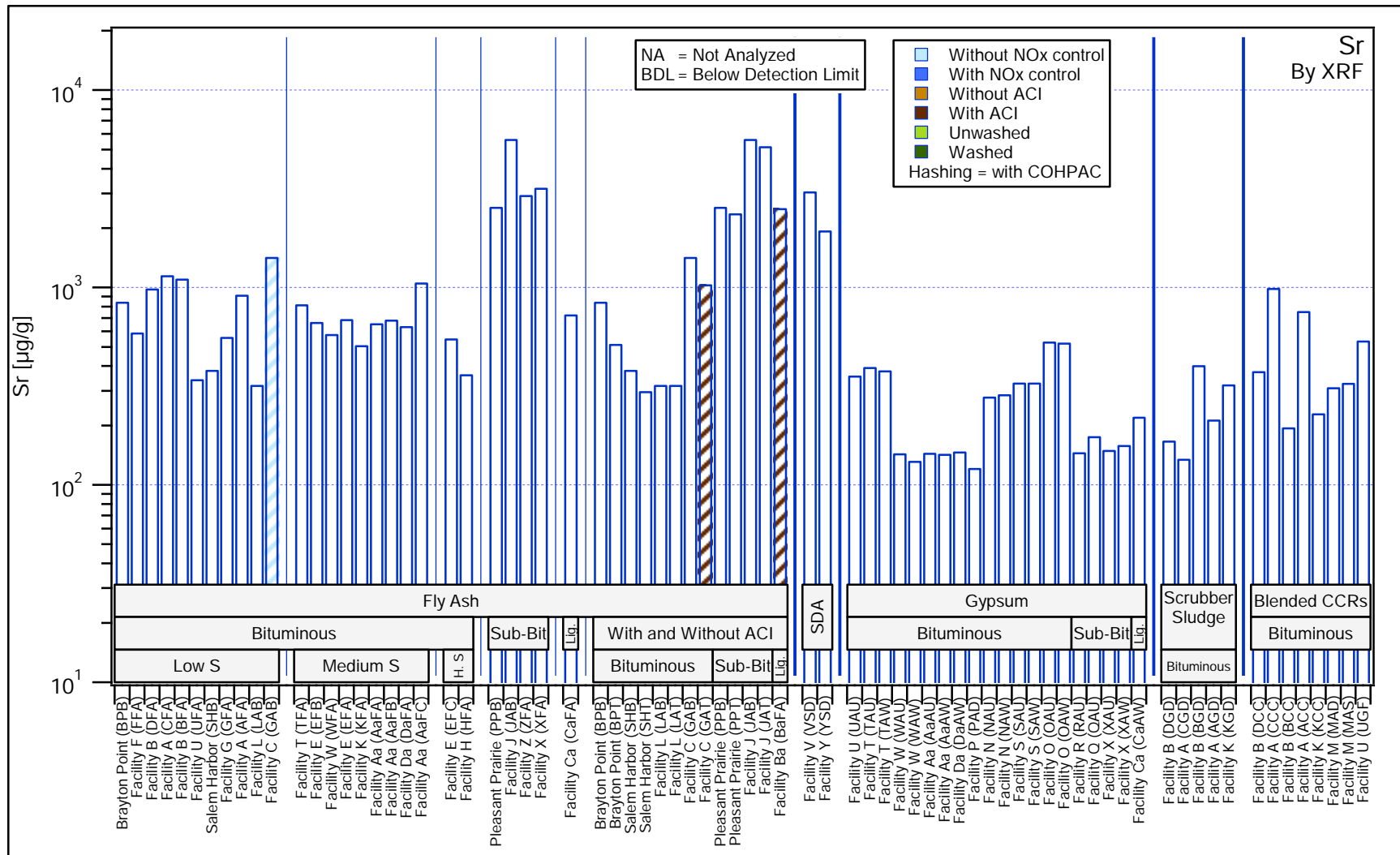


Figure 35. Strontium. Comparison of total elemental content by XRF.

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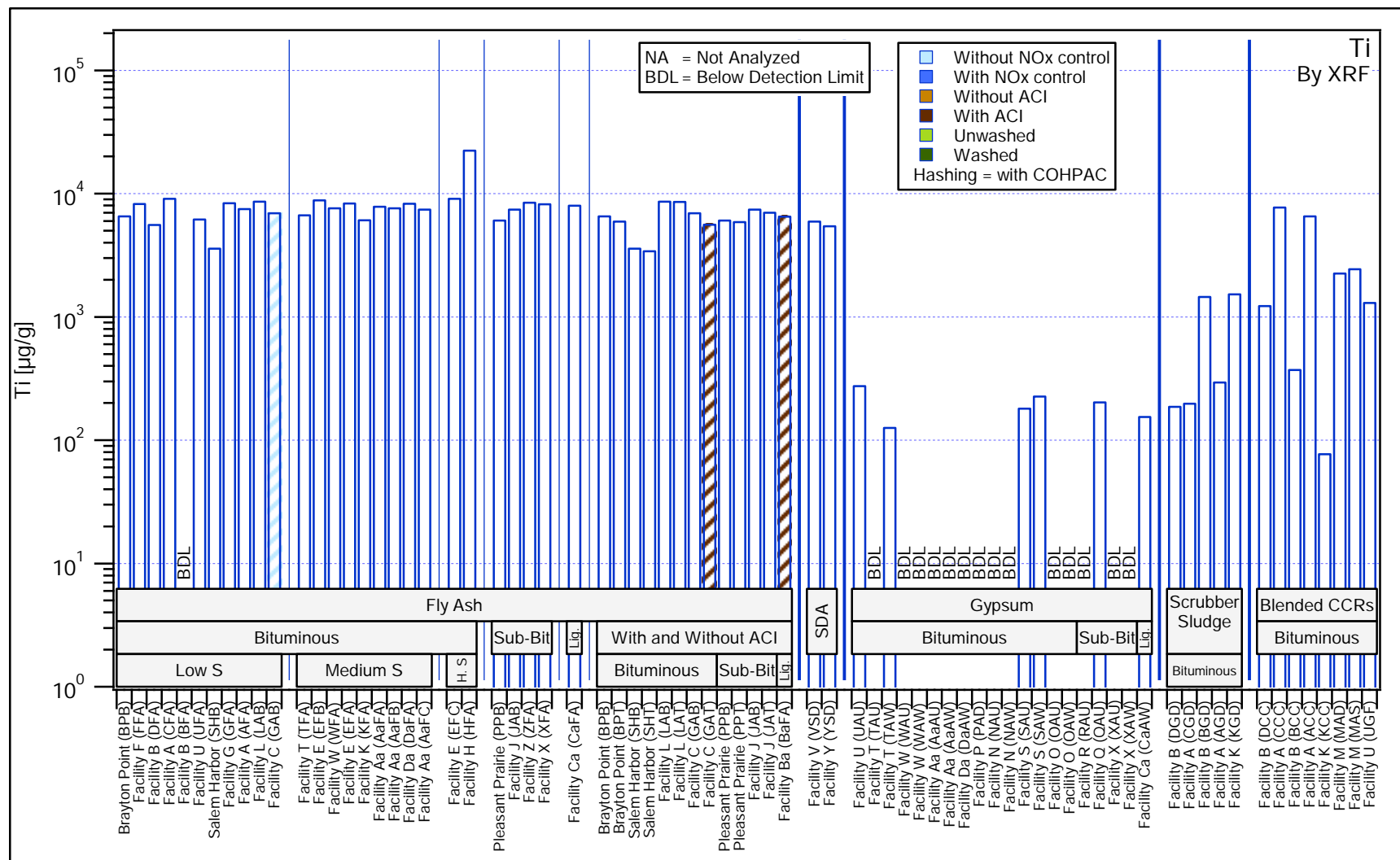


Figure 36. Thallium. Comparison of total elemental content by XRF.

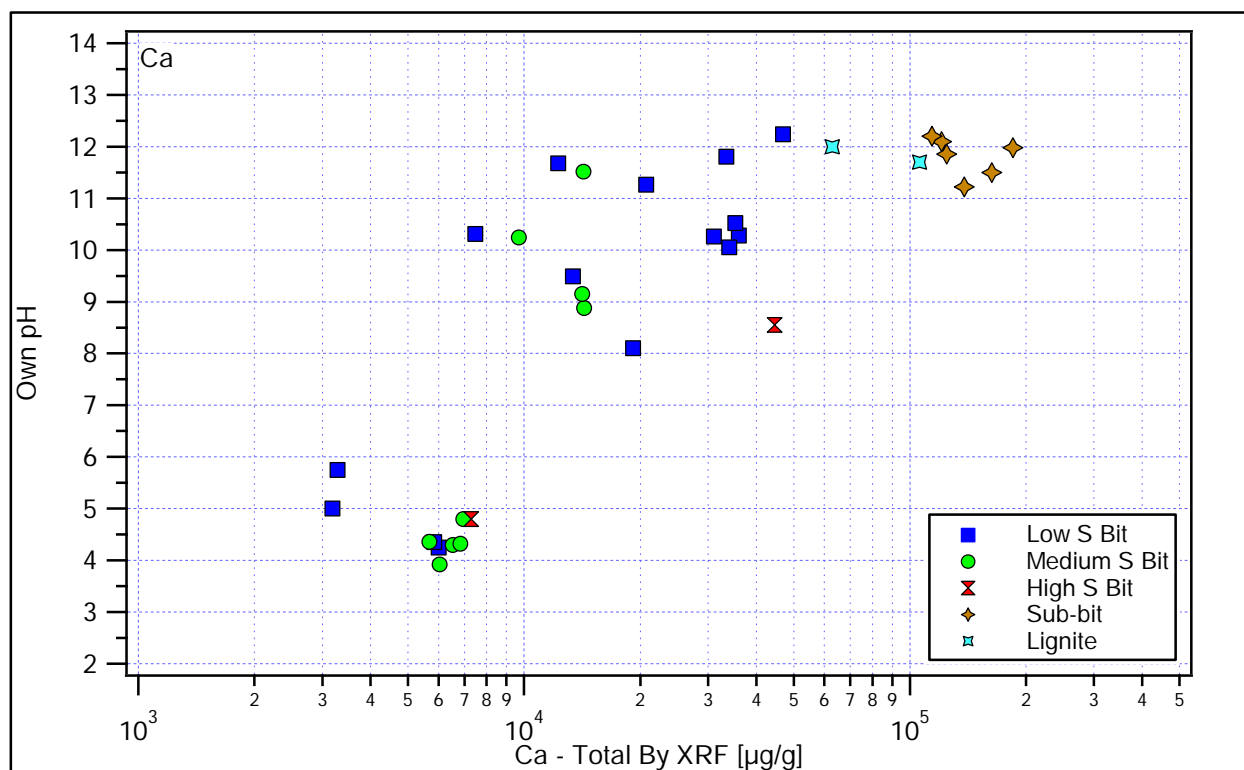


Figure 37. Total calcium content (by XRF) and own pH for fly ash samples.

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 potential⁴¹. 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.

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 $\text{pH} < 10.5$ with a few samples, e.g. AFA, showing a decrease in B eluate concentration with increasing pH for $\text{pH} > 8$. In general, samples with decreasing concentration for $\text{pH} > 8$ 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 $\text{pH} < 5$ was observed for Cd for most cases except for sample AFA that showed increasing eluate concentration with decreasing pH for $\text{pH} < 8$.

Cobalt (Co). Cobalt leaching behavior was similar for all samples tested with minimum values observed for $\text{pH} > 11$, an increase in eluate concentration with decreasing pH for $\text{pH} < 11$, 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 $\text{pH} > 5$ with an increase in concentration for $\text{pH} < 5$ (e.g., AFA and GAB) [Both have fabric filter (one fabric filter and one COHPAC)], and (iii) concentration peaking at $8 < \text{pH} < 10$ 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 $\text{pH} \sim 8$ (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 $\text{pH} < 5$ with a peak concentration at $\text{pH} \sim 3.8$ and a relatively constant concentration for $\text{pH} > 5.5$ (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 $\text{pH} < 7$ (e.g., GAB and LAB) or $\text{pH} < 4$ (UFA) followed by an increase. As with Hg, sample AFA exhibited a Mo concentration peaking at $\text{pH} \sim 8$, 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 $\text{pH} \sim 8$ (e.g., ZAF).

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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 $7 < \text{pH} < 10$ (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 $5 < \text{pH} < 6$. 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 $\text{pH} < 12$ (e.g., UAF and AaFC), $\text{pH} < 9$ (e.g., AFA), or $\text{pH} < 7$ (e.g., LAB and ZFA) and (ii) relatively constant concentration with an increase at $\text{pH} < 7$ (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 NO_x 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.

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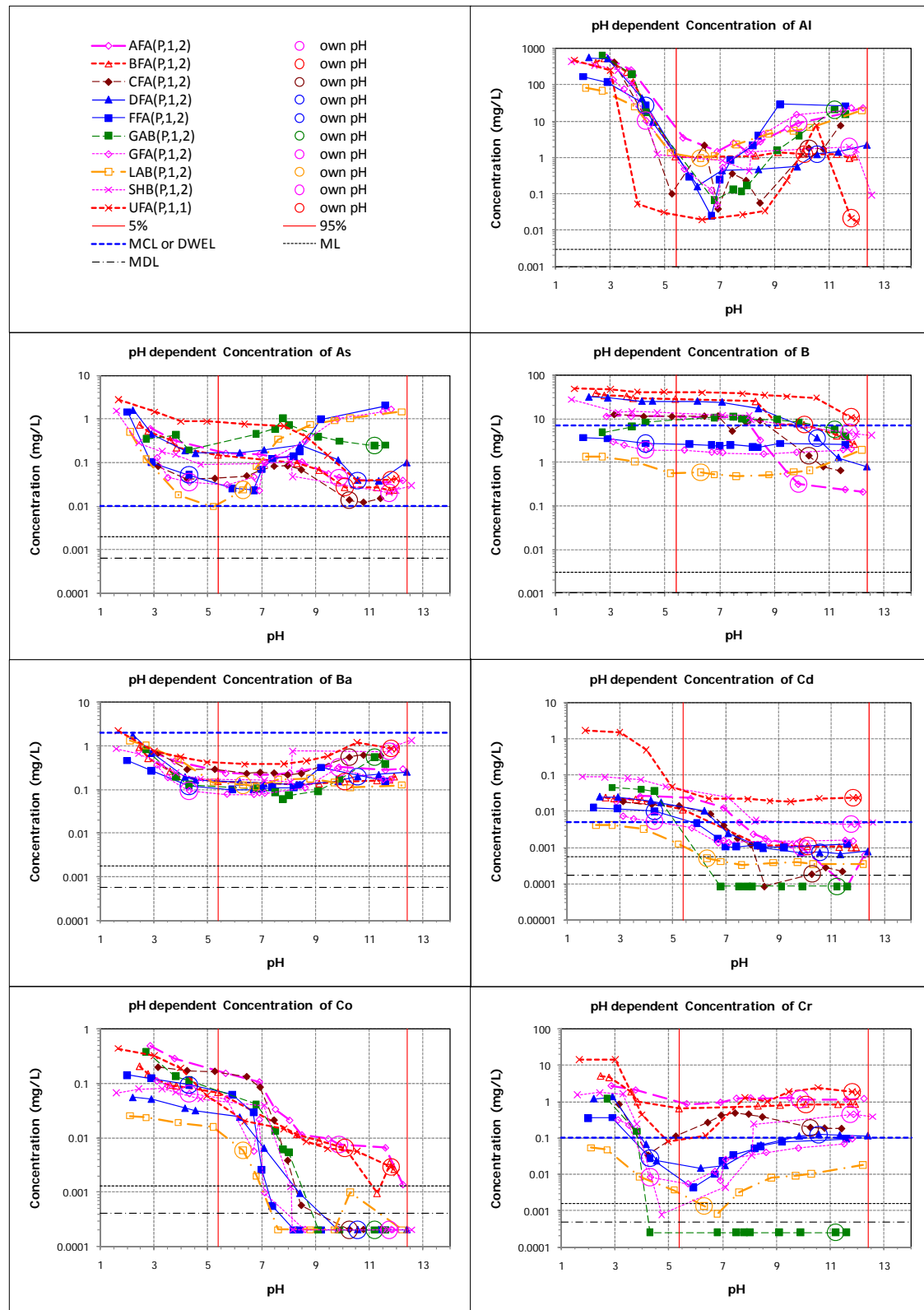


Figure 38. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous low sulfur coal]. Facility A (AFA, CFA), Facility B (BFA, DFA), Facility C (GAB), Facility G (GFA), Facility L (LAB), Salem Harbor (SHB).

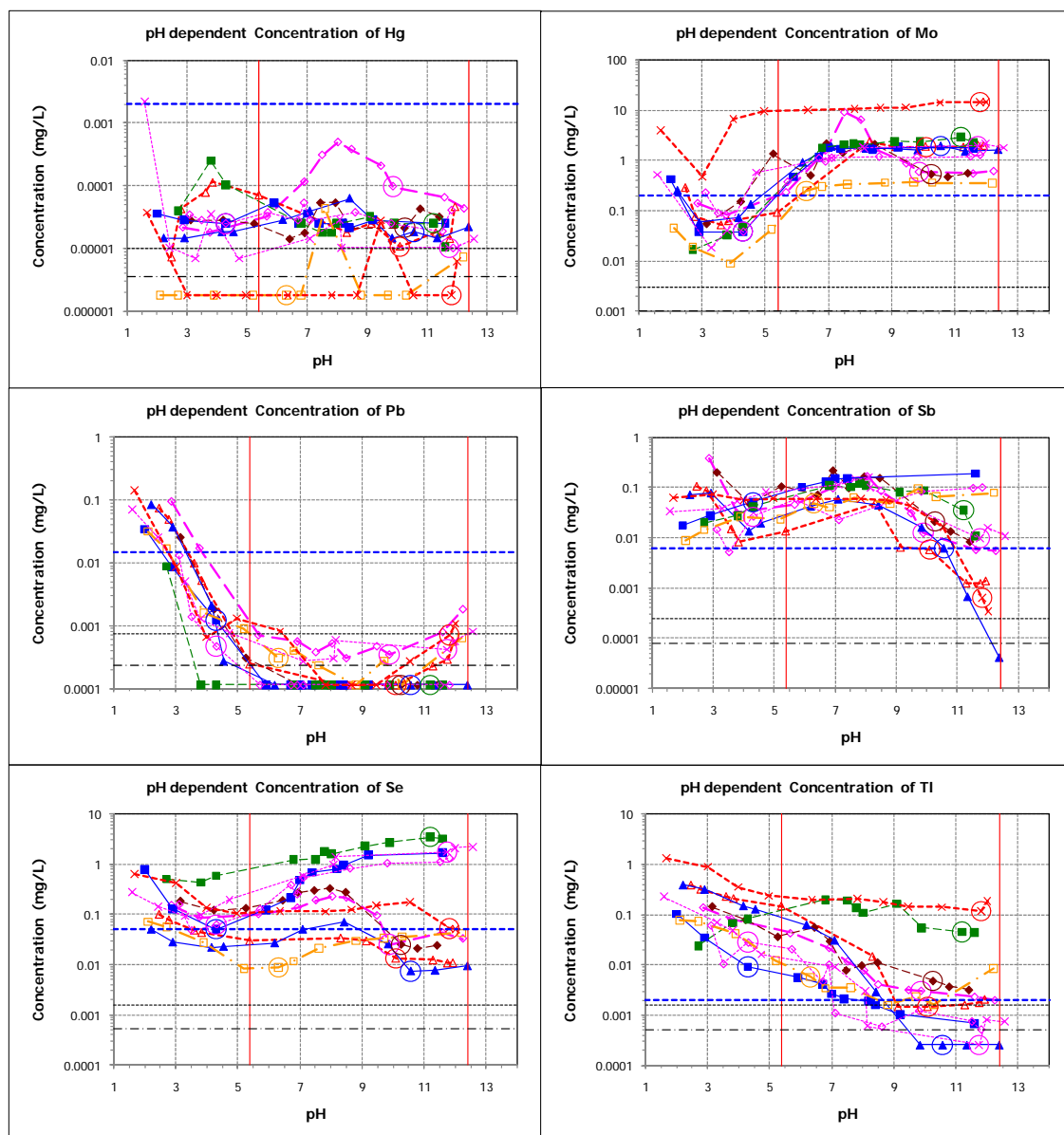


Figure 38 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous low sulfur coal]. Facility A (AFA, CFA), Facility B (BFA, DFA), Facility C (GAB), Facility G (GFA), Facility L (LAB), Salem Harbor (SHB).

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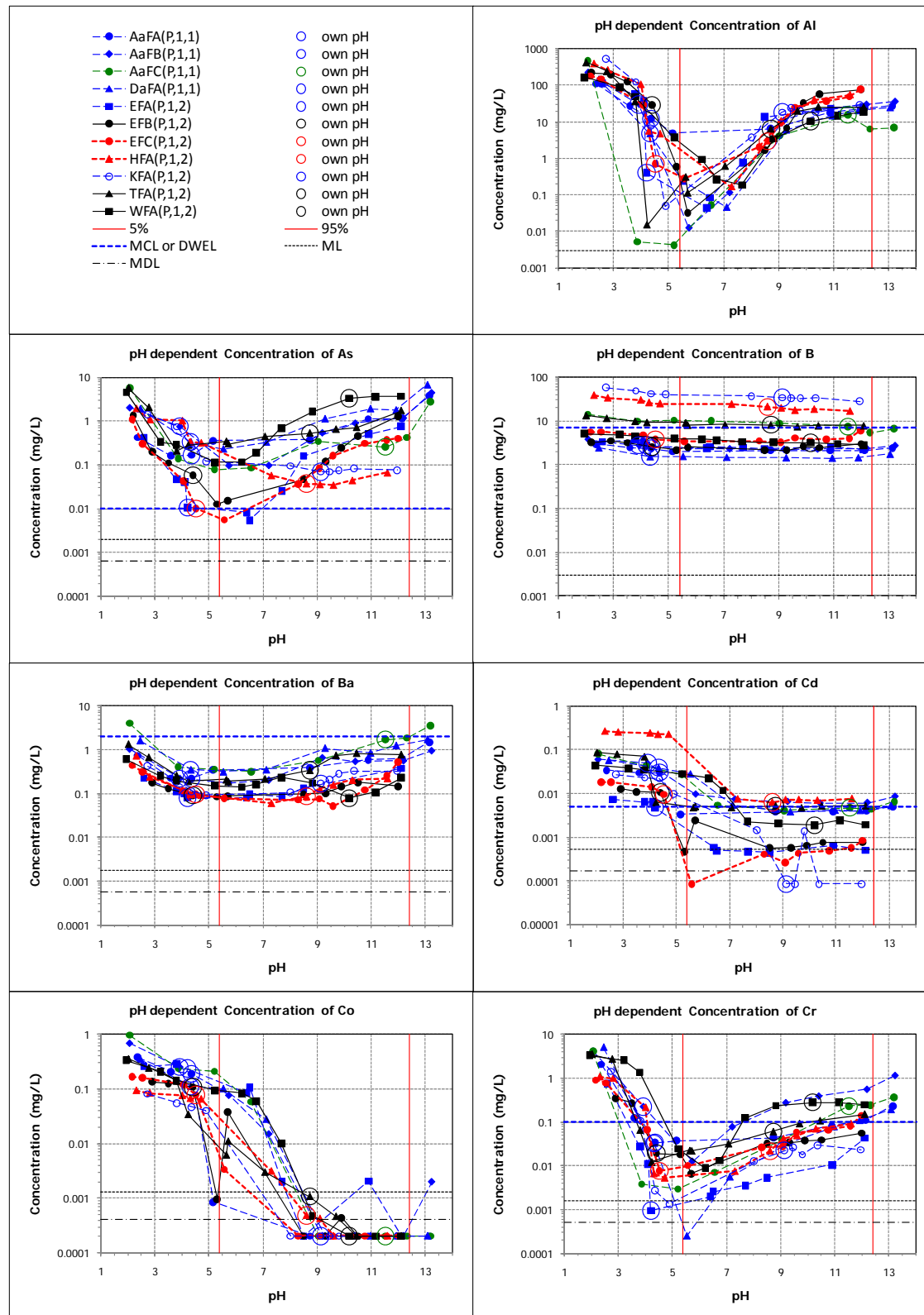


Figure 39. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous medium and high sulfur coal]. Facility E (EFA, EFB), Facility K (KFA), Facility T (TFA), Facility W (WFA), Facility Aa (AaFA, AaFB, AaFC), Facility Da (DaFA).

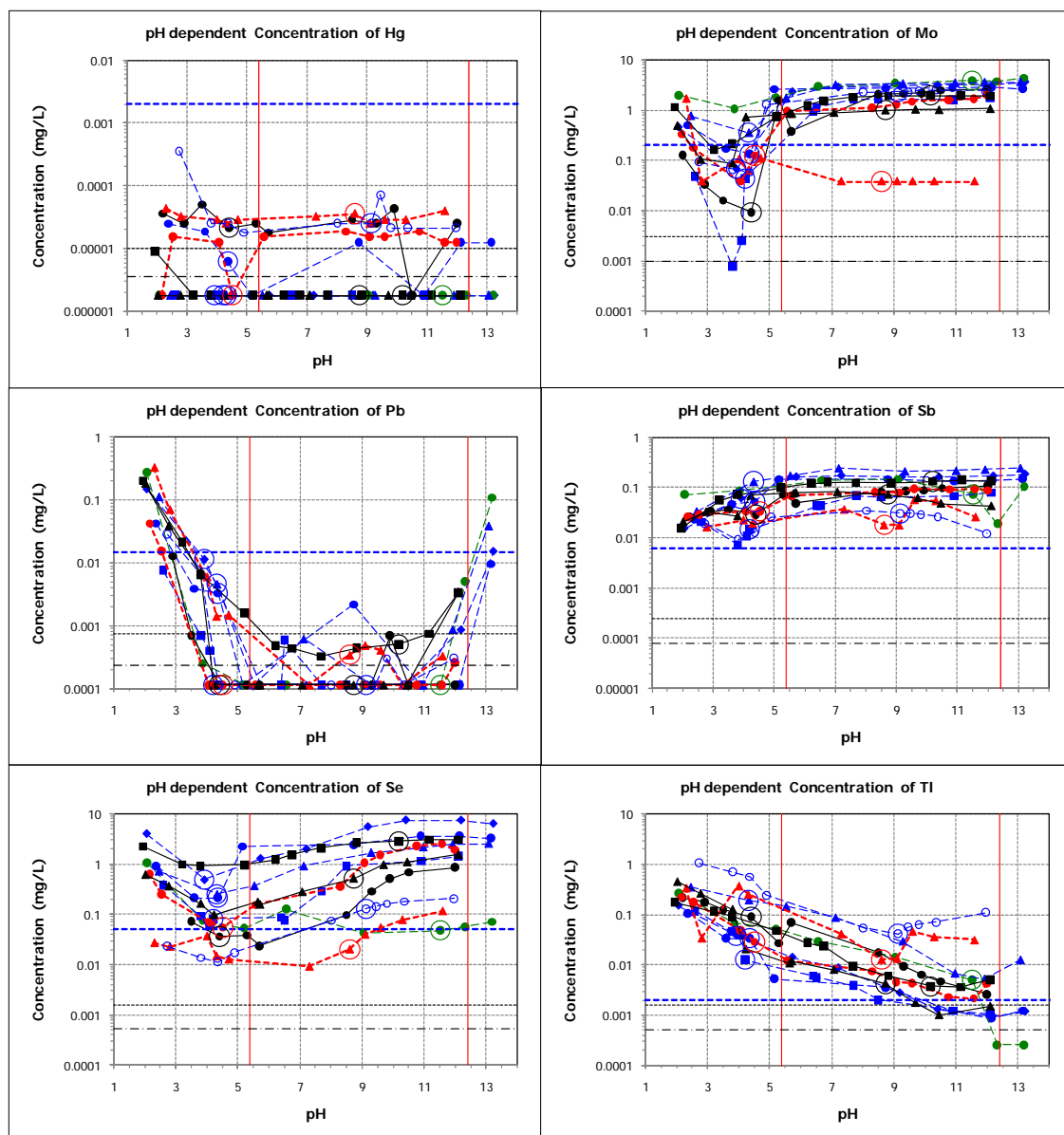


Figure 39 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [bituminous medium and high sulfur coal]. Facility E (EFA, EFB), Facility K (KFA), Facility T (TFA), Facility W (WFA), Facility Aa (AaFA, AaFB, AaFC), Facility Da (DaFA).

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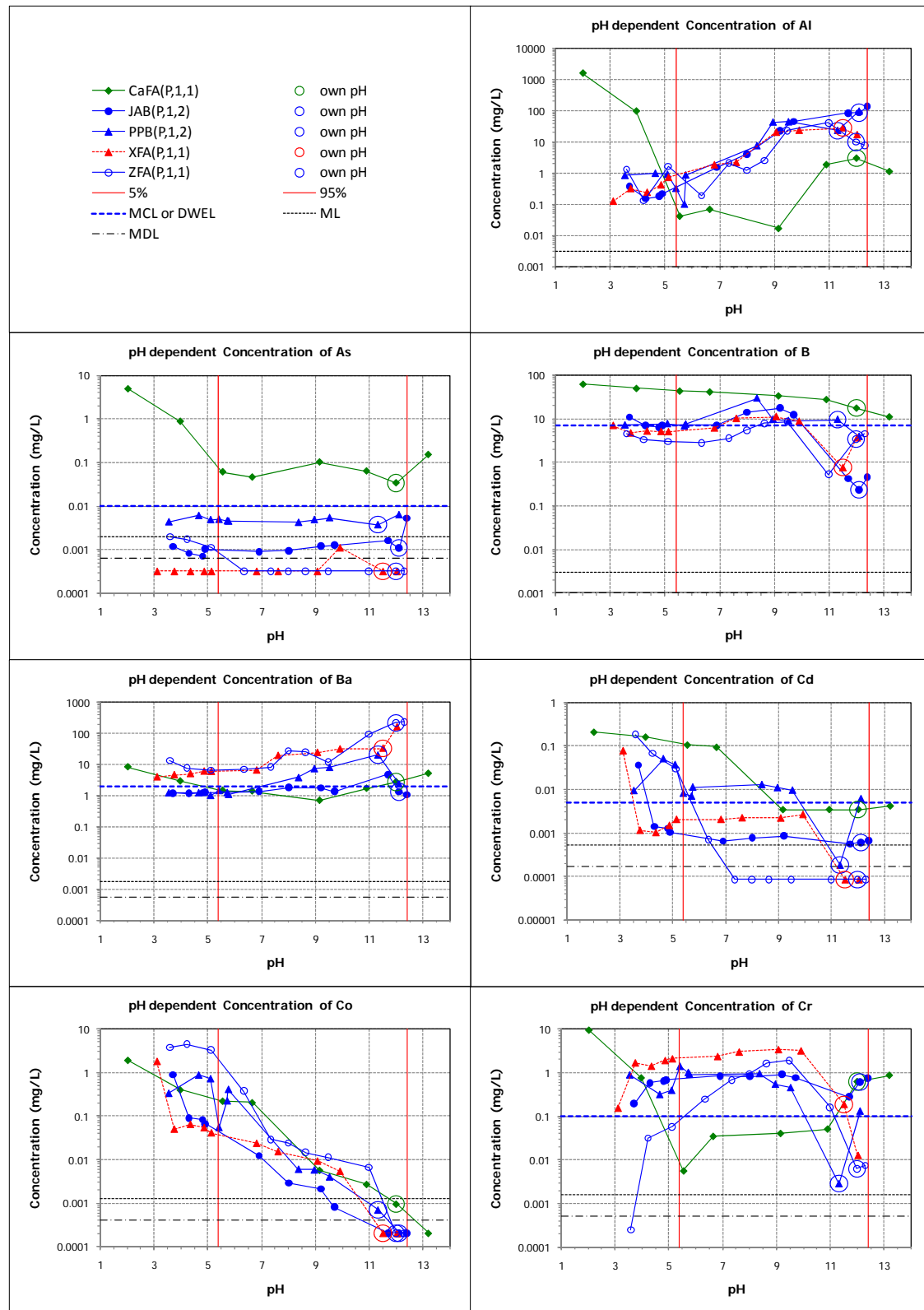


Figure 40. pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [sub-bituminous and lignite coal]. Sub-bituminous: Facility J (JAB), Facility X (XFA), Facility Z (ZFA), Pleasant Prairie (PPB). Lignite: Facility Ca (CaFA).

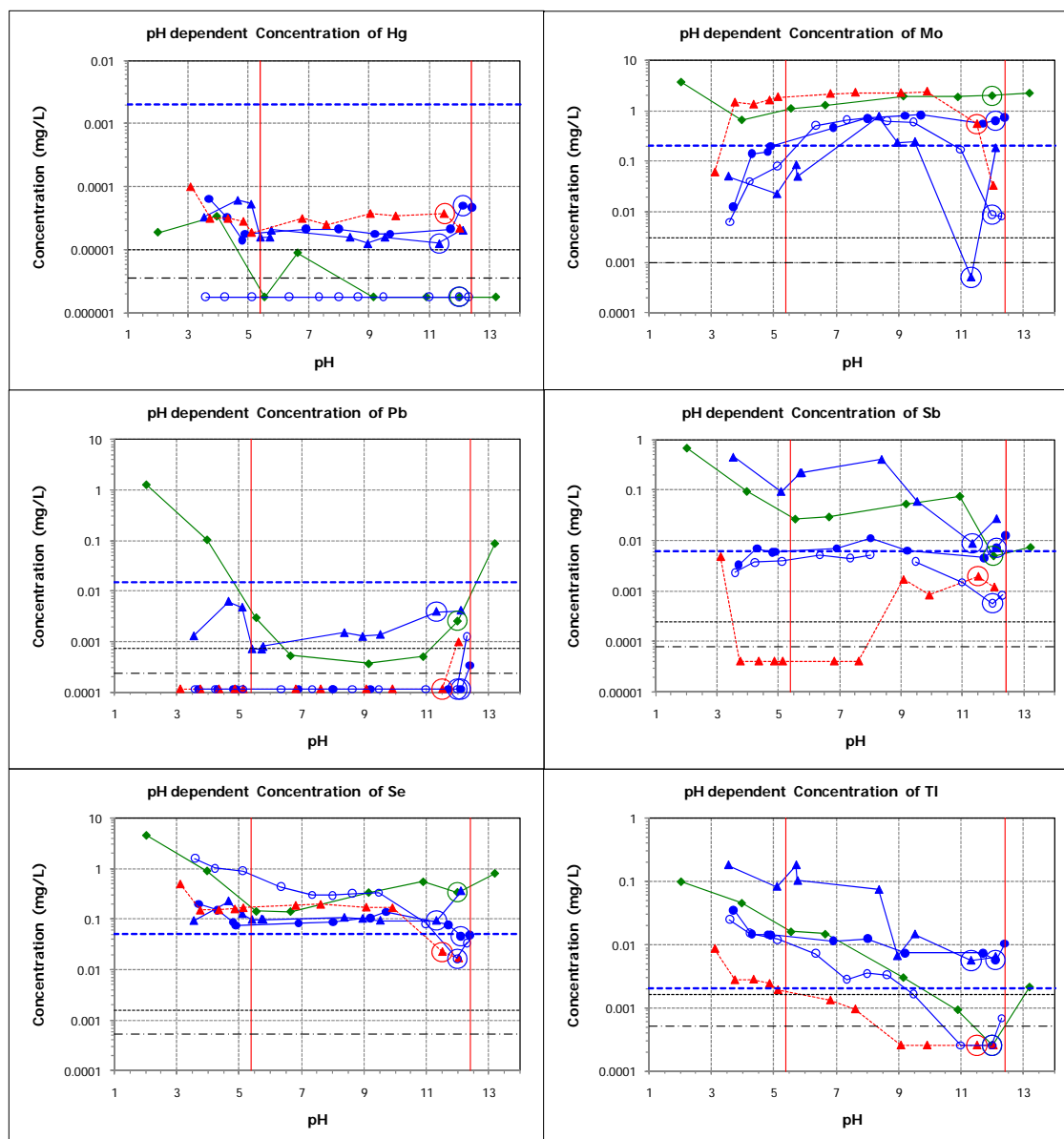


Figure 40 (continued). pH dependent leaching results. Fly ash samples from facilities without mercury sorbent injection [sub-bituminous and lignite coal]. Sub-bituminous: Facility J (JAB), Facility X (XFA), Facility Z (ZFA), Pleasant Prairie (PPB). Lignite: Facility Ca (CaFA).

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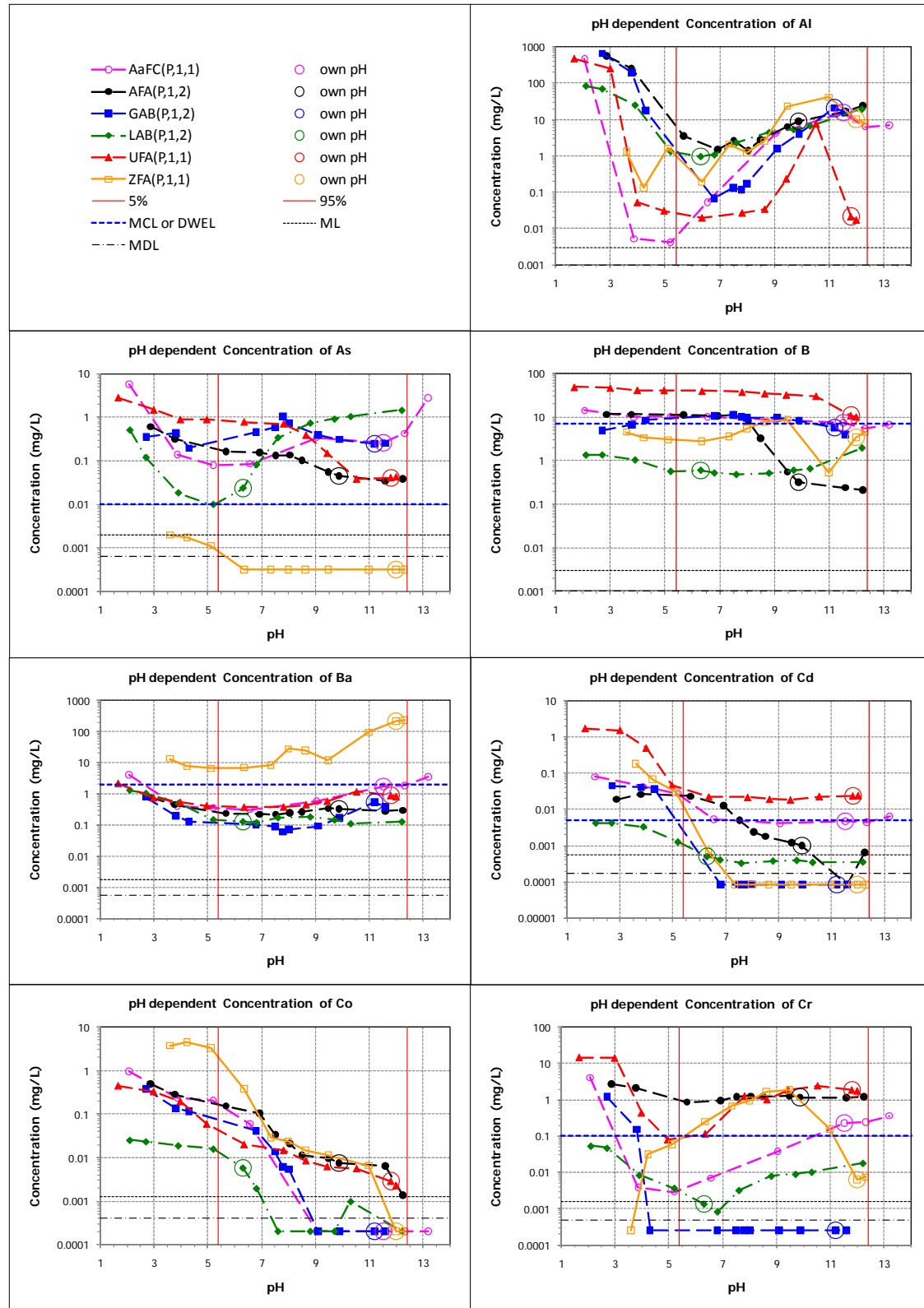


Figure 41. pH dependent leaching results. Selected results to illustrate characteristic leaching behavior.

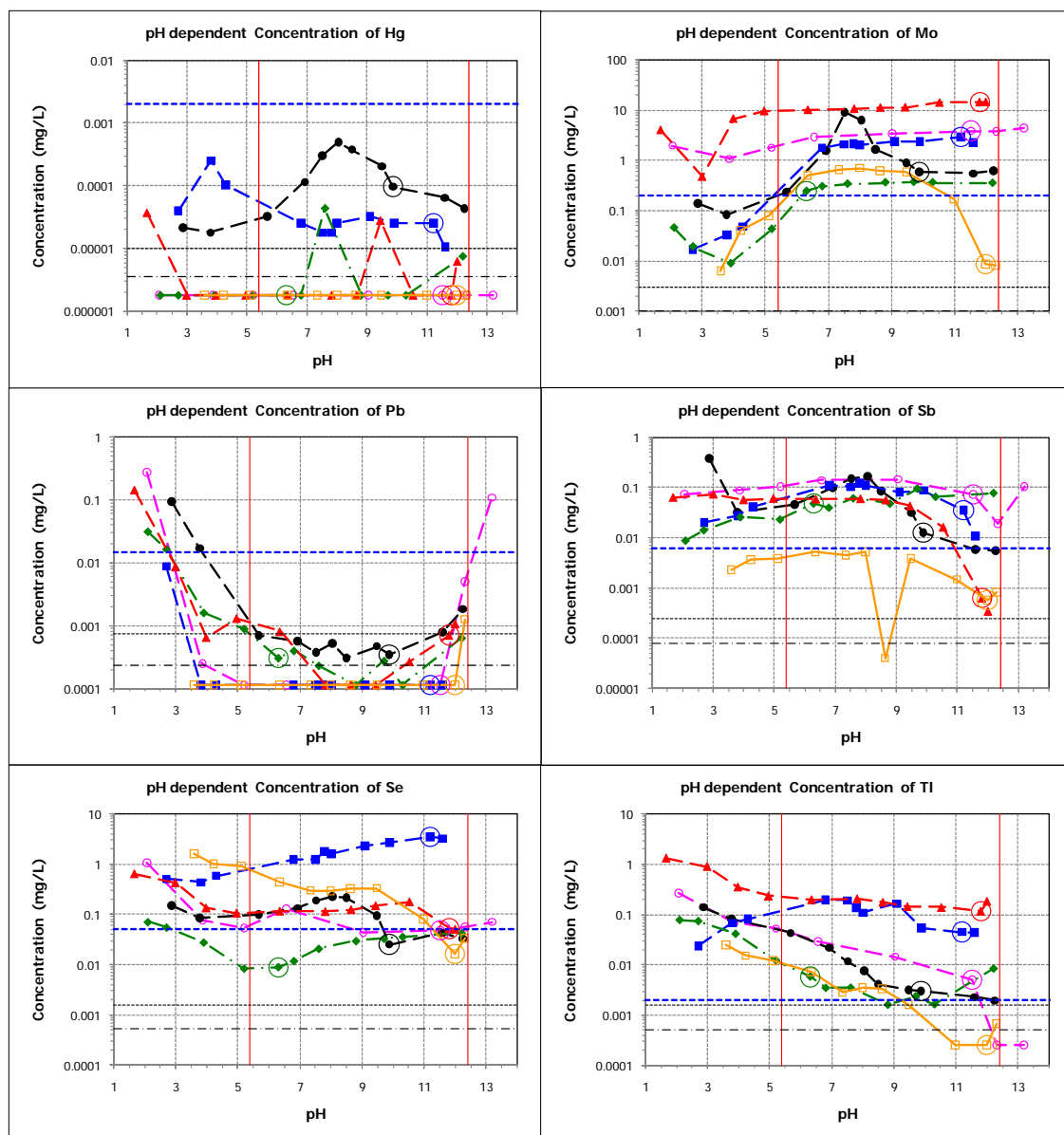


Figure 41 (continued). pH dependent leaching results. Selected results to illustrate characteristic leaching behavior.

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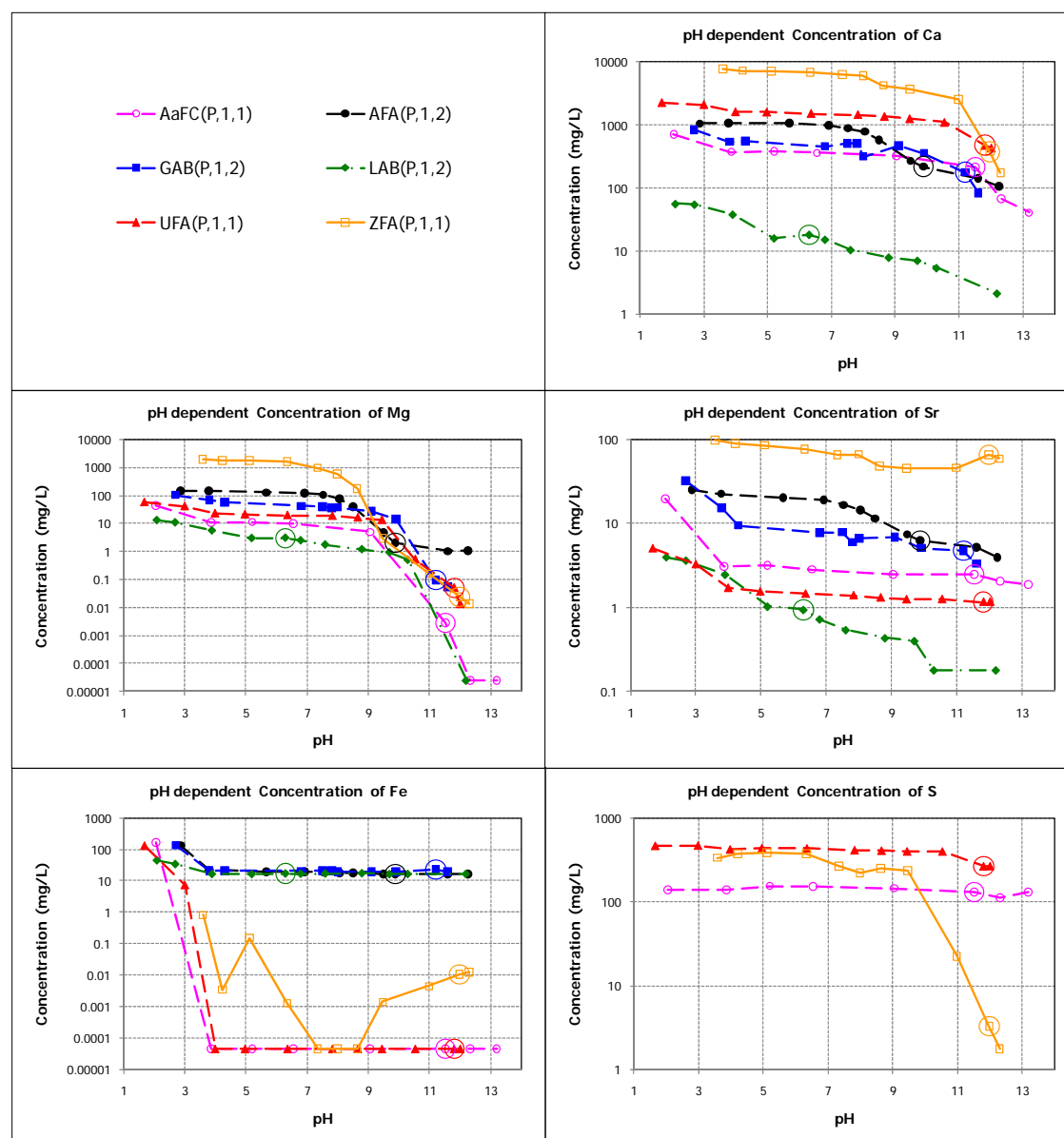


Figure 42. pH dependent leaching results. Selected results to illustrate characteristic leaching behavior of calcium, magnesium, strontium, iron, and sulfur.

Characterization of Coal Combustion Residues III

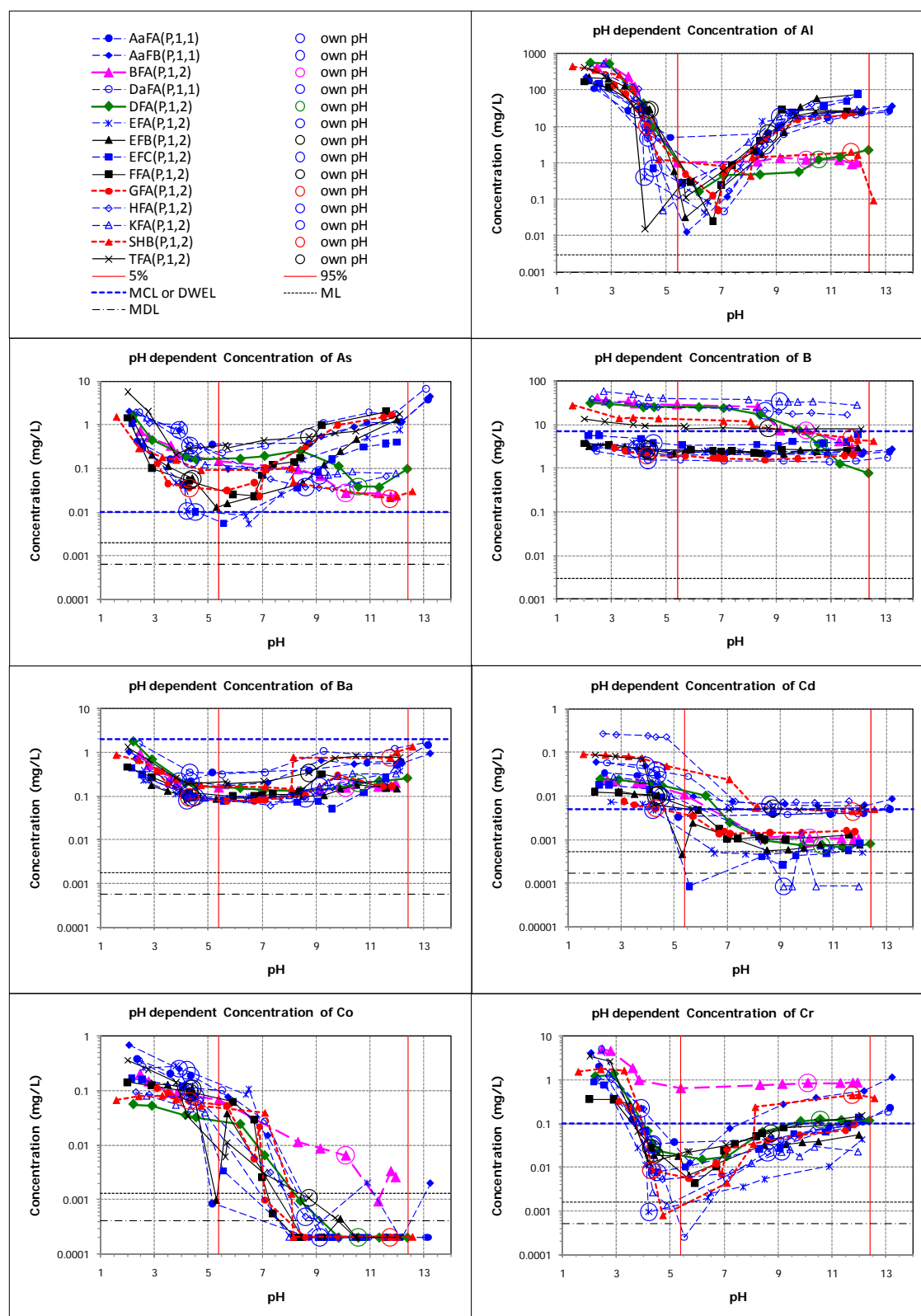


Figure 43. Effect of NO_x controls - none (or by-passed; samples DFA, EFB, FFA, TFA), SNCR (samples GFA, SHB) or SCR (all other samples) for facilities burning Eastern Bituminous coal and using CS-ESP for particulate control.

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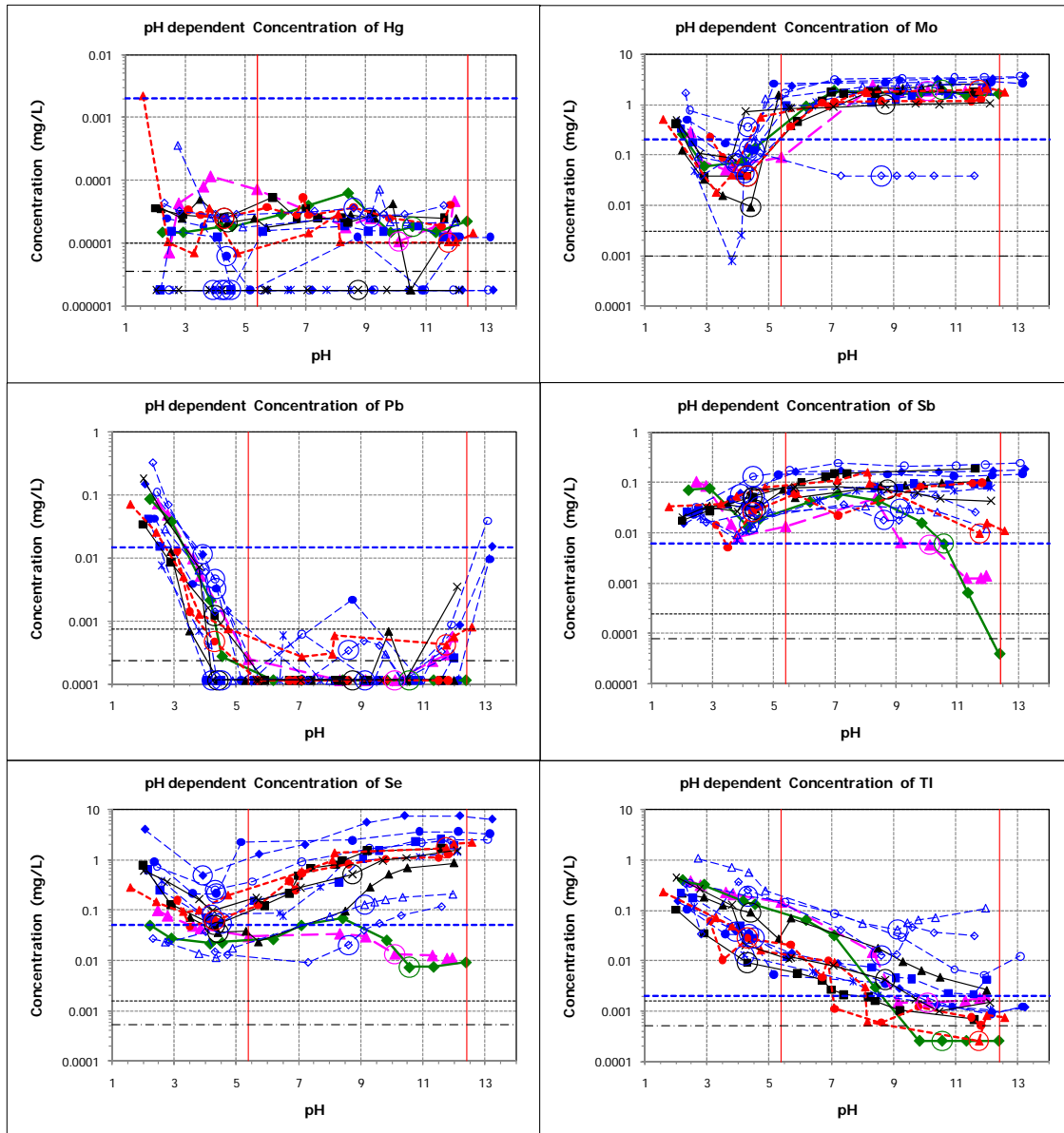


Figure 43 (continued). Effect of NO_x controls - none (or by-passed; samples DFA, EFB, FFA, TFA), SNCR (samples GFA, SHB) or SCR (all other samples) for facilities burning Eastern Bituminous coal and using CS-ESP for particulate control.

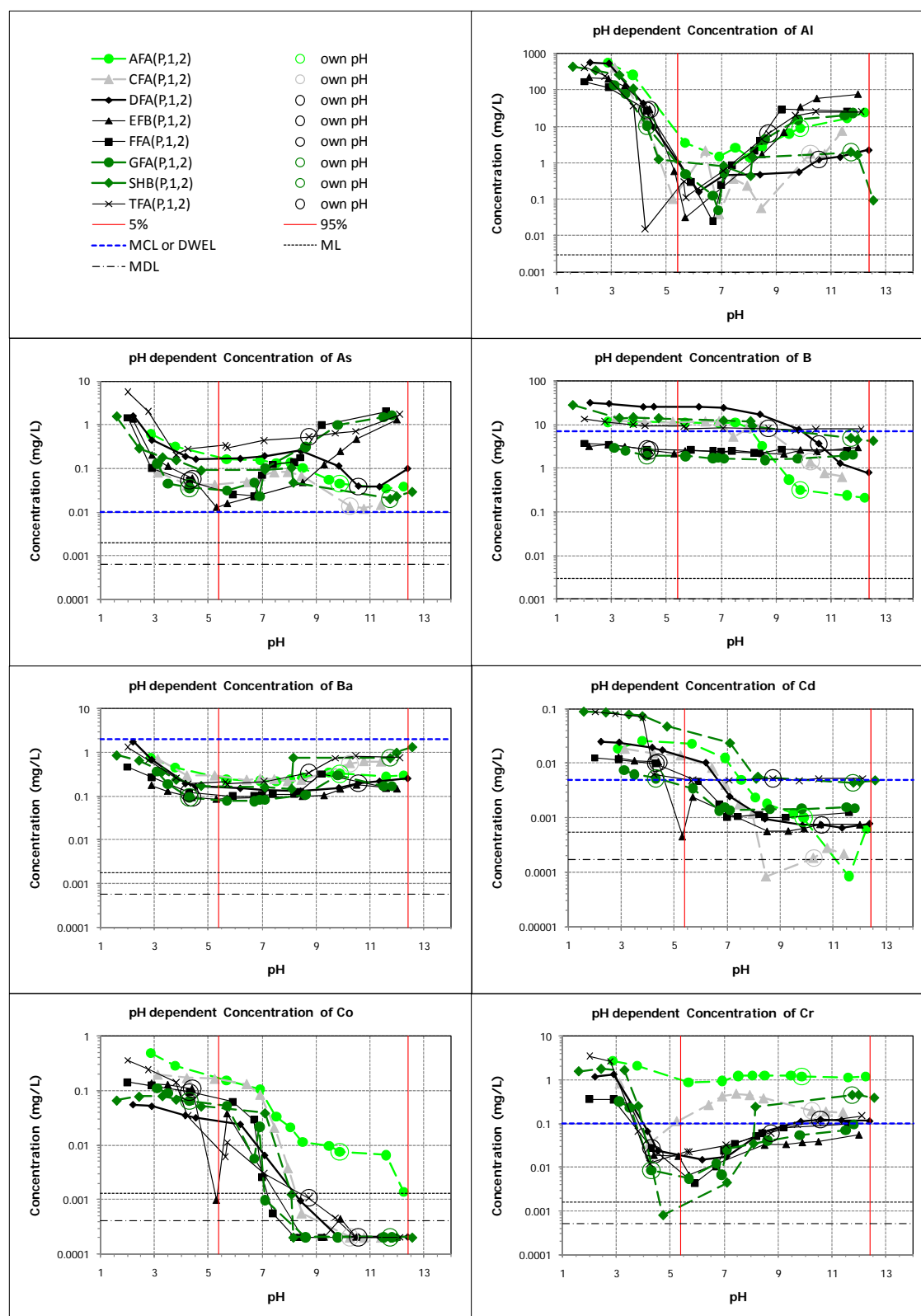


Figure 44. Effect of fabric filter vs. CS-ESP (fabric filter without NO_x control, sample CFA; with SNCR, sample AFA; CS-ESP without NO_x control, samples DFA, EFB, FFA, TFA; with SNCR, samples GFA, SHB) for facilities burning Eastern Bituminous coal.

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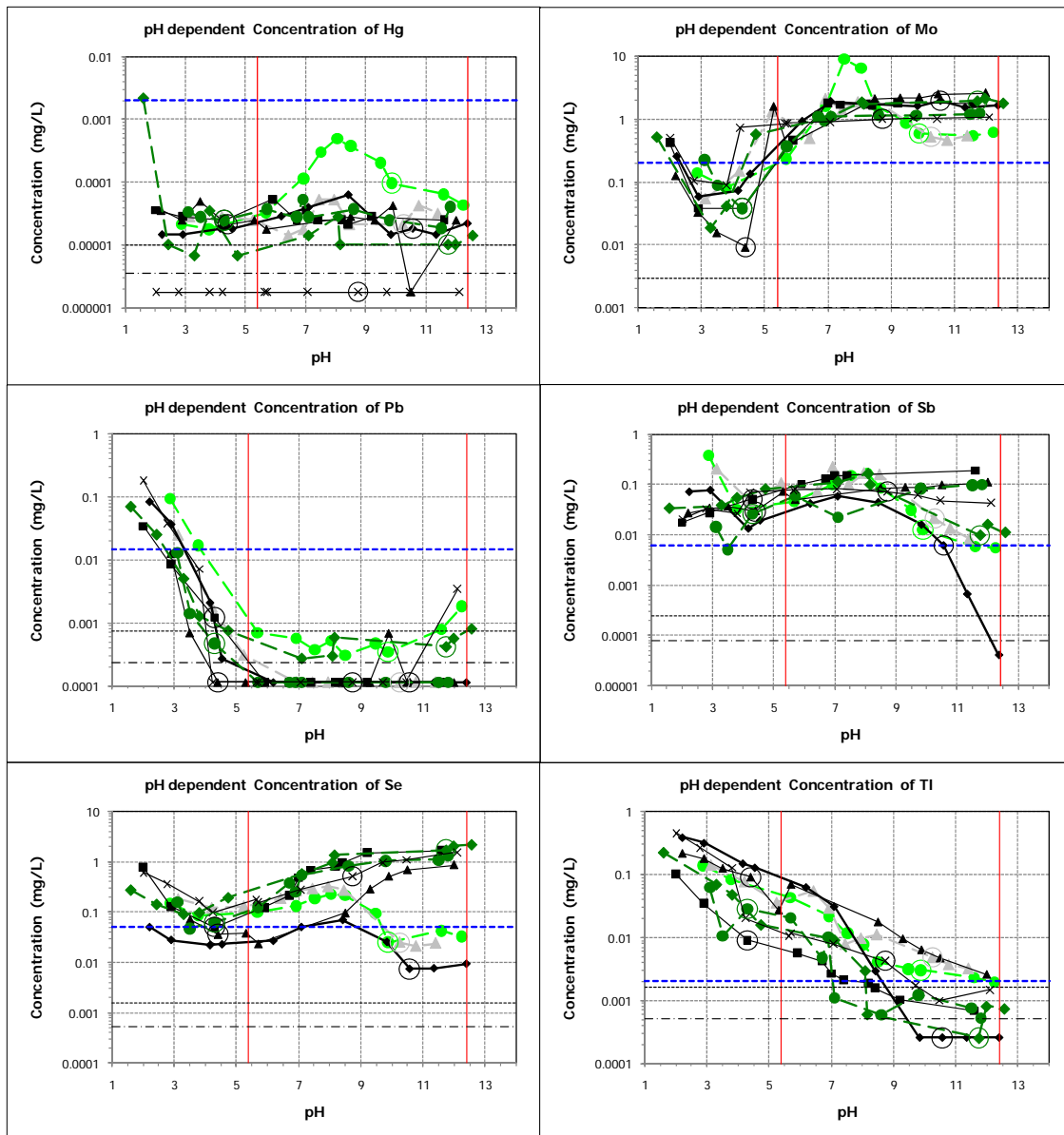


Figure 44 (continued). Effect of fabric filter vs. CS-ESP (fabric filter without NO_x control, sample CFA; with SNCR, sample AFA; CS-ESP without NO_x control, samples DFA, EFB, FFA, TFA; with SNCR, samples GFA, SHB) for facilities burning Eastern Bituminous coal.

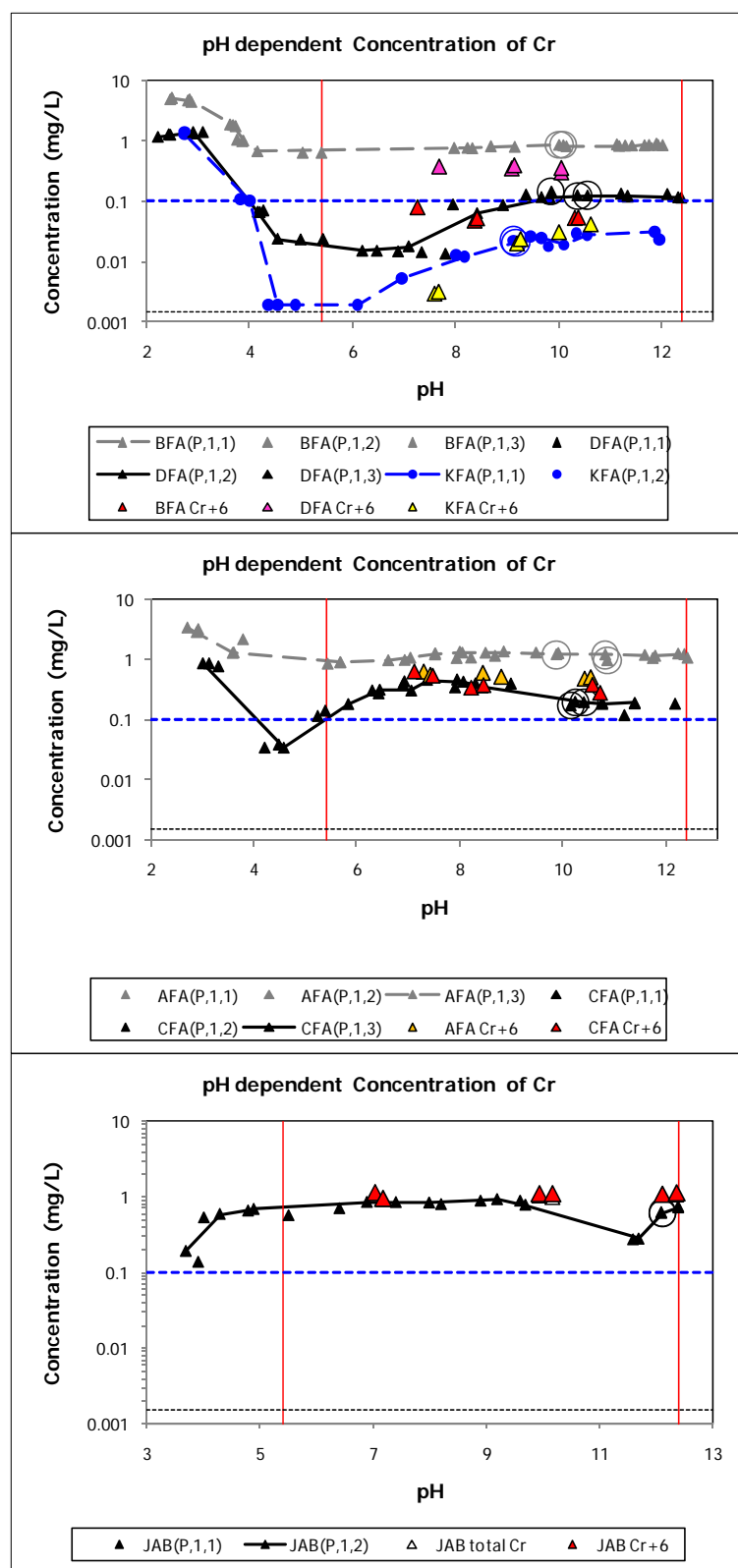


Figure 45. Chromium speciation results. Bituminous coal: Facility B with SCR (BFA), with SCR-BP (DFA); Facility K with SCR (KFA); Facility A with SNCR (AFA), with SNCR-BP (CFA). Sub-bituminous coal: Facility J with SCR (JAB).

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 $8 < \text{pH} < 12$ 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 $9.5 < \text{pH} < 12$.

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 $6 < \text{pH} < 11.5$ 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 $\text{pH} < 7$ and $\text{pH} > 12$ (above the MCL).

Cadmium (Cd). For Salem Harbor, the case with ACI had an increase in Cd eluate concentrations for $\text{pH} > 4.5$ compared to the same facility without ACI. For Brayton Point a decrease in Cd concentrations was observed with ACI for $\text{pH} < 7$. 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 $\text{pH} > 7$ 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 $0.2 \mu\text{g/L}$ 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 $5.4 \leq \text{pH} \leq 12.4$ 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

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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 $4 < \text{pH} < 12$. For Facility J, the case with ACI showed an increase in Pb eluate concentrations for $4 < \text{pH} < 10$ 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 $\text{pH} > 8$ and a decrease for $\text{pH} < 7.5$ 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 $\text{pH} > 10$ and a decrease for $\text{pH} < 9$.

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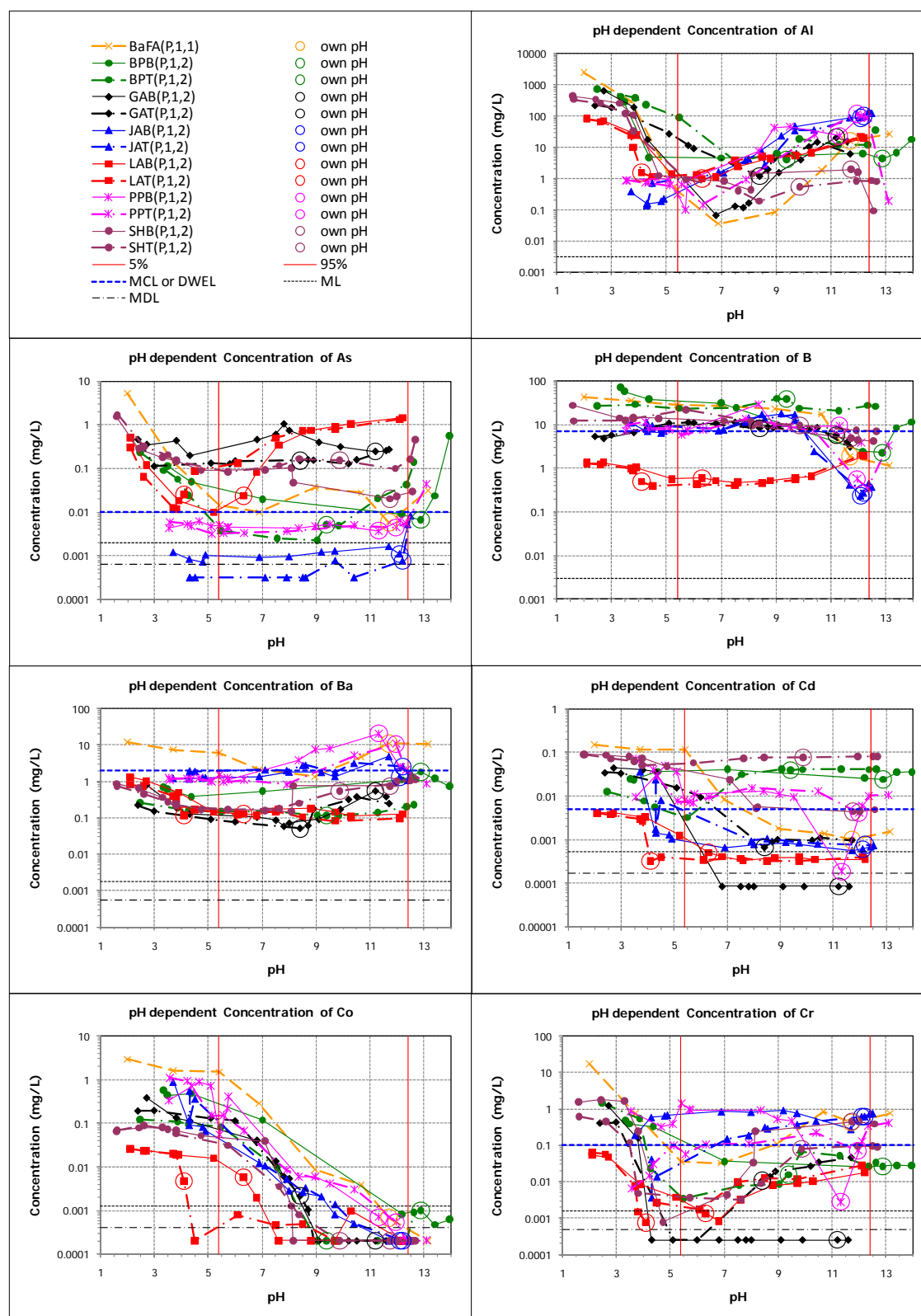


Figure 46. pH dependent leaching results. Fly ash samples from facility pairs with and without mercury sorbent injection. Sample codes ending __B (BPB) indicate without sorbent injection; Sample codes ending __T (BPT) indicate with sorbent injection for the corresponding facility.

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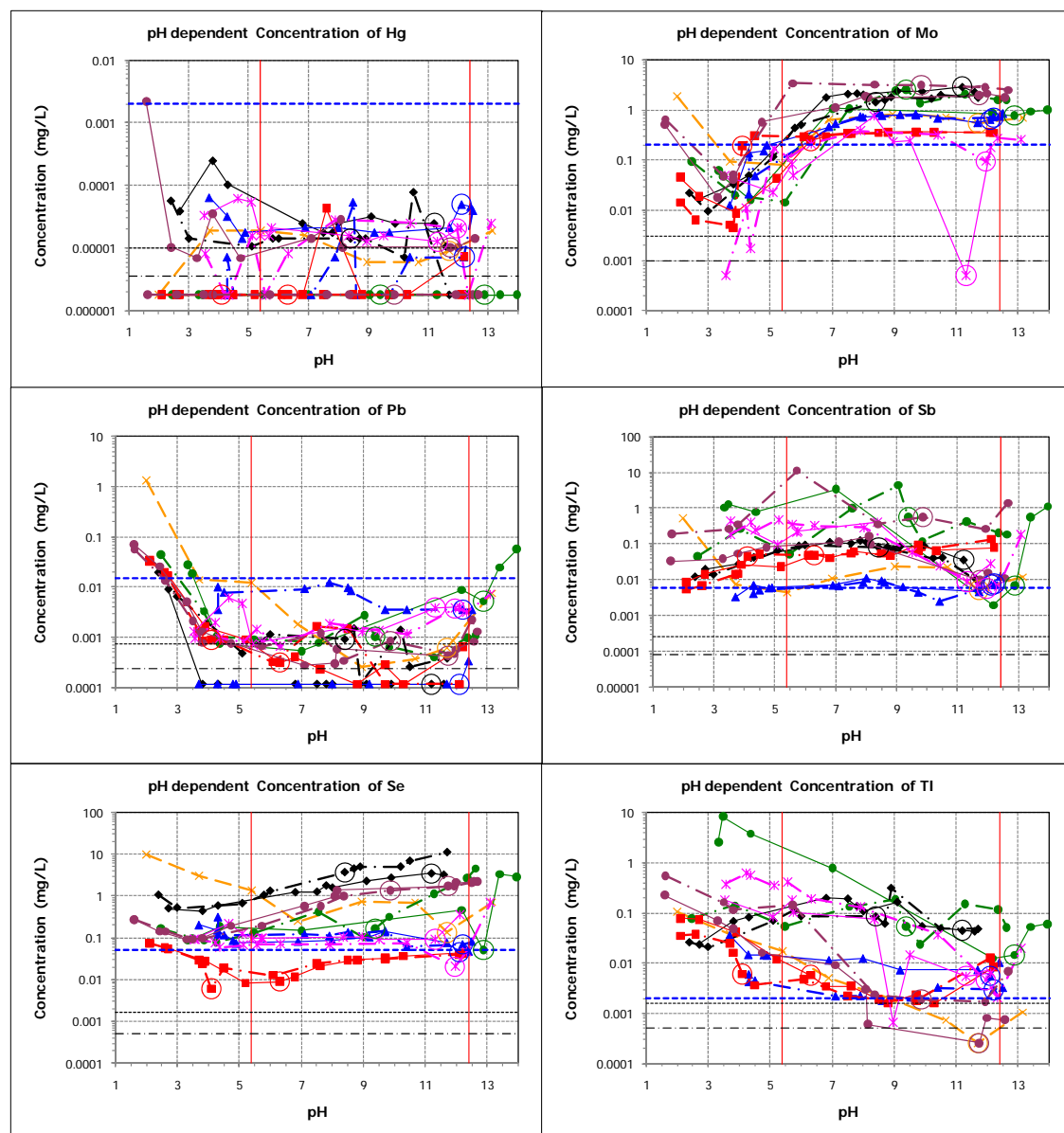


Figure 46 (continued). pH dependent leaching results. Fly ash samples from facility pairs with and without mercury sorbent injection. Fly ash samples from facility pairs with and without mercury sorbent injection. Sample codes ending __B (BPB) indicate without sorbent injection; Sample codes ending __T (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 ($7 < \text{pH} < 10$) and Cr ($4 < \text{pH} < 12$) 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.

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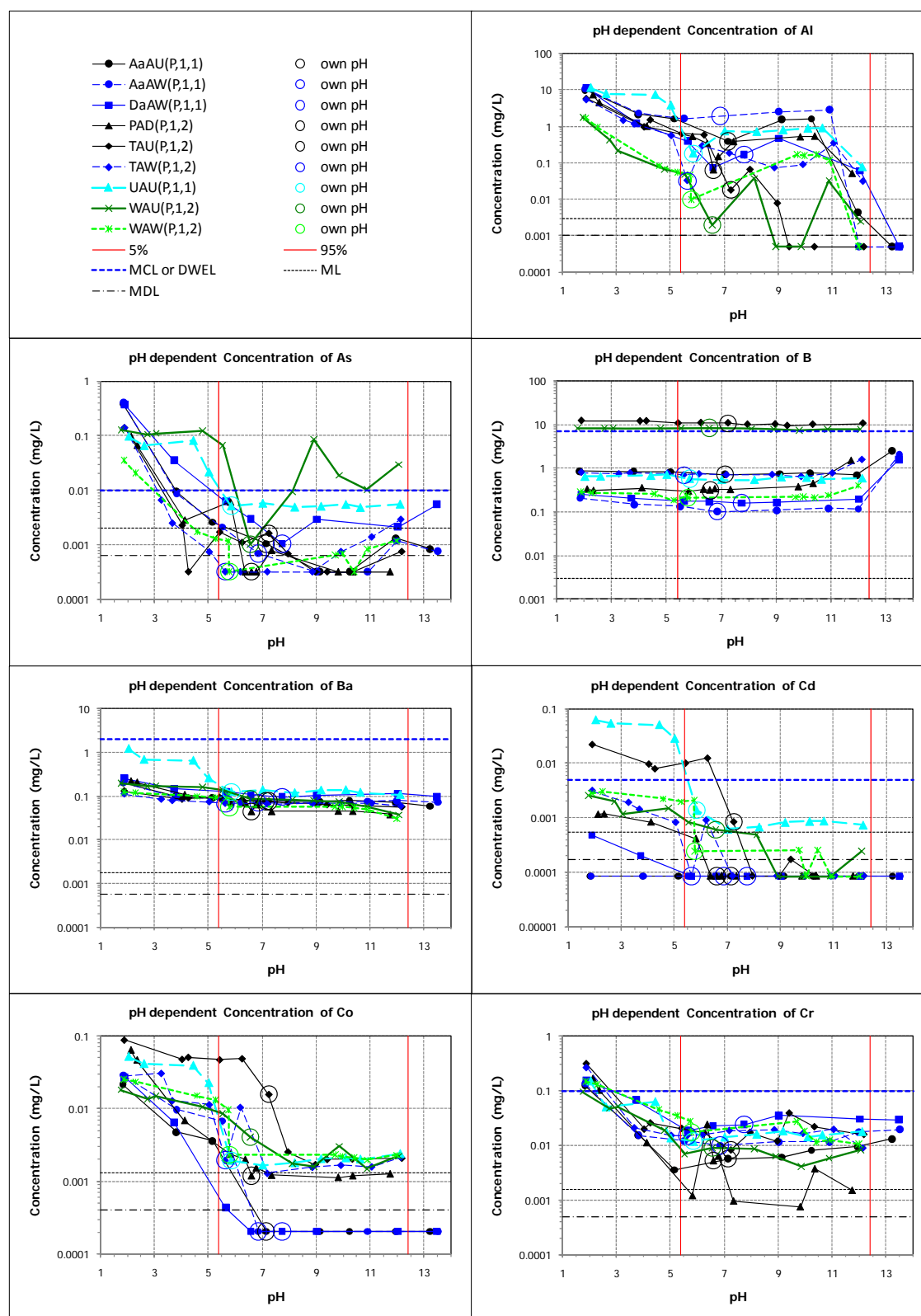


Figure 47. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using low and medium sulfur bituminous coals.

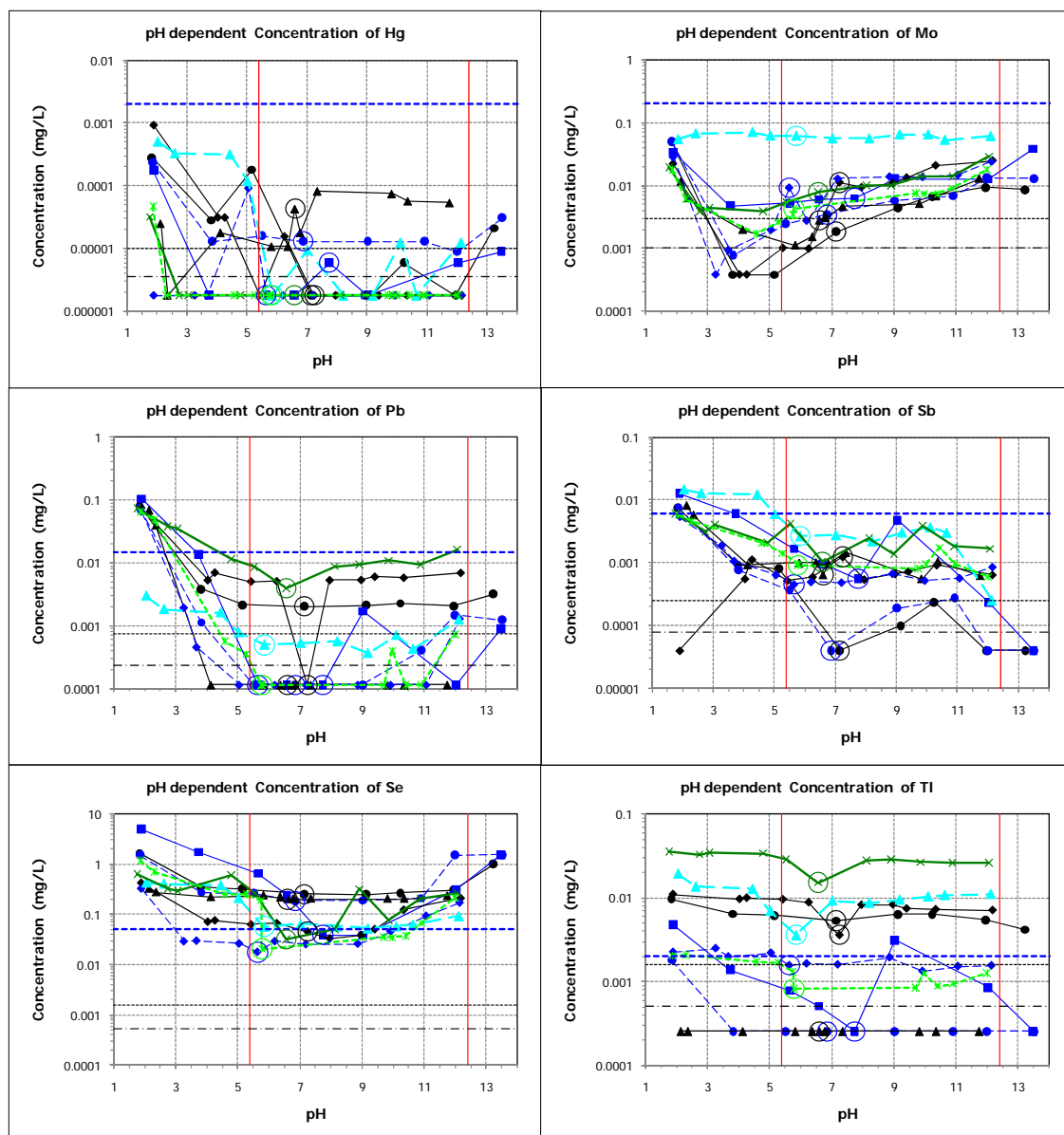


Figure 47 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using low and medium sulfur bituminous coals.

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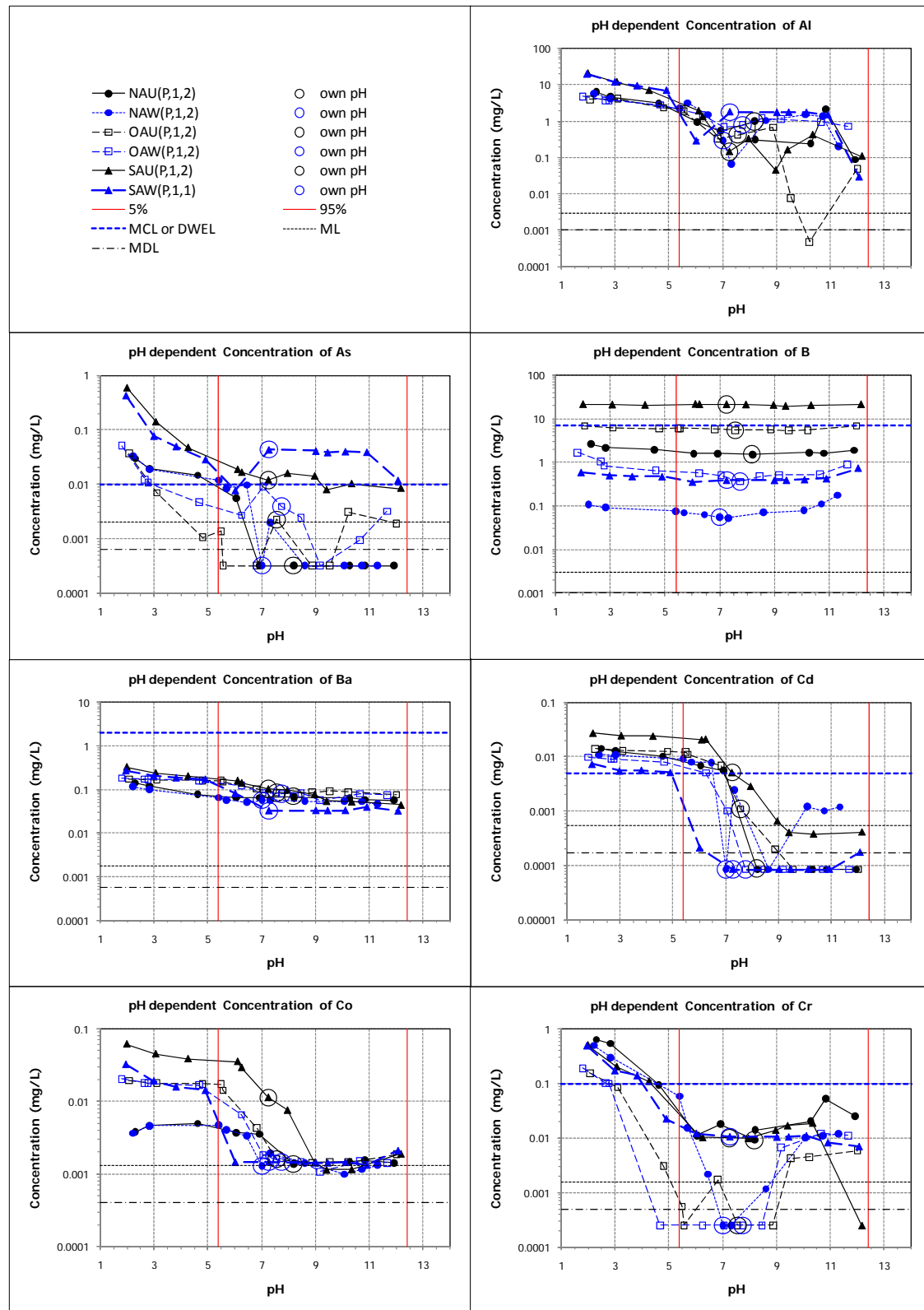


Figure 48. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using high sulfur bituminous coal.

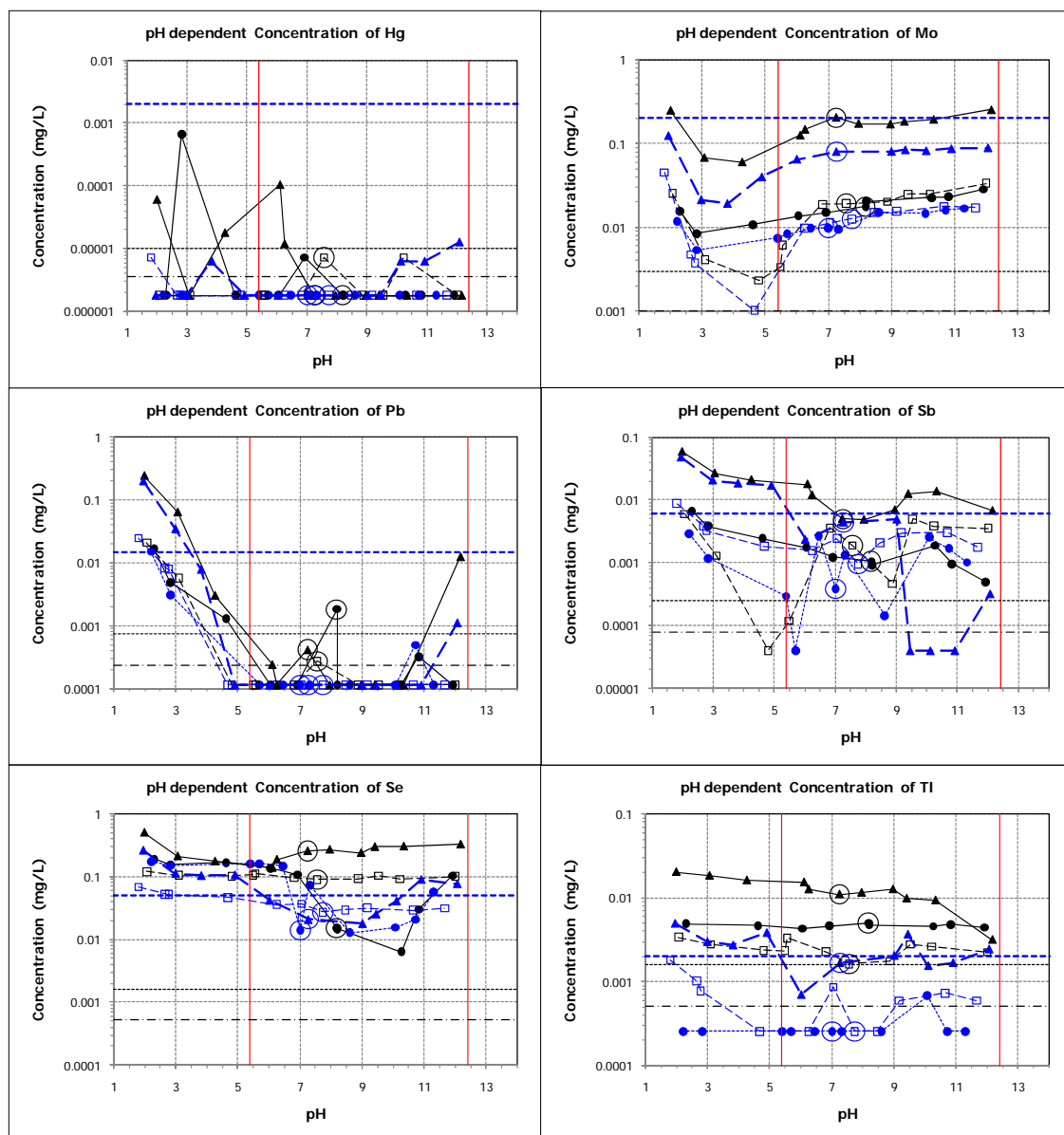


Figure 48 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using high sulfur bituminous coal.

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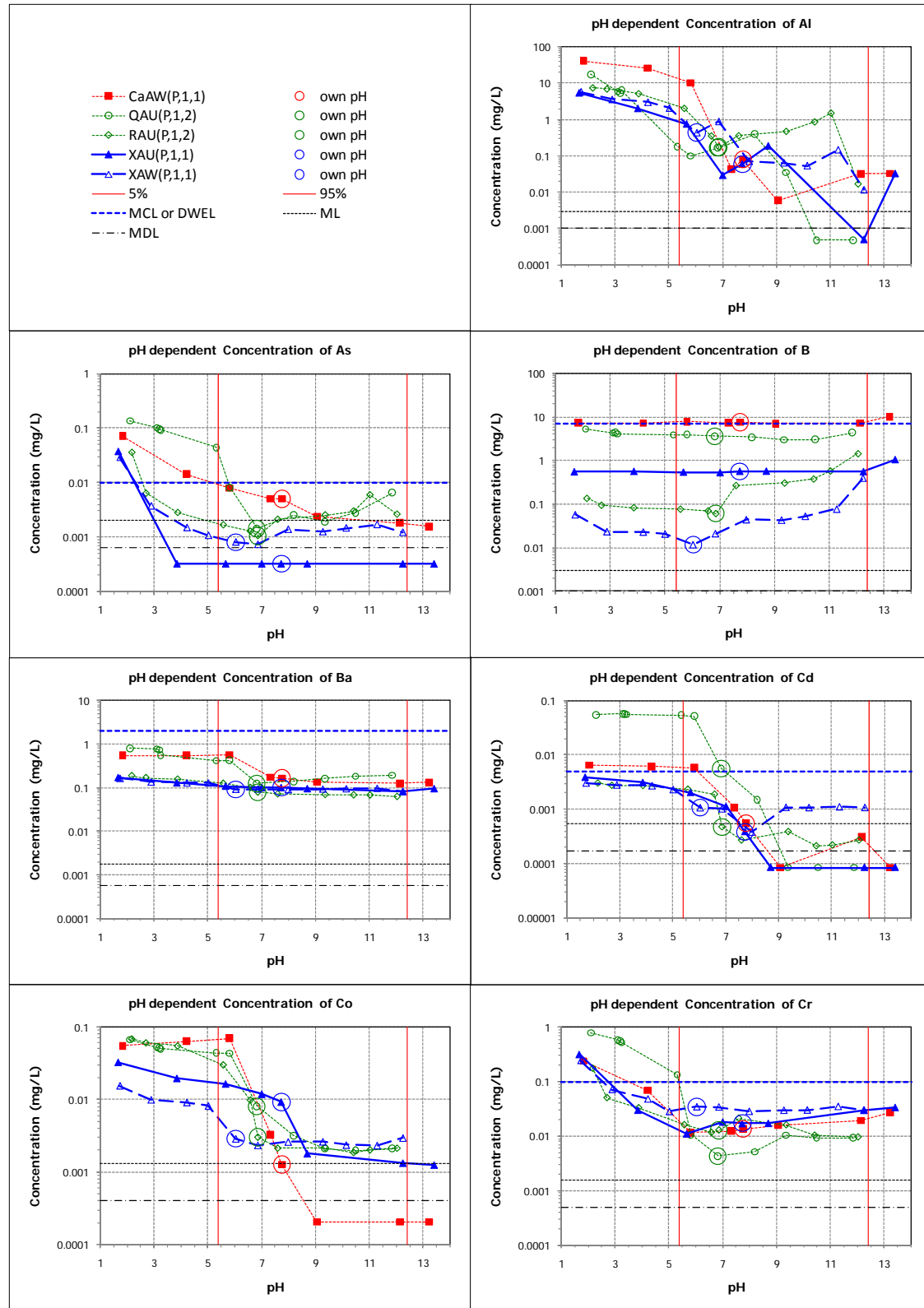


Figure 49. pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using sub-bituminous and lignite bituminous coals.

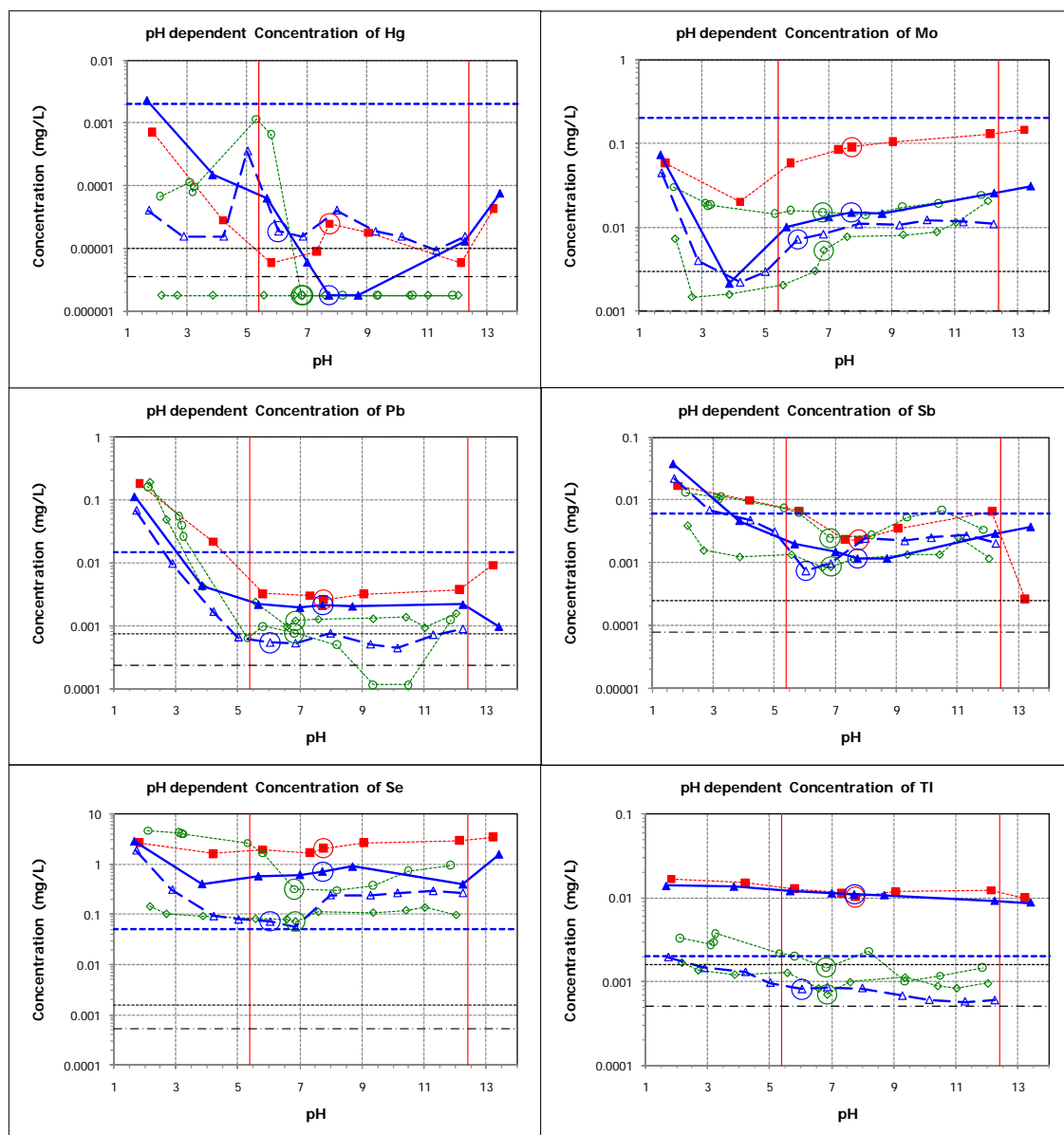


Figure 49 (continued). pH dependent leaching results. Gypsum samples unwashed (sample codes __U) and washed (sample codes __W) from facilities using sub-bituminous and lignite bituminous coals.

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.

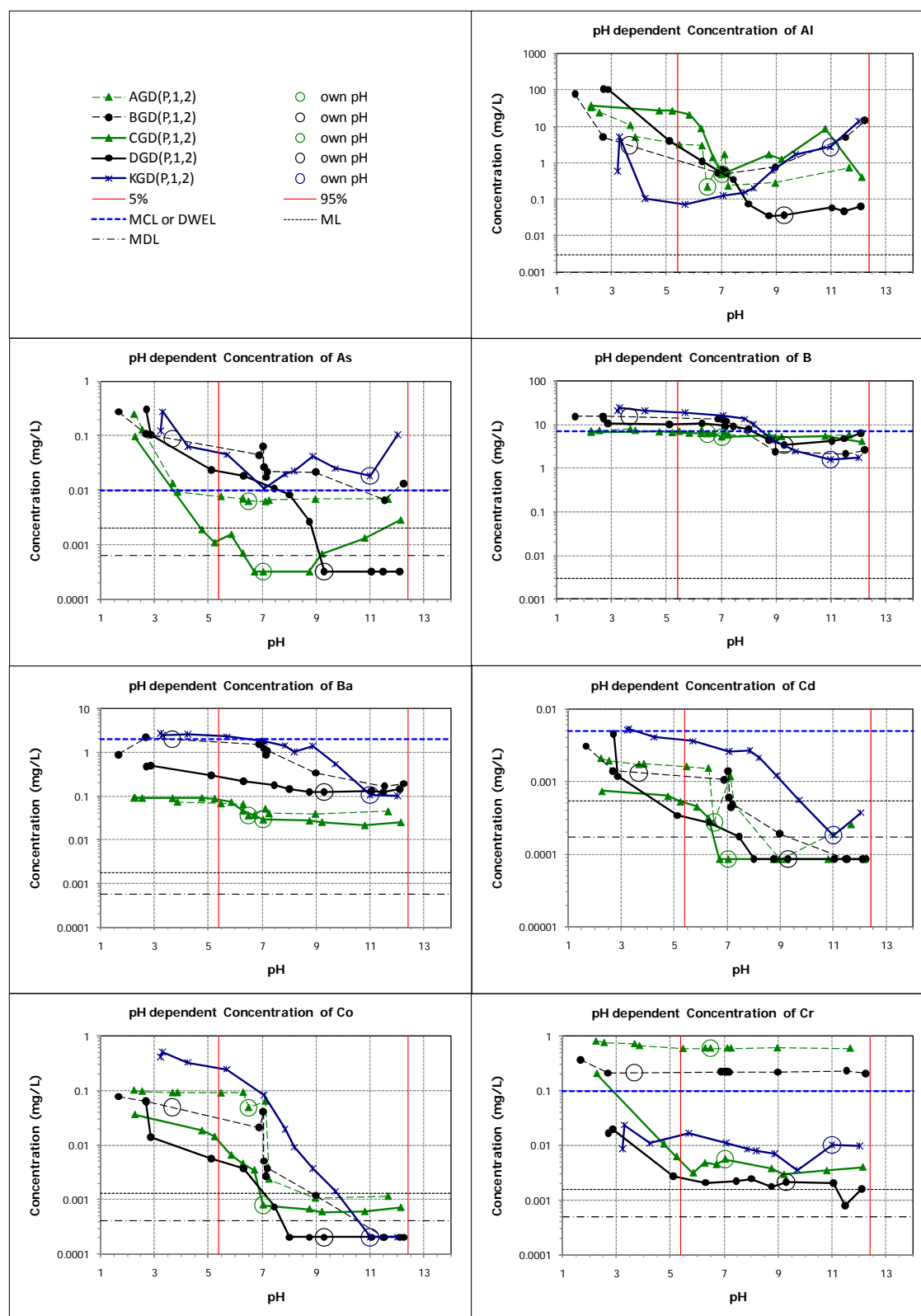


Figure 50. pH dependent leaching results. Scrubber sludges. Facility A (AGD, CGD), Facility B (BGD, DGD), Facility K (KGD). Samples DGD and KGD with SCR, Samples BGD with SNCR. Samples CGD and DGD without post-combustion NO_x controls.

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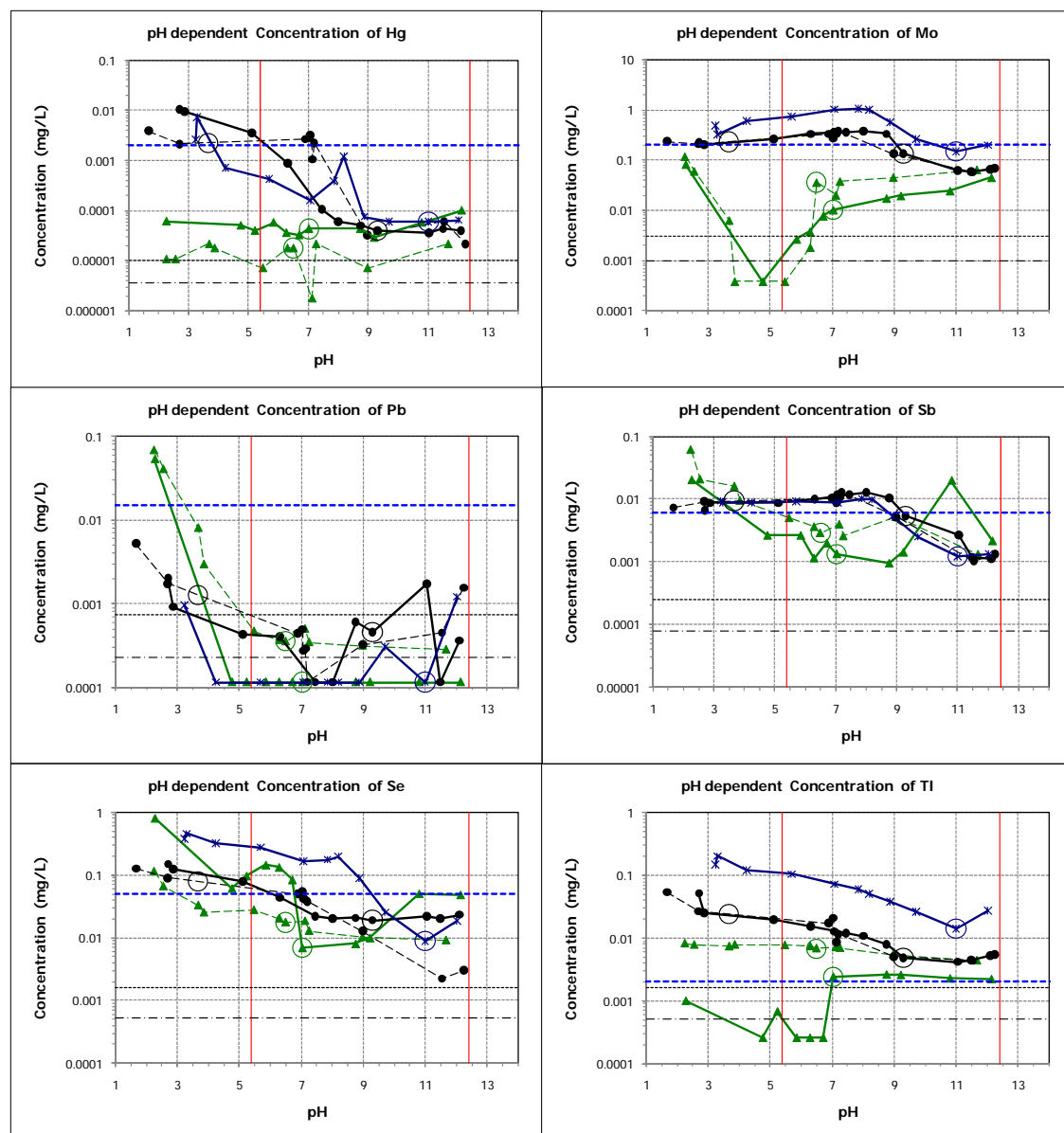


Figure 50 (continued). pH dependent leaching results. Scrubber sludges. Facility A (AGD, CGD), Facility B (BGD, DGD), Facility K (KGD). Samples DGD and KGD with SCR, Samples BGD with SNCR. Samples CGD and DGD without post-combustion NO_x controls.

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 ($9 < \text{pH} < 12$), Ba ($8 < \text{pH} < 12$), Cr ($\text{pH} < 6$), and Tl ($\text{pH} < 6$) and a lower release of Co and Pb ($4 < \text{pH} < 12$) 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.

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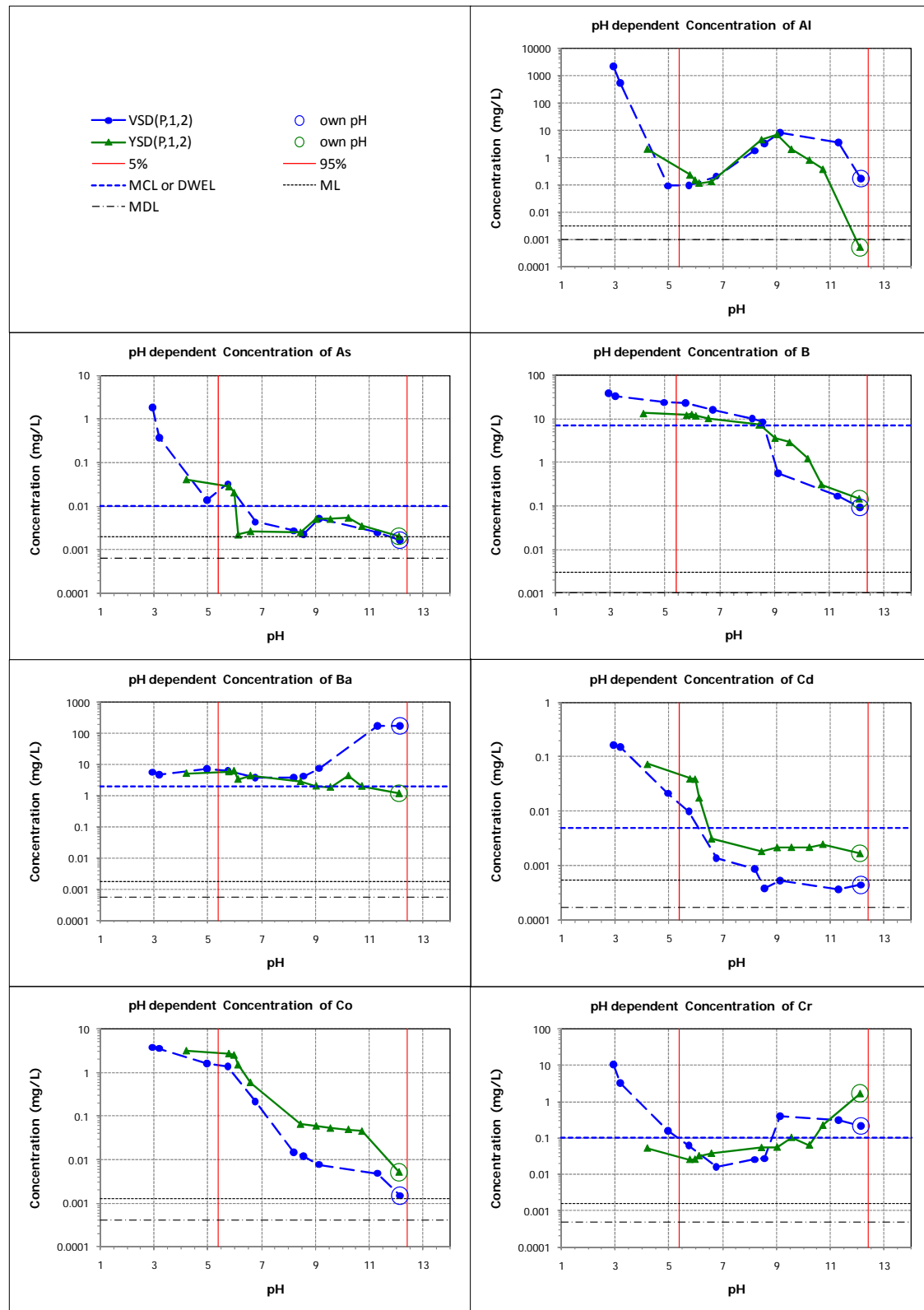


Figure 51. pH dependent leaching results. Spray dryer residue samples (sub-bituminous coal).

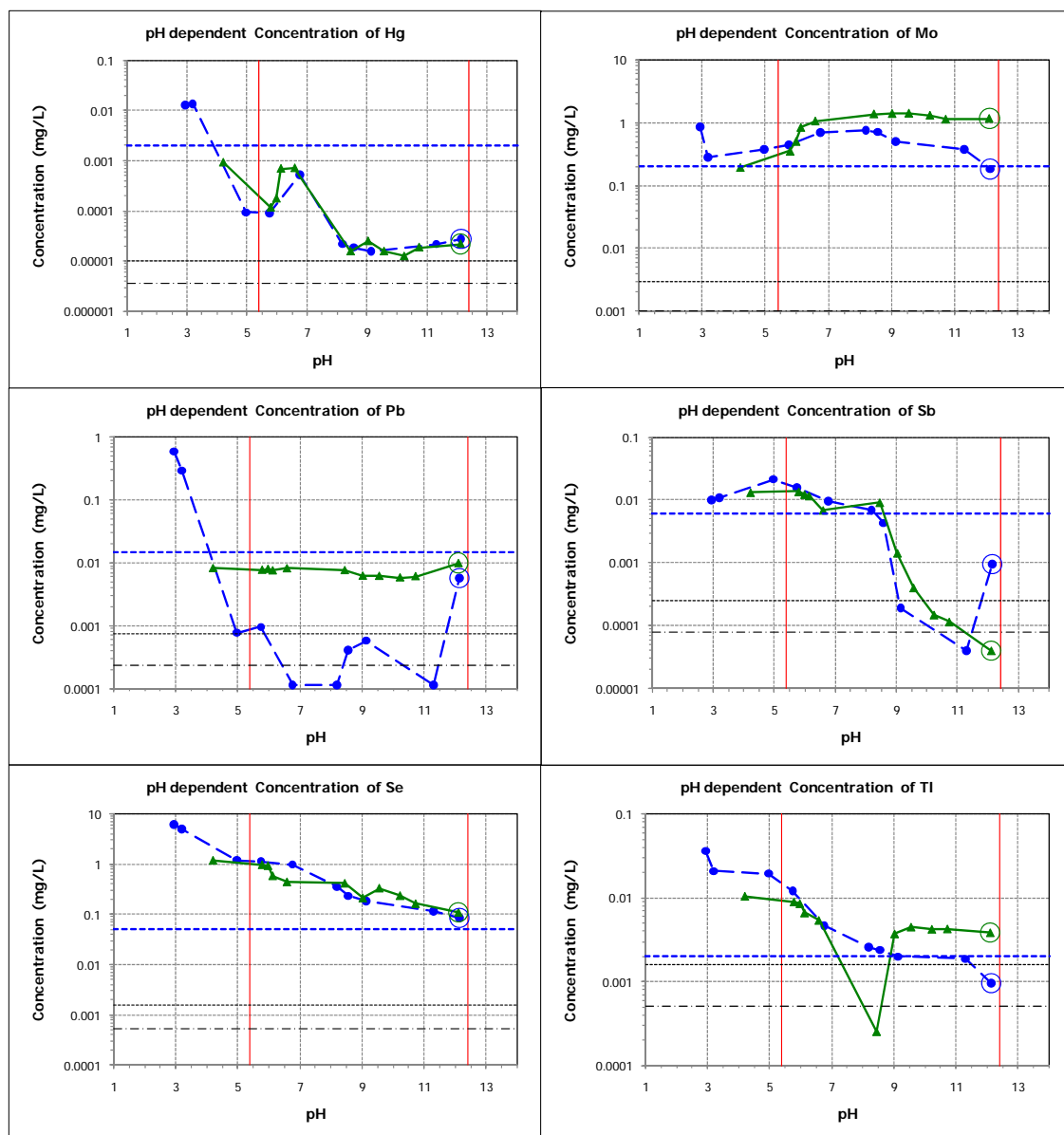


Figure 51 (continued). pH dependent leaching results. Spray dryer residue samples (sub-bituminous coal).

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).

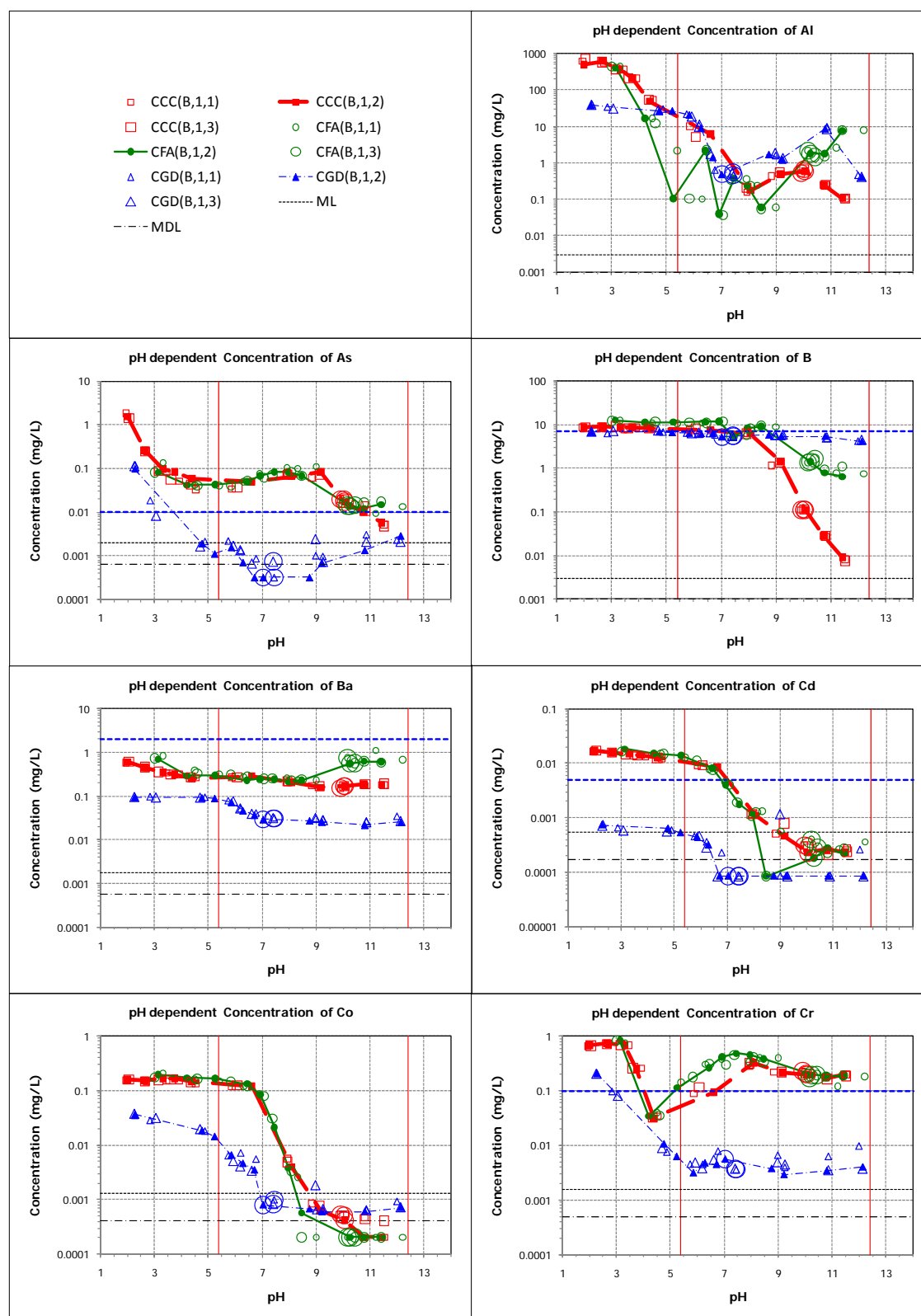


Figure 52. pH dependent leaching results. Facility A samples (low S east-bit., fabric filter, limestone, natural oxidation). SNCR-BP. Fly ash (CFA); scrubber sludge (CGD); blended fly ash and scrubber sludge (“as managed,” CCC).

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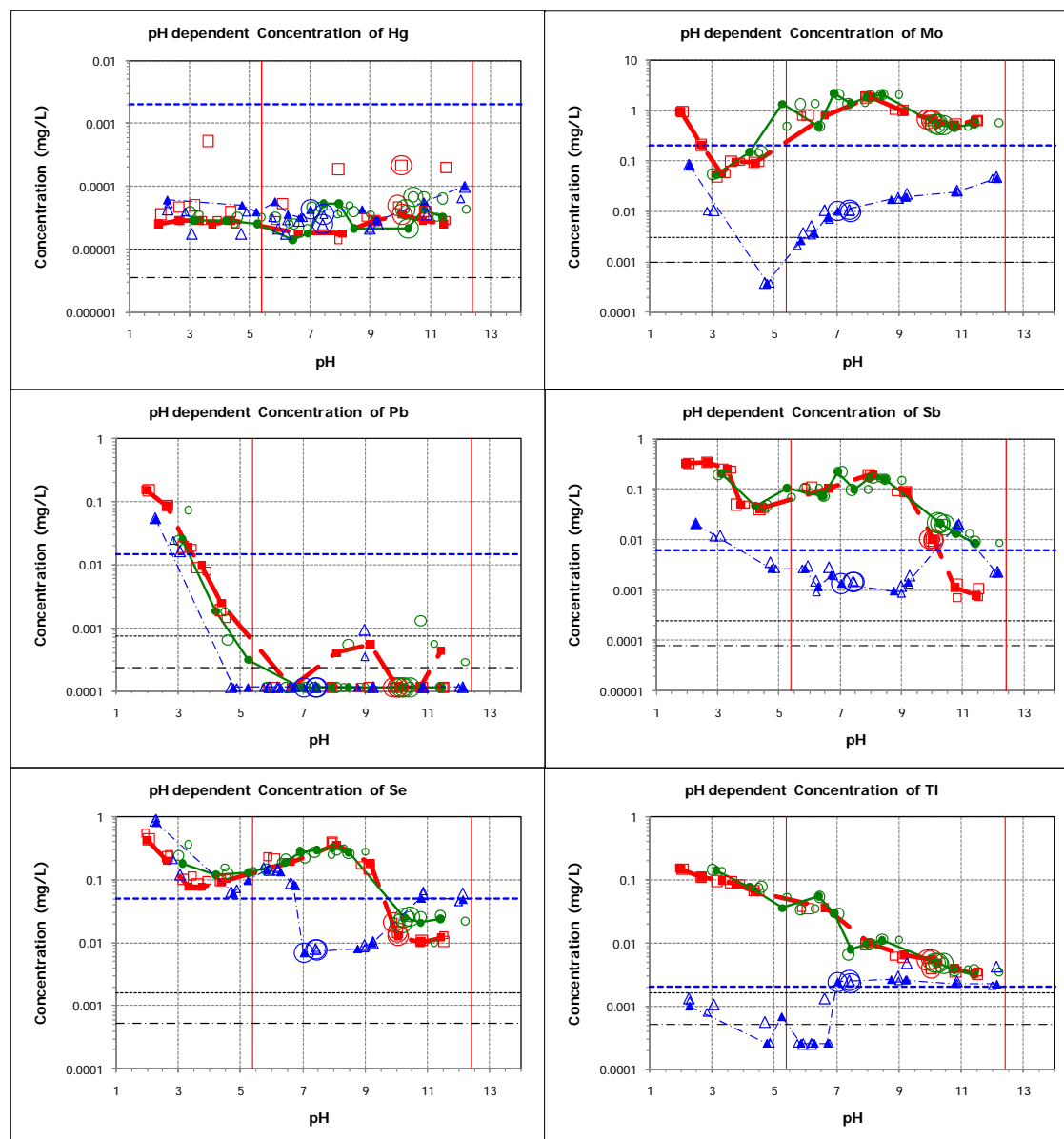


Figure 52 (continued). pH dependent leaching results. Facility A samples (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP. Fly ash (CFA); Scrubber sludge (CGD); Blended fly ash and scrubber sludge ("as managed," CCC).

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.

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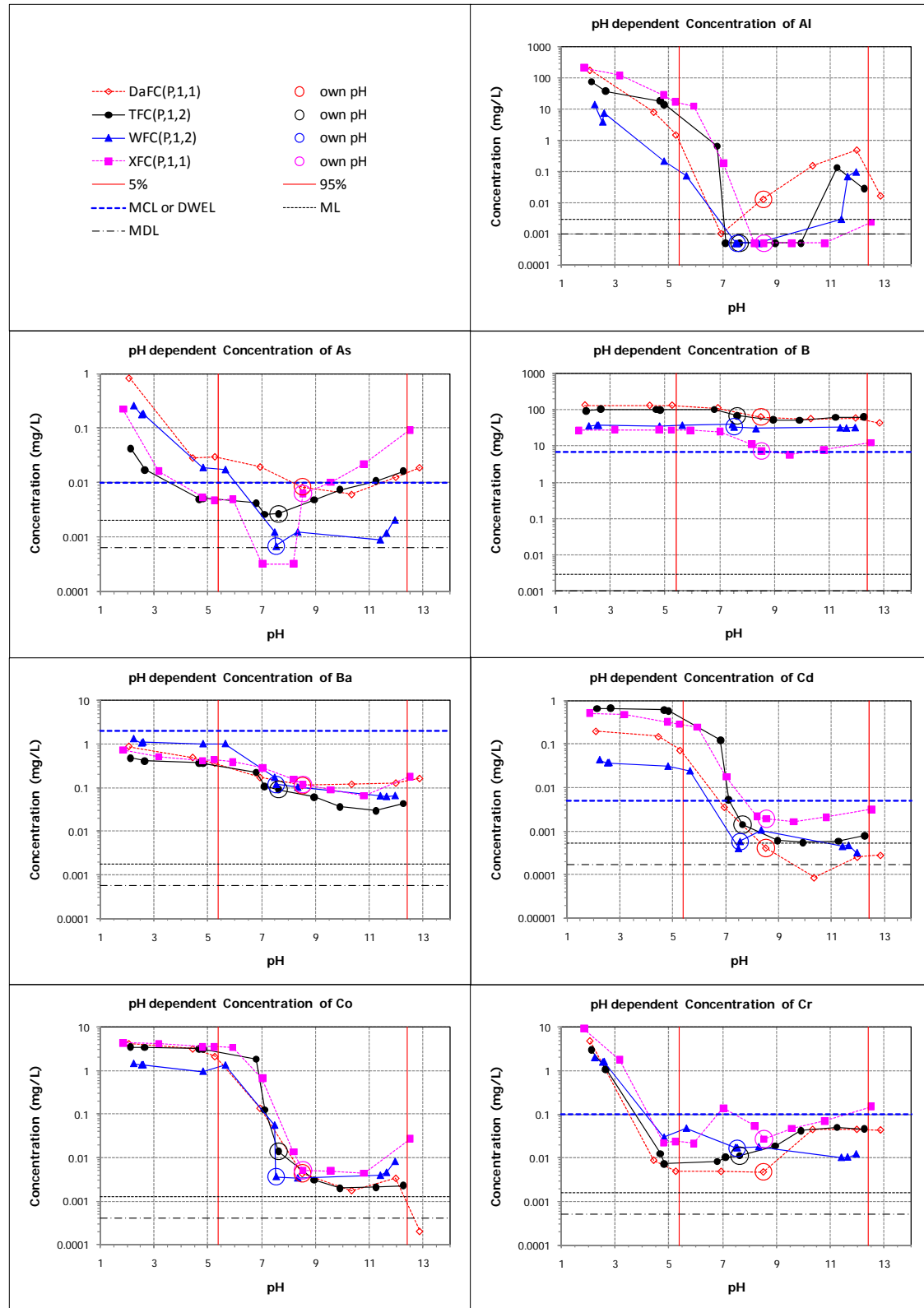


Figure 53. pH dependent leaching results. Filter cake samples.

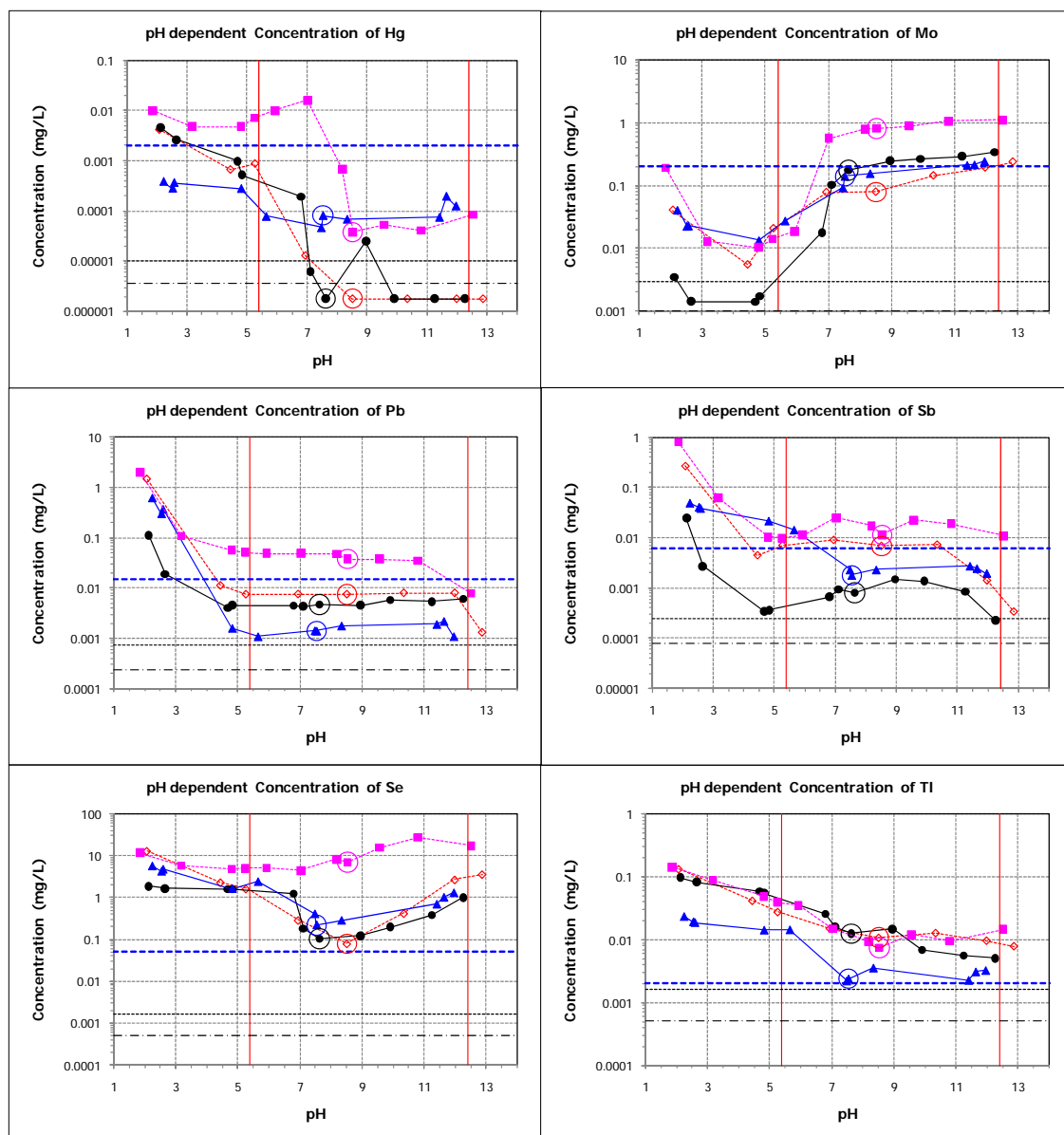


Figure 53 (continued). pH dependent leaching results. Filter cake samples.

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.

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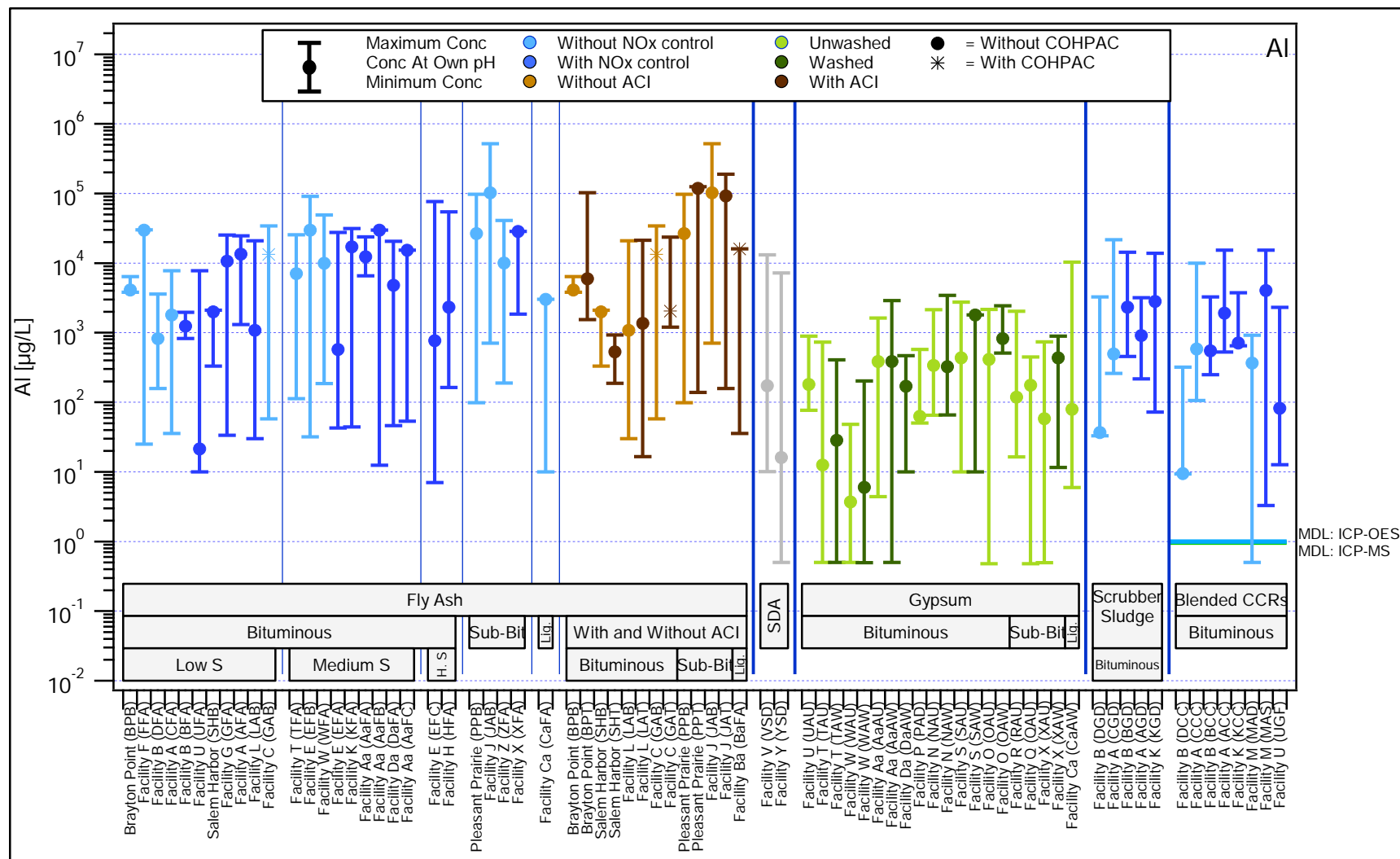


Figure 54. Aluminum. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

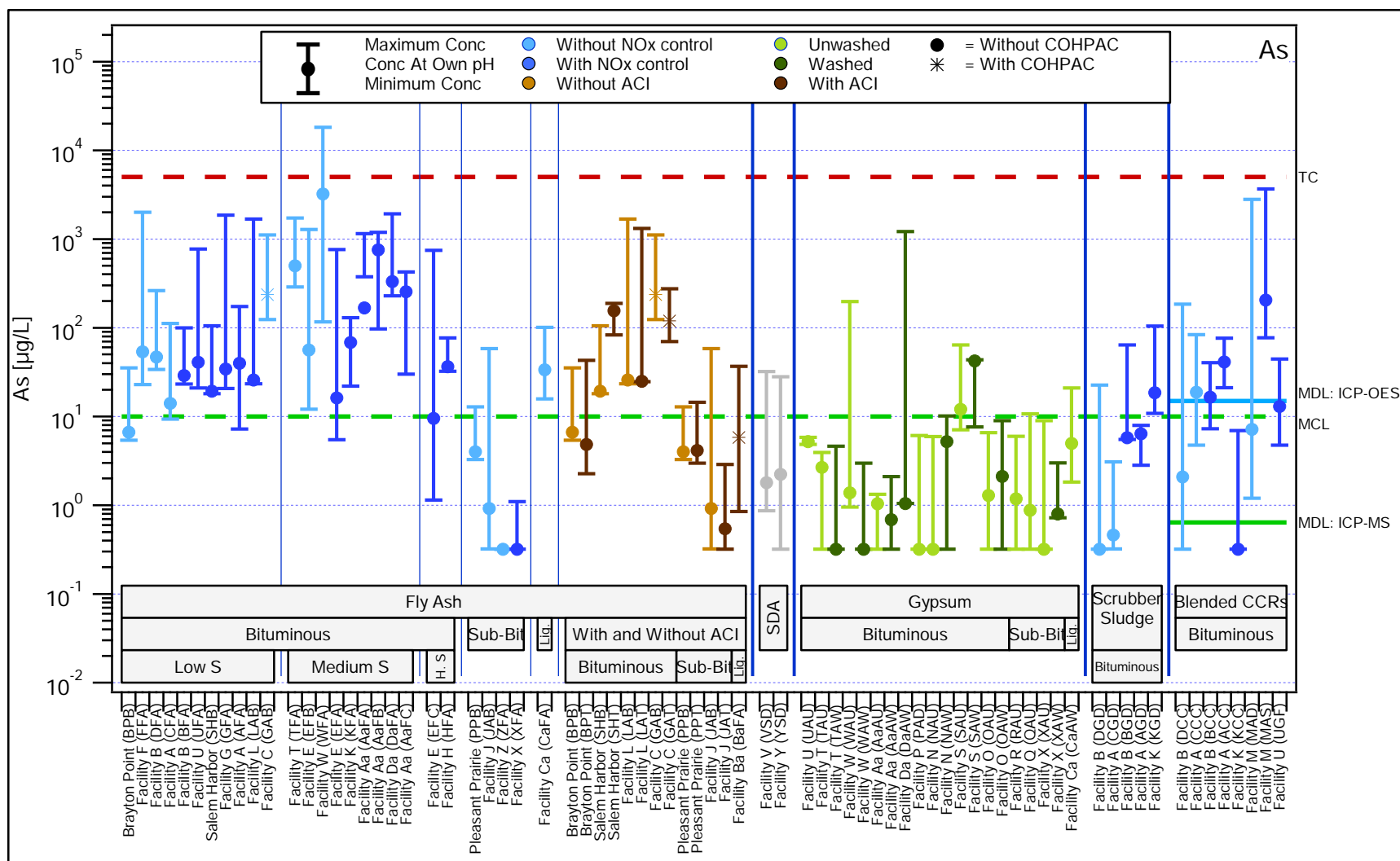


Figure 55. Arsenic. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

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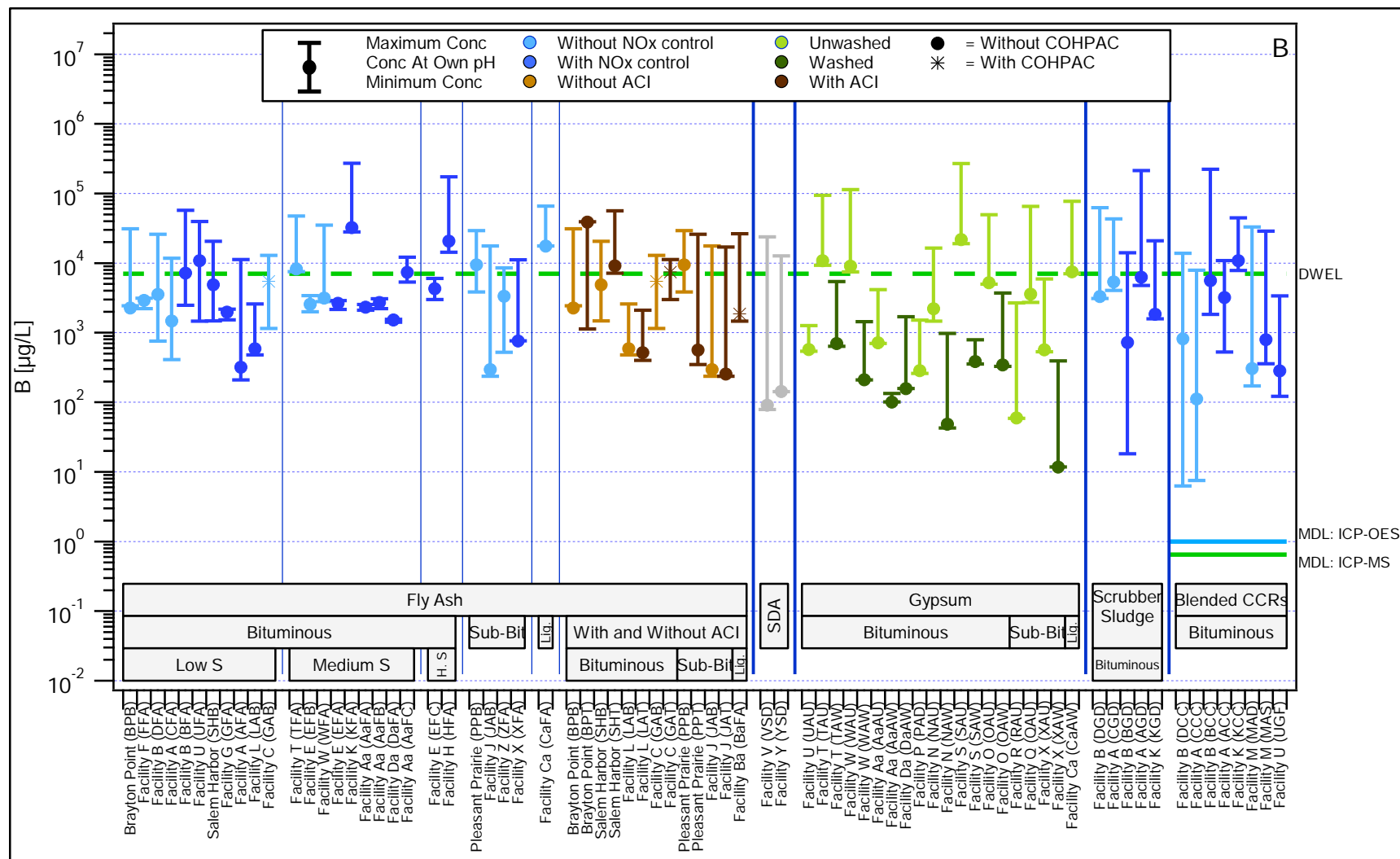


Figure 56. Boron. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

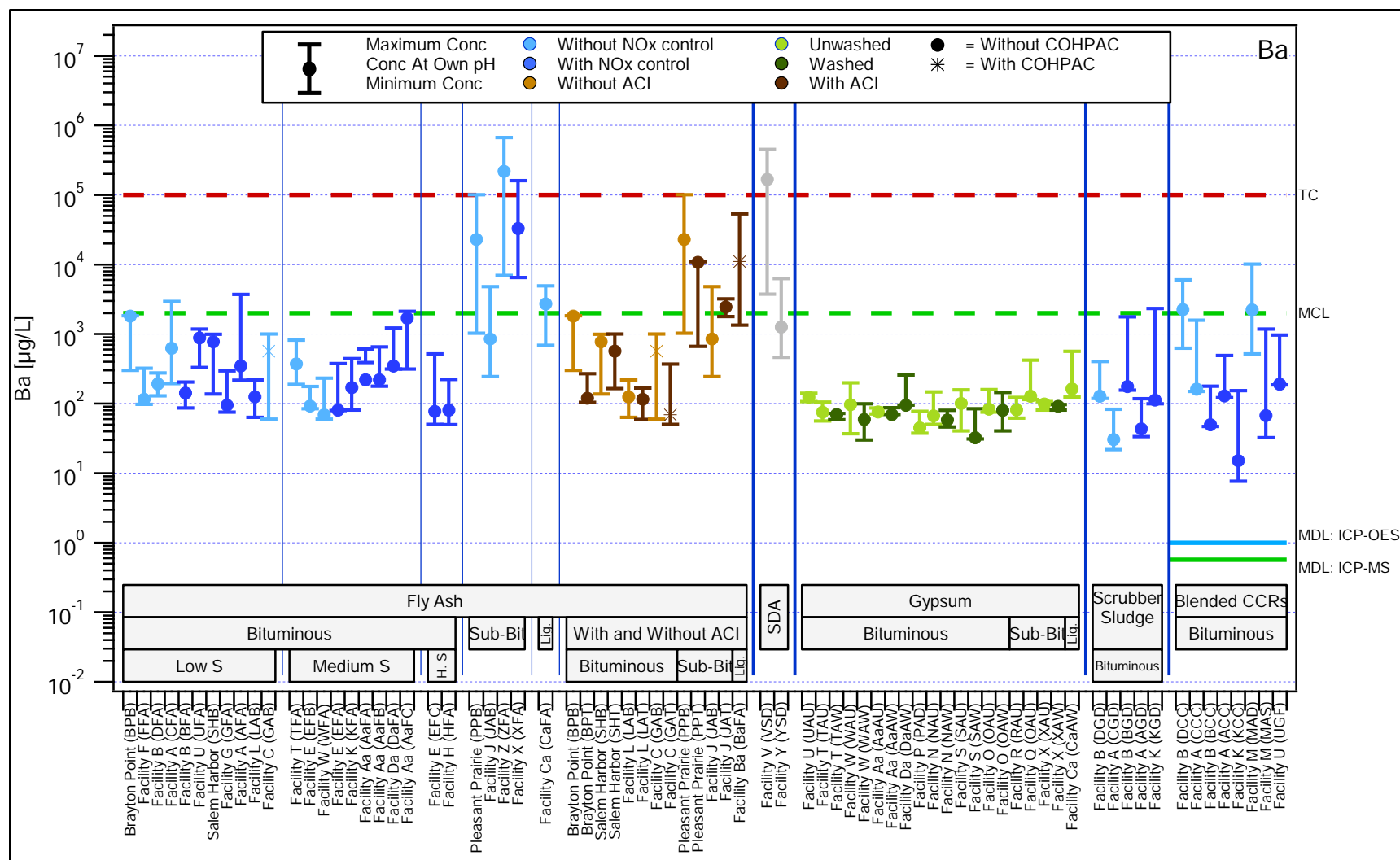


Figure 57. Barium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

Characterization of Coal Combustion Residues III

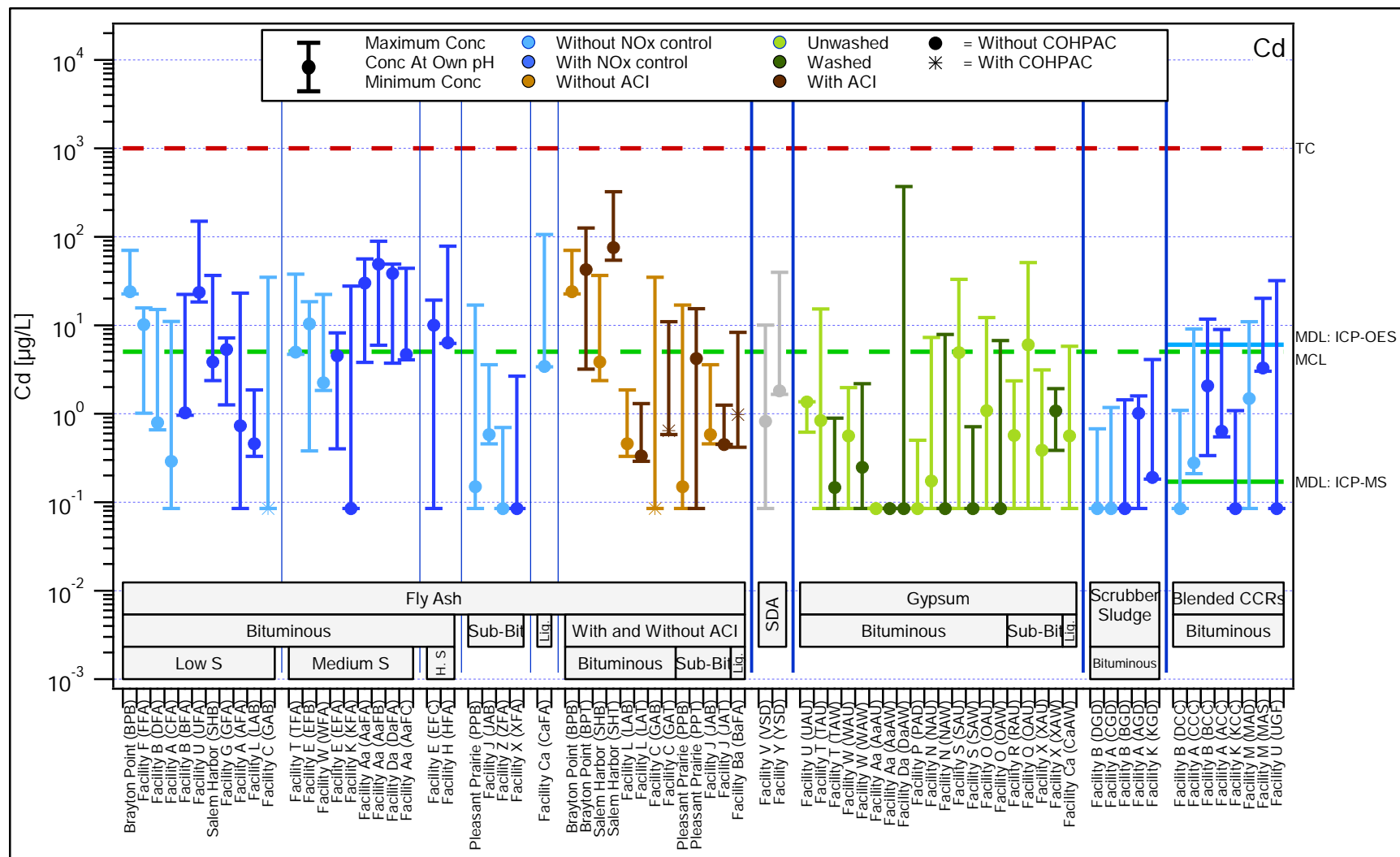


Figure 58. Cadmium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

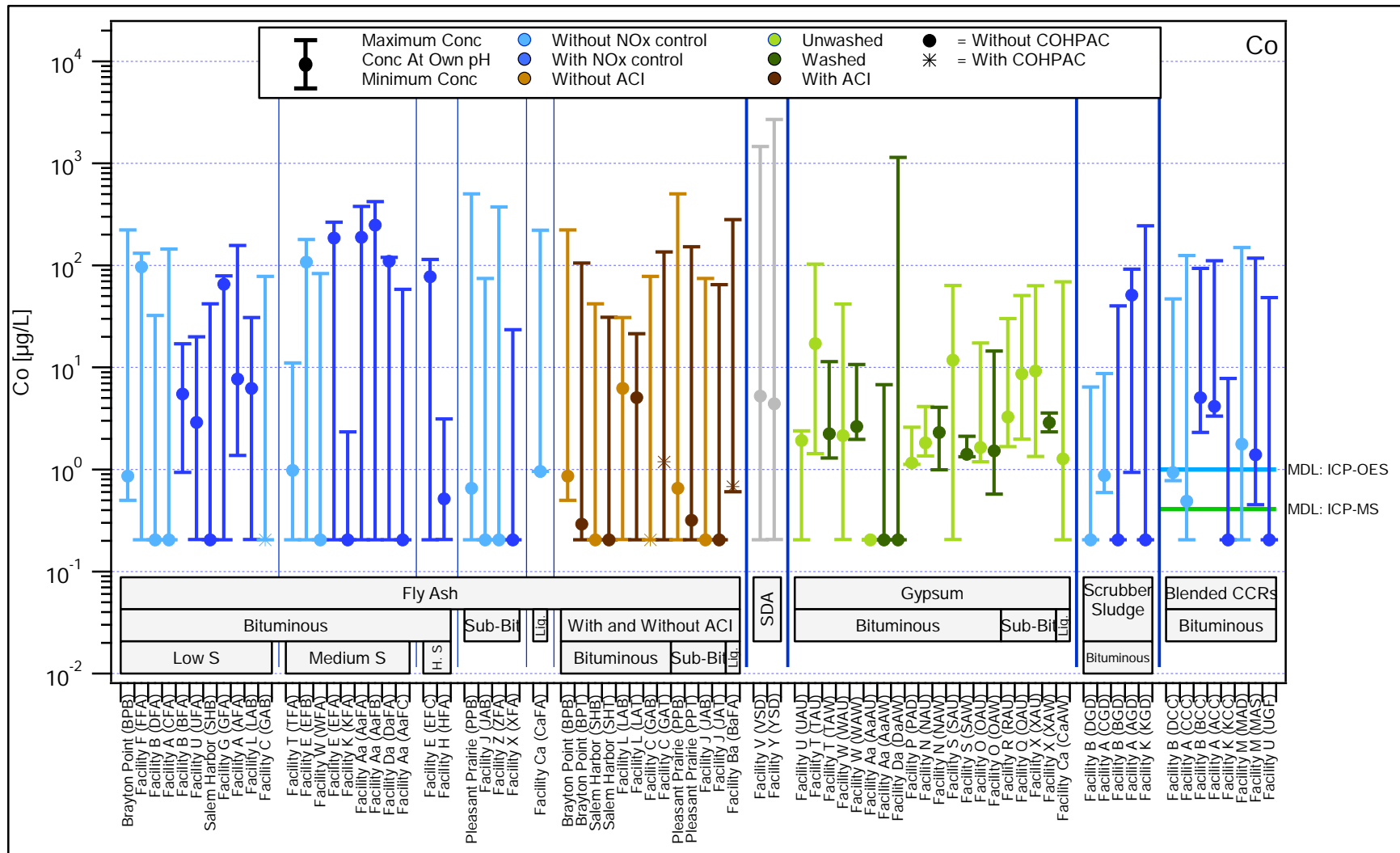


Figure 59. Cobalt. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

Characterization of Coal Combustion Residues III

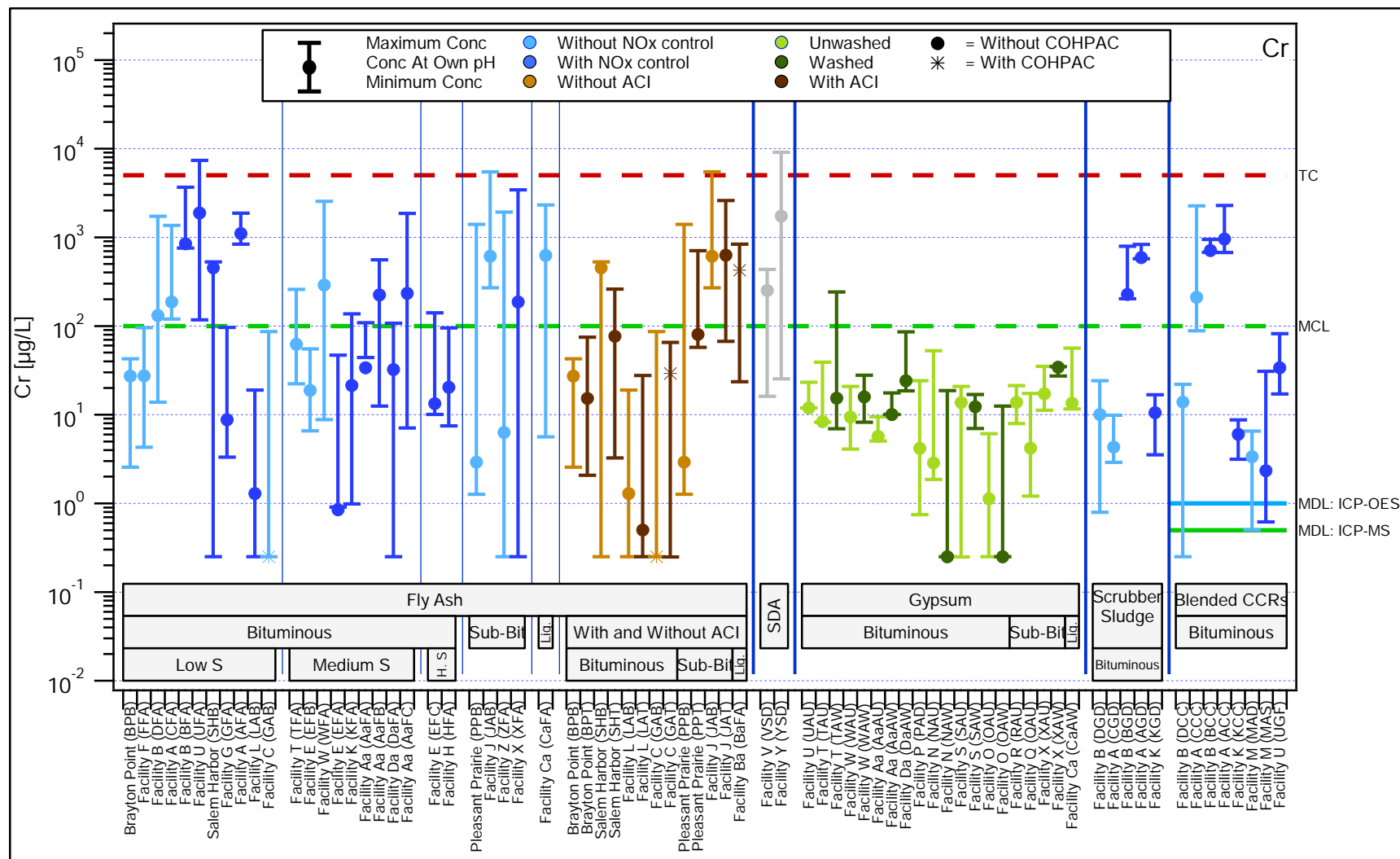


Figure 60. Chromium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

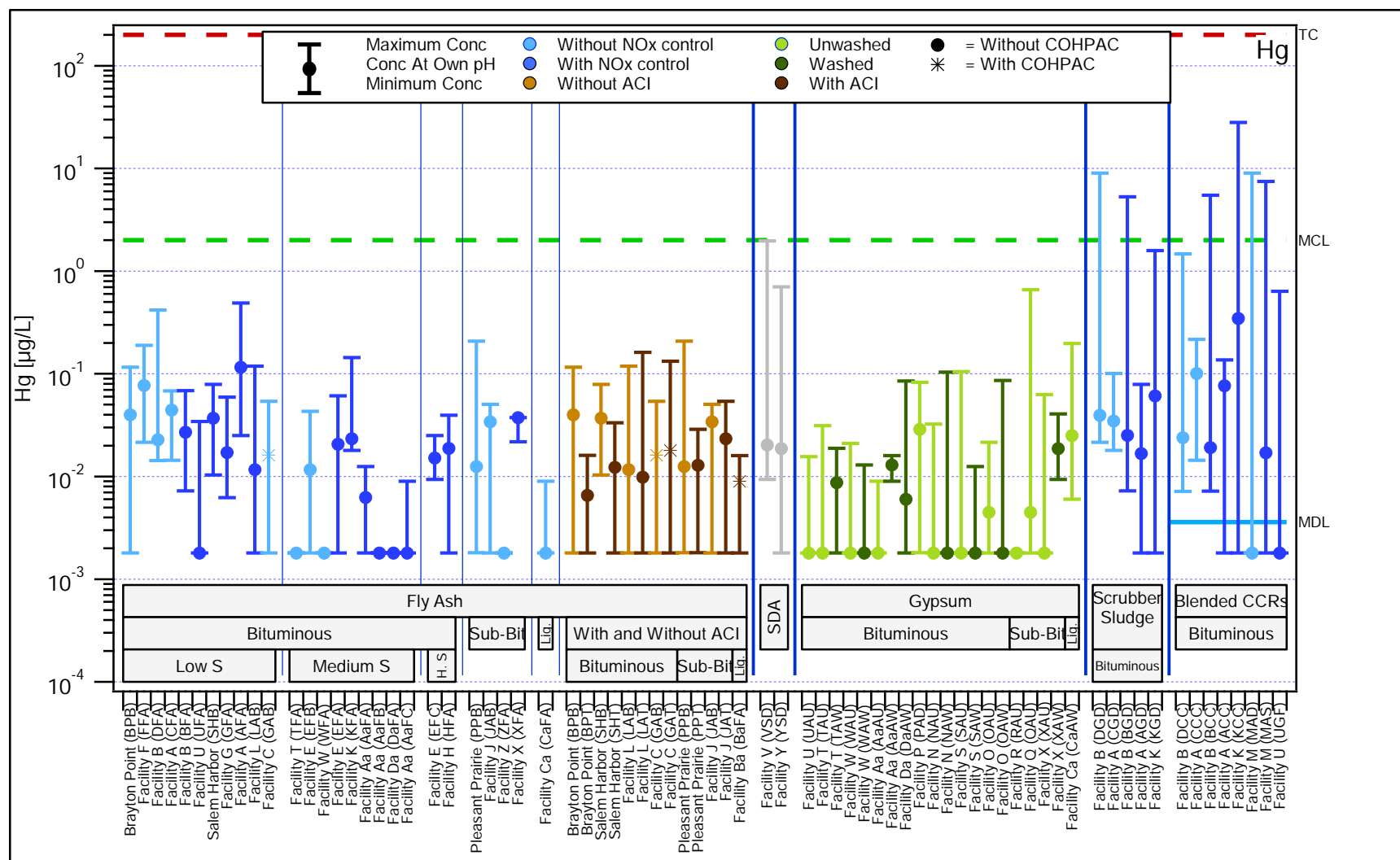


Figure 61. Mercury. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

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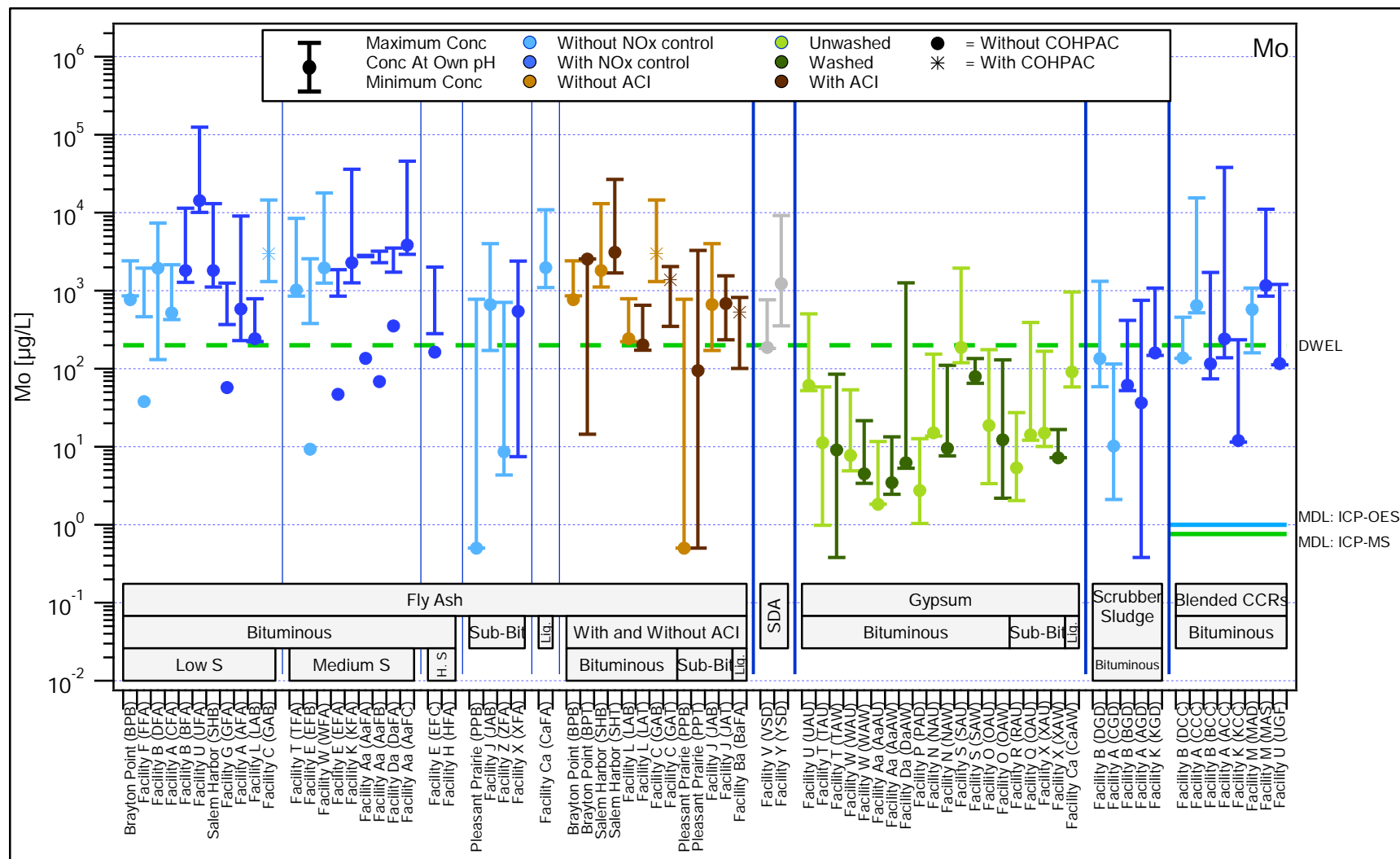


Figure 62. Molybdenum. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

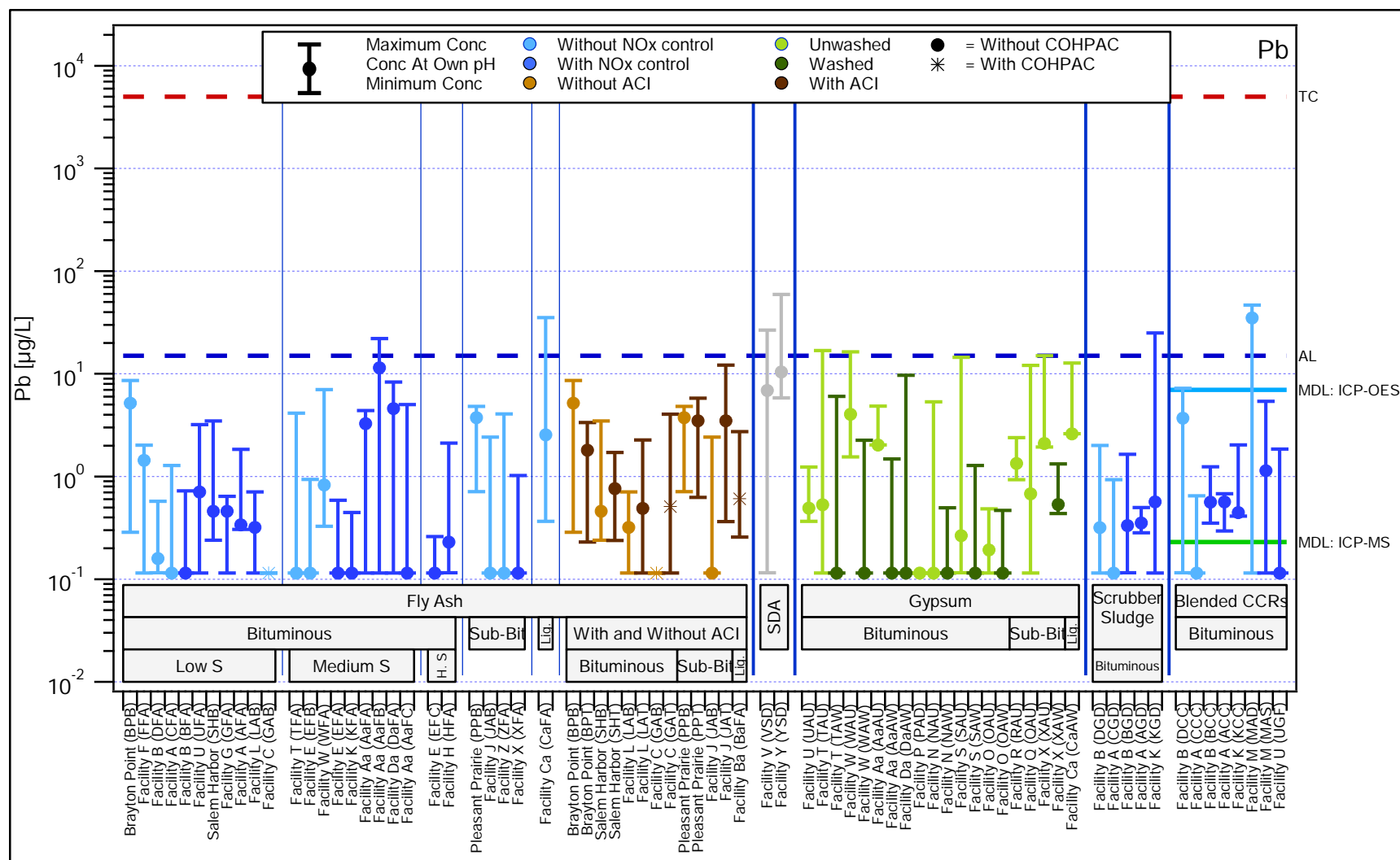


Figure 63. Lead. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

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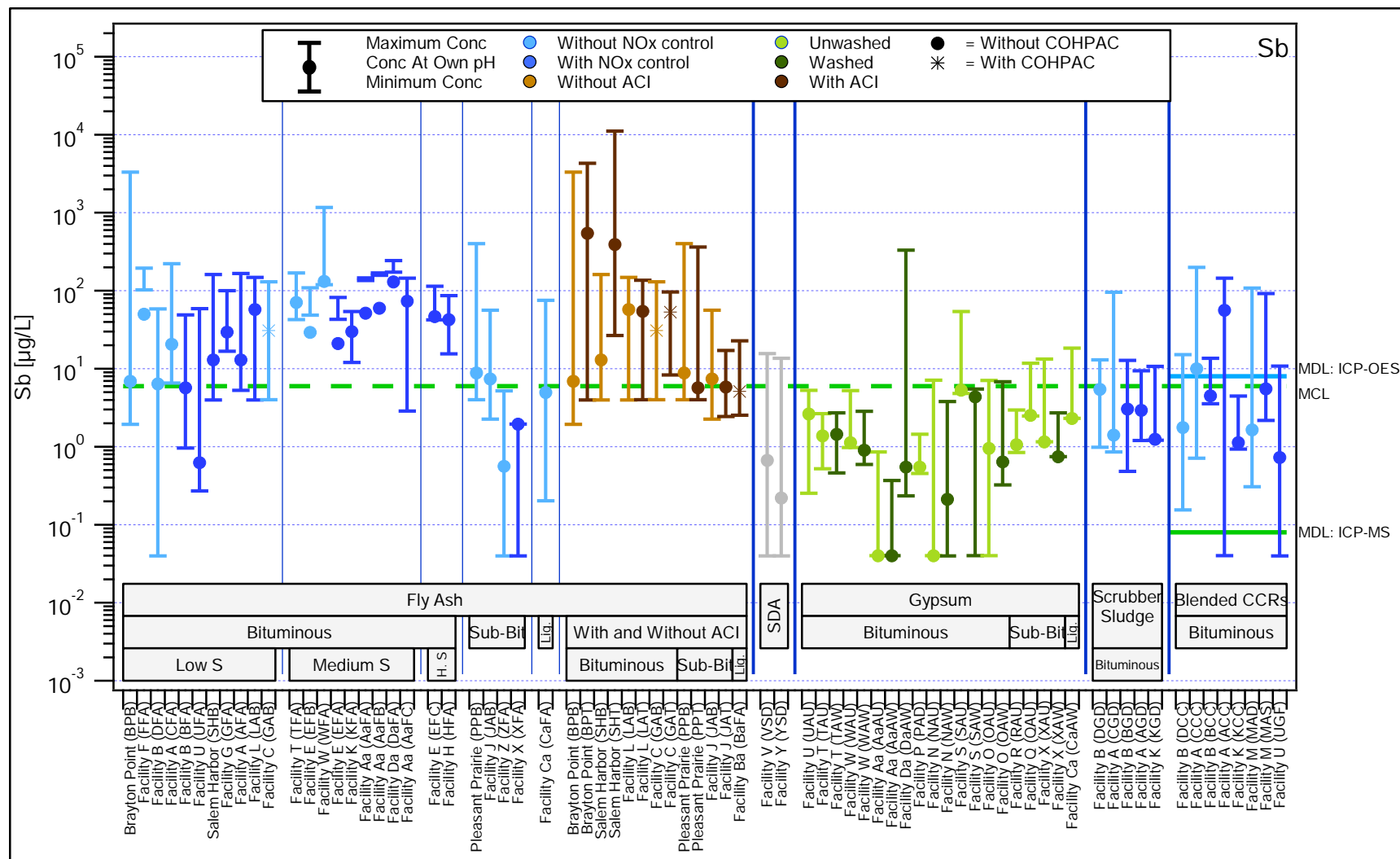


Figure 64. Antimony. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

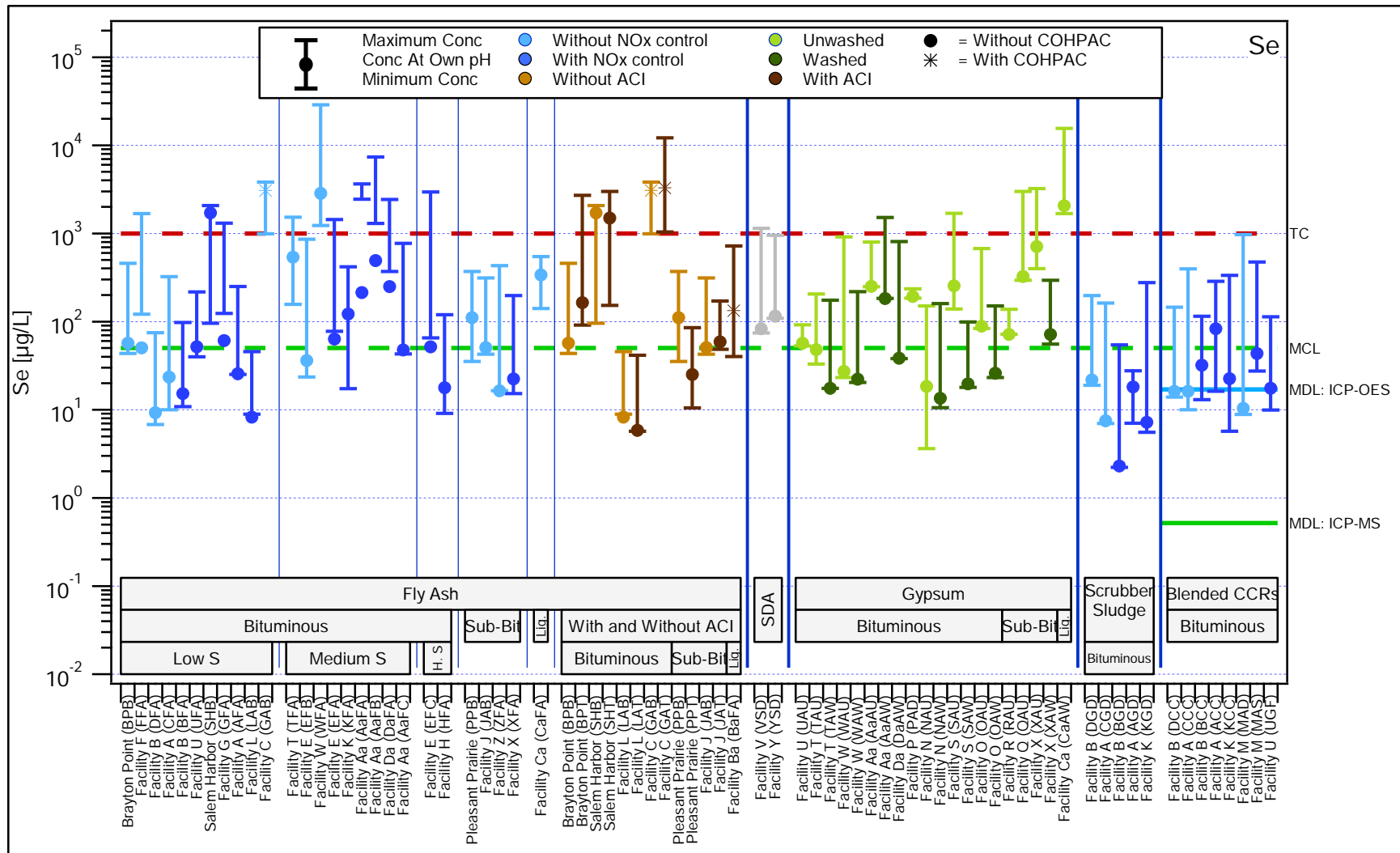


Figure 65. Selenium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

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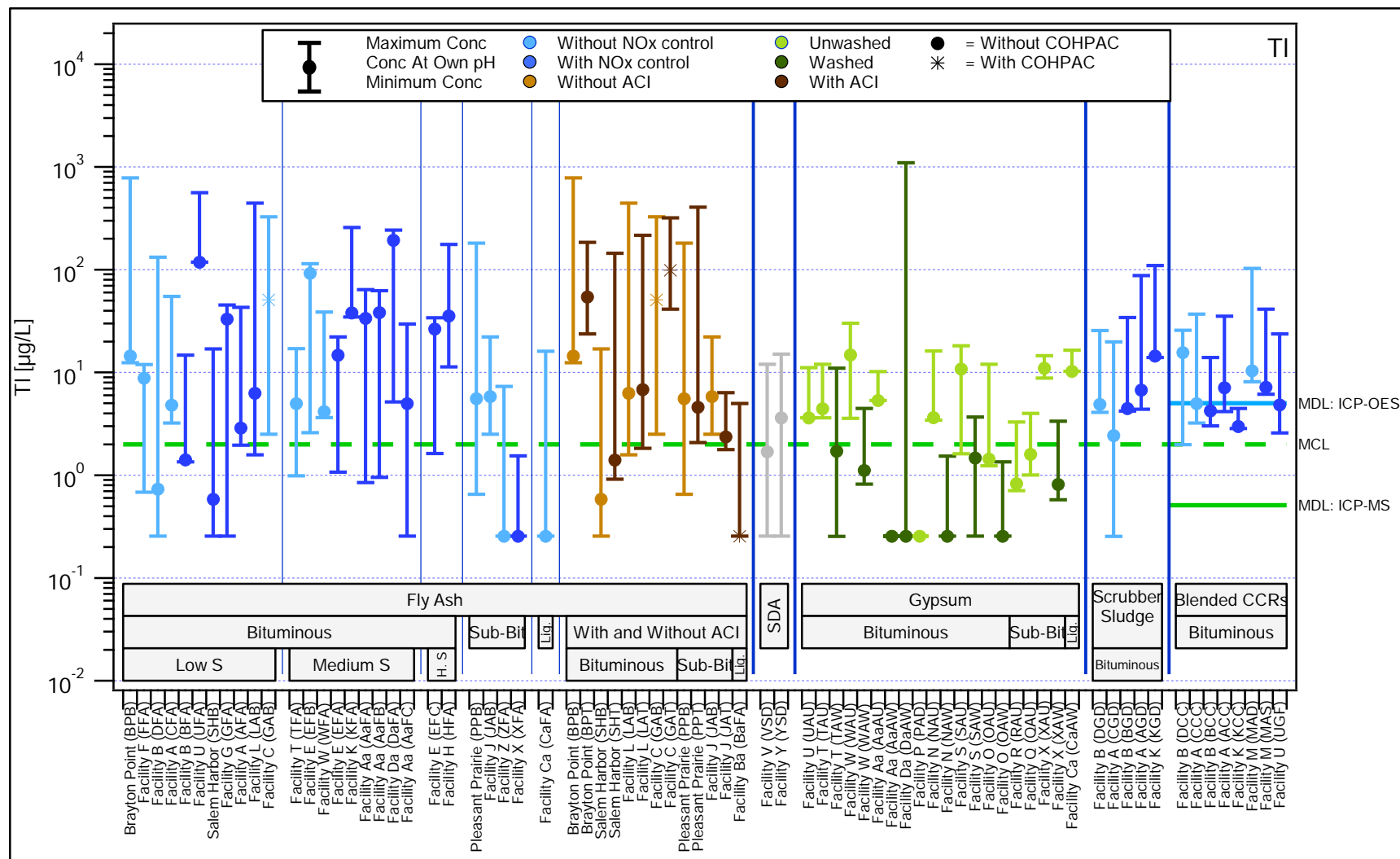


Figure 66. Thallium. Comparison of maximum, minimum and own pH concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

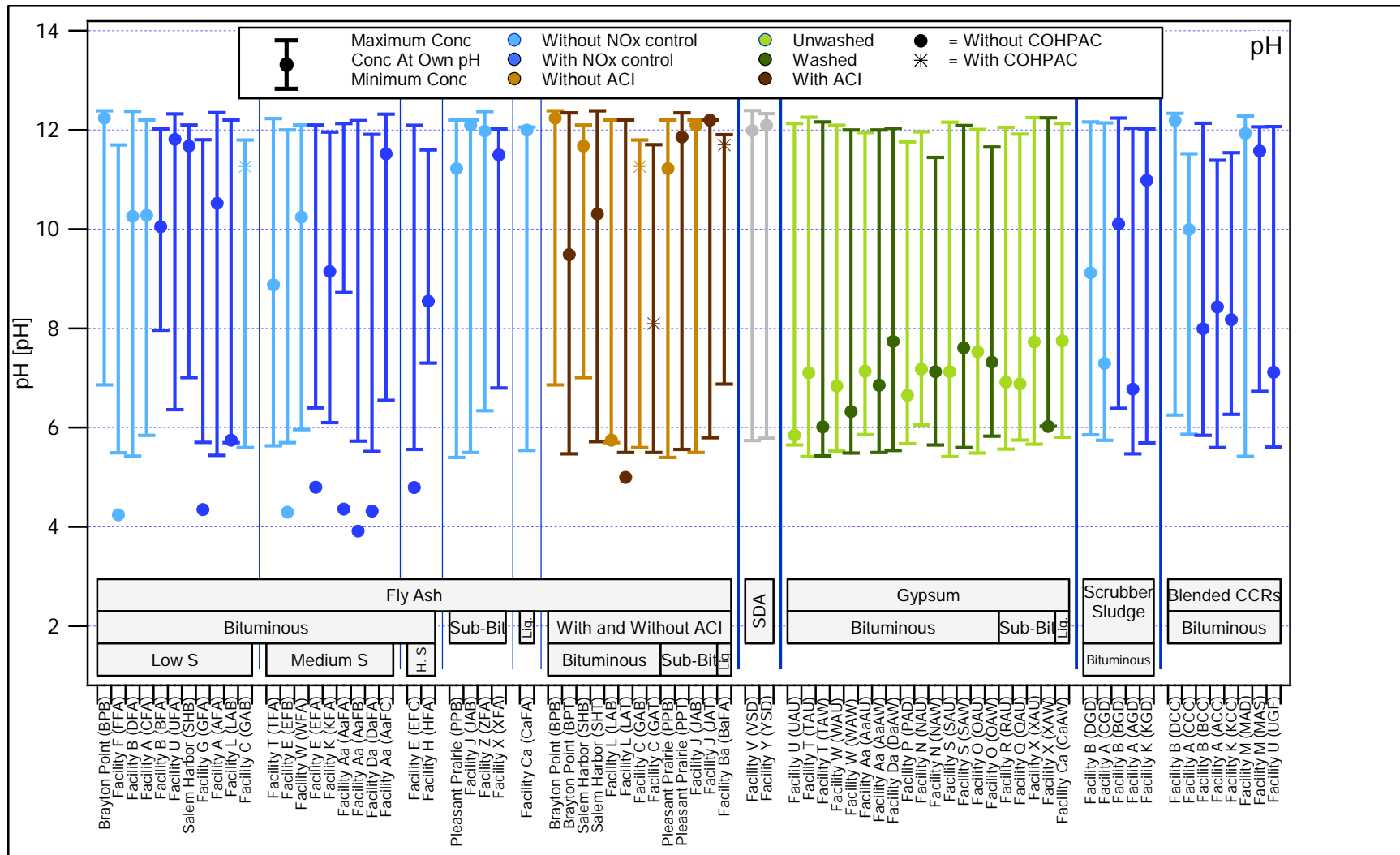


Figure 67. pH. Comparison of maximum, minimum and own pH observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$. SDA samples were from facilities burning sub-bituminous coal.

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 $5.4 \leq \text{pH} \leq 12.4$ 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.

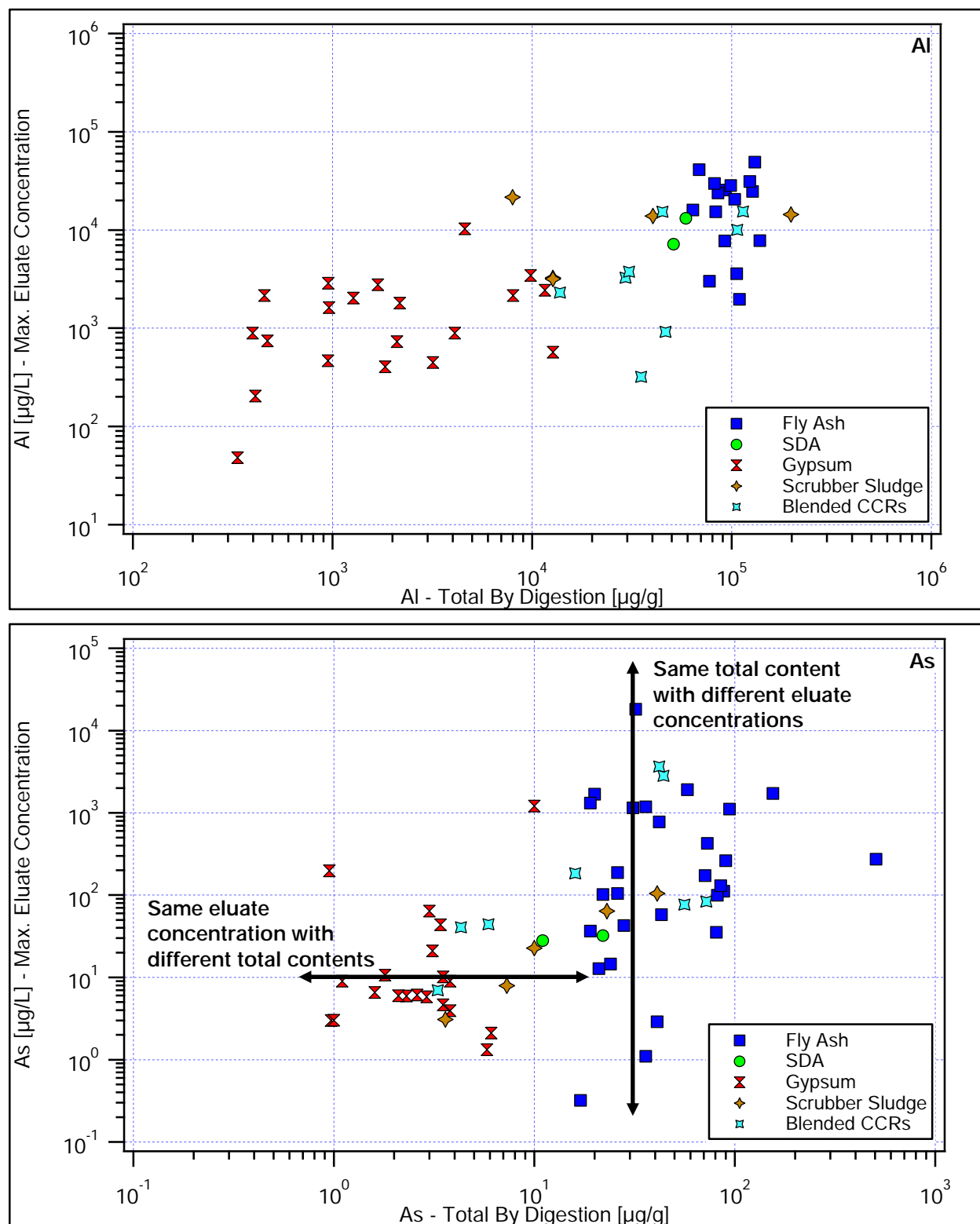


Figure 68 and Figure 69. Aluminum and Arsenic. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

Characterization of Coal Combustion Residues III

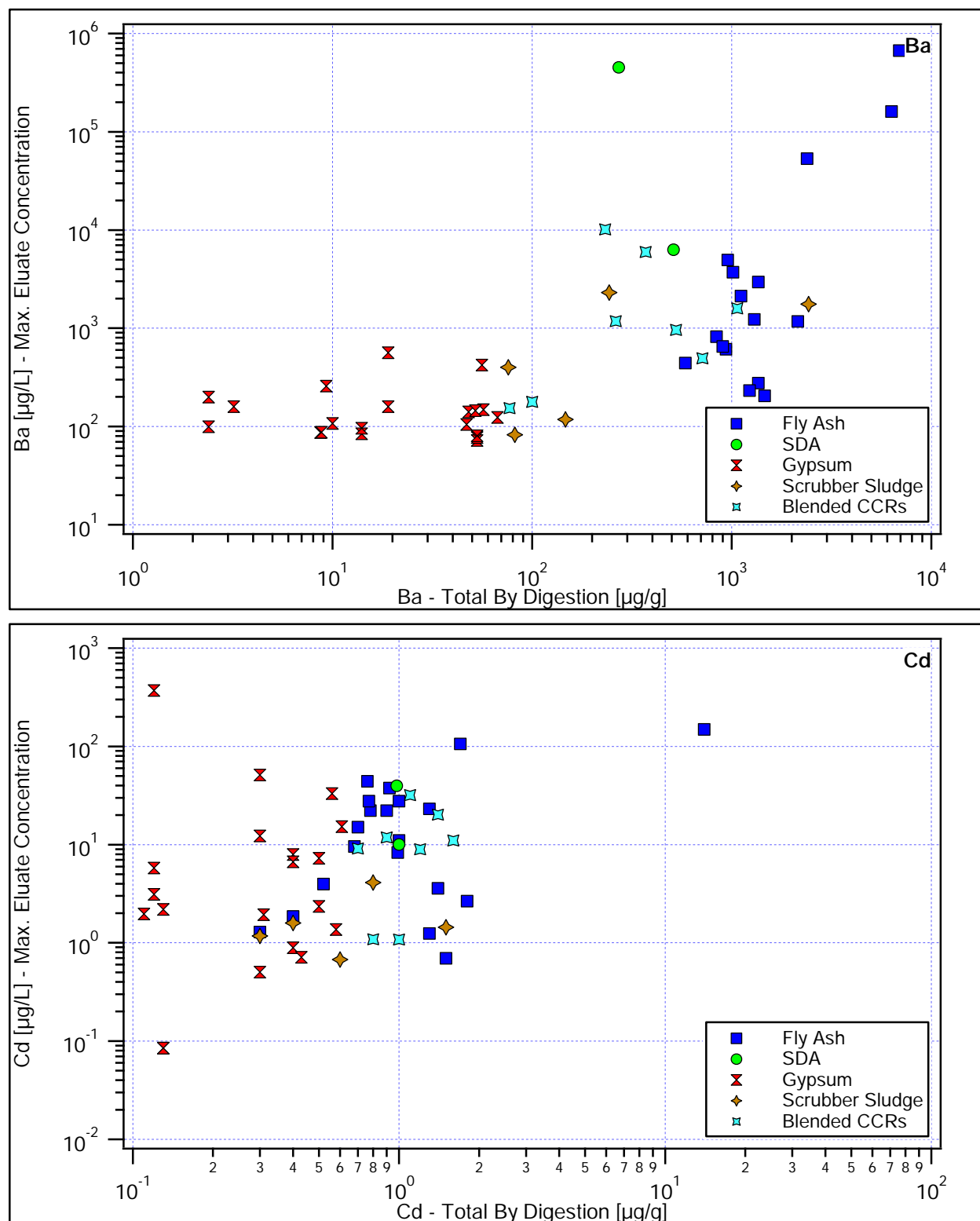


Figure 70 and Figure 71. Barium and Cadmium. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

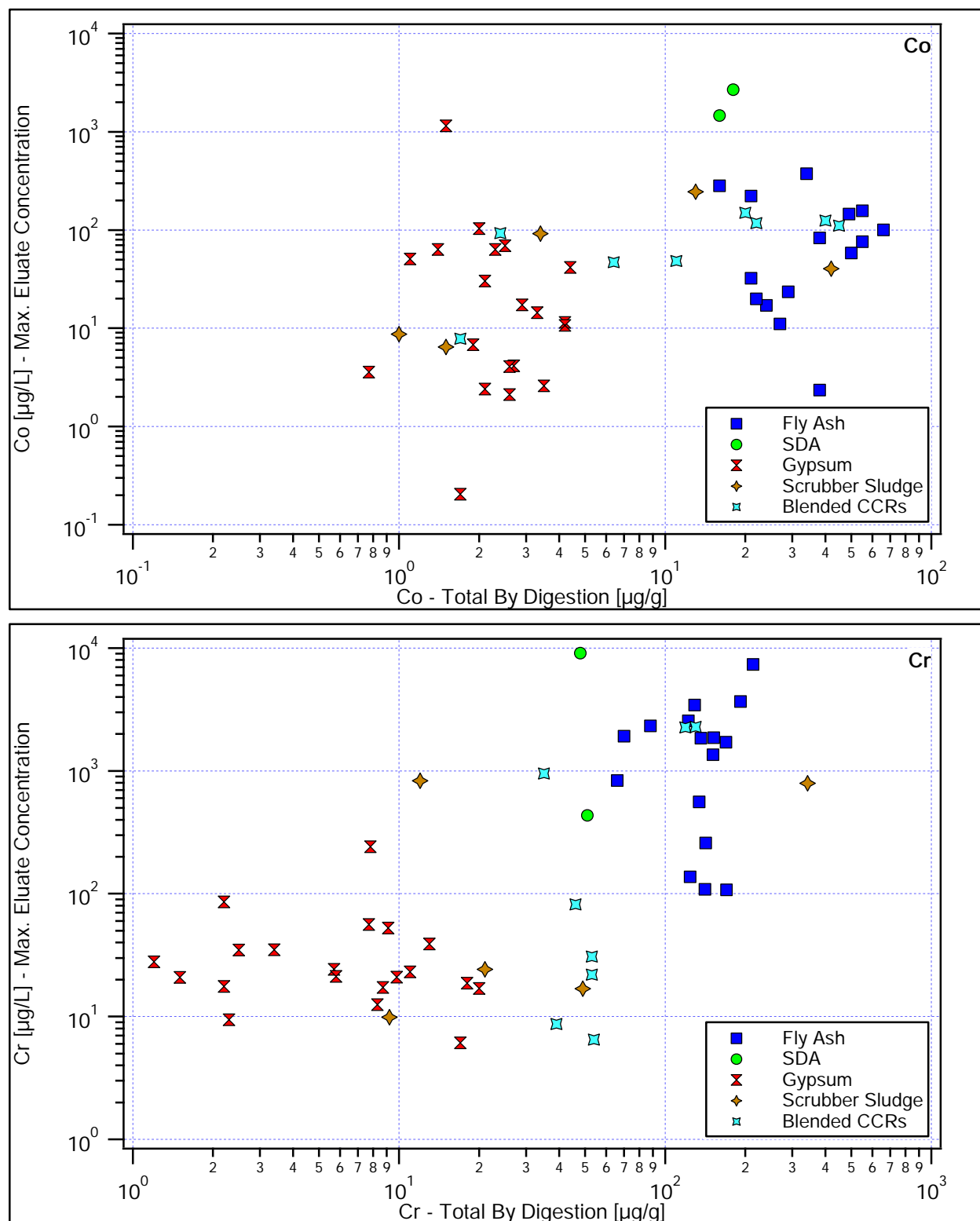


Figure 72 and Figure 73. Cobalt and Chromium. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

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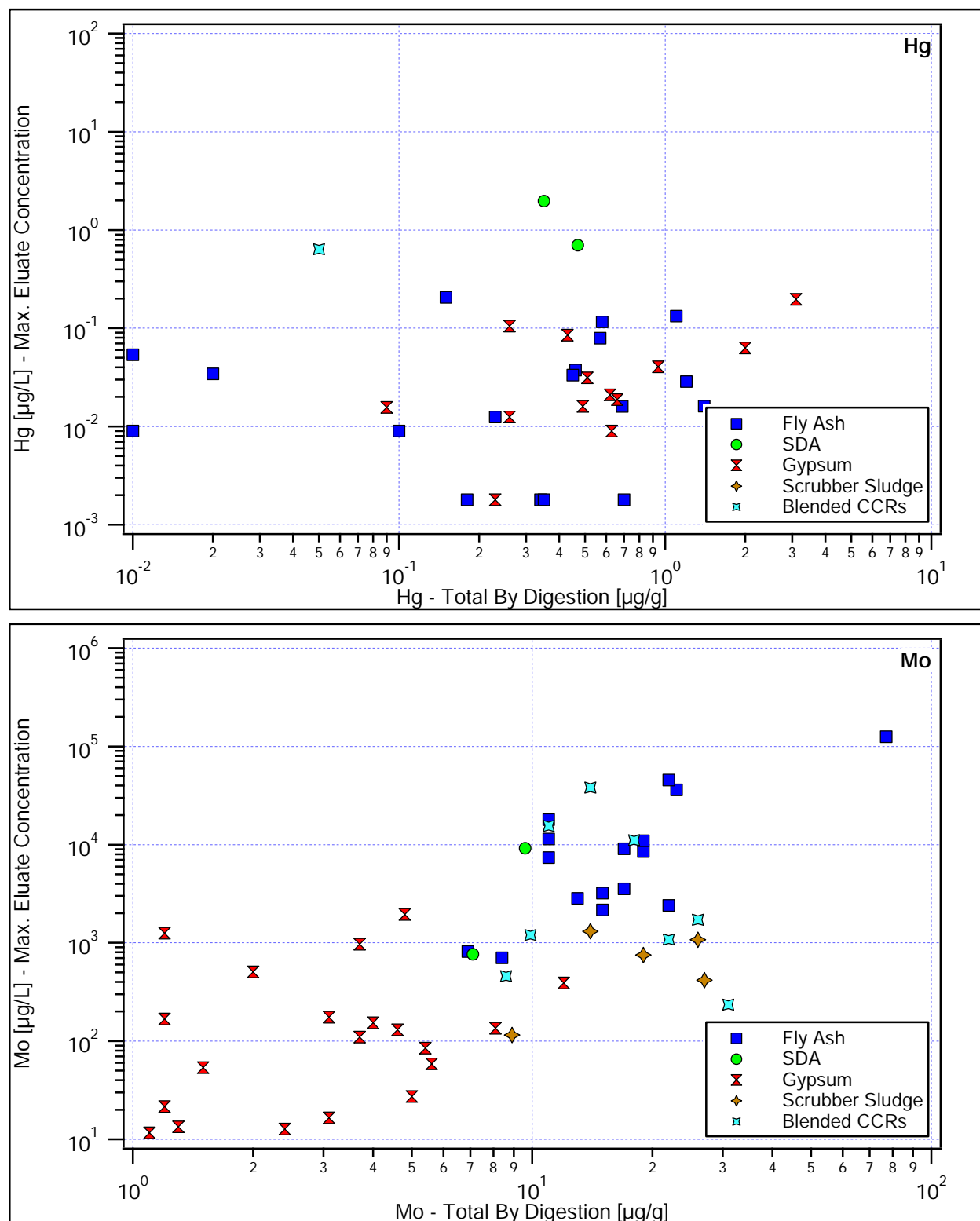


Figure 74 and Figure 75. Mercury and Molybdenum. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

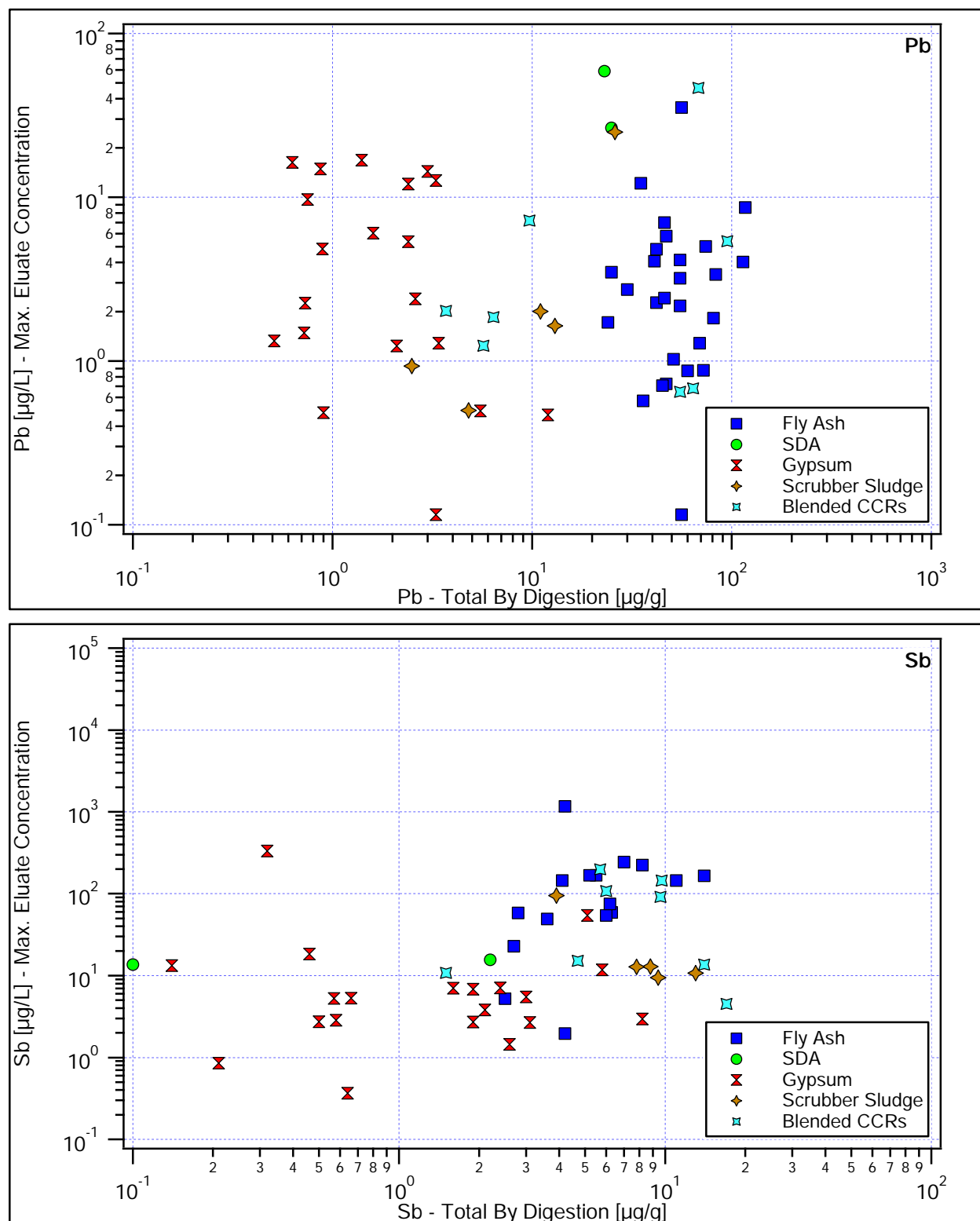


Figure 76 and Figure 77. Lead and Antimony. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

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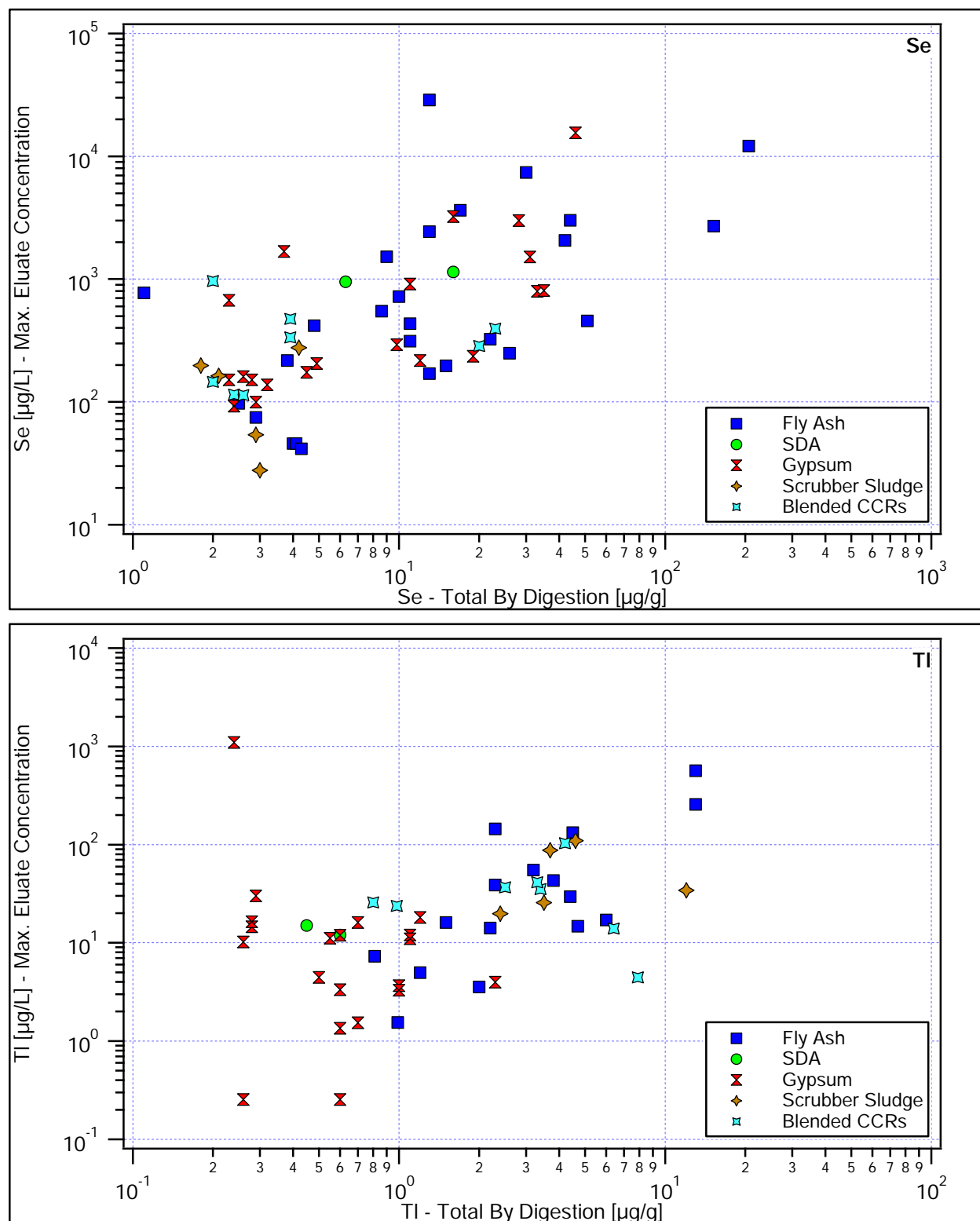


Figure 78 and Figure 79. Selenium and Thallium. Maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) as a function of total content by digestion.

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.

Characterization of Coal Combustion Residues III

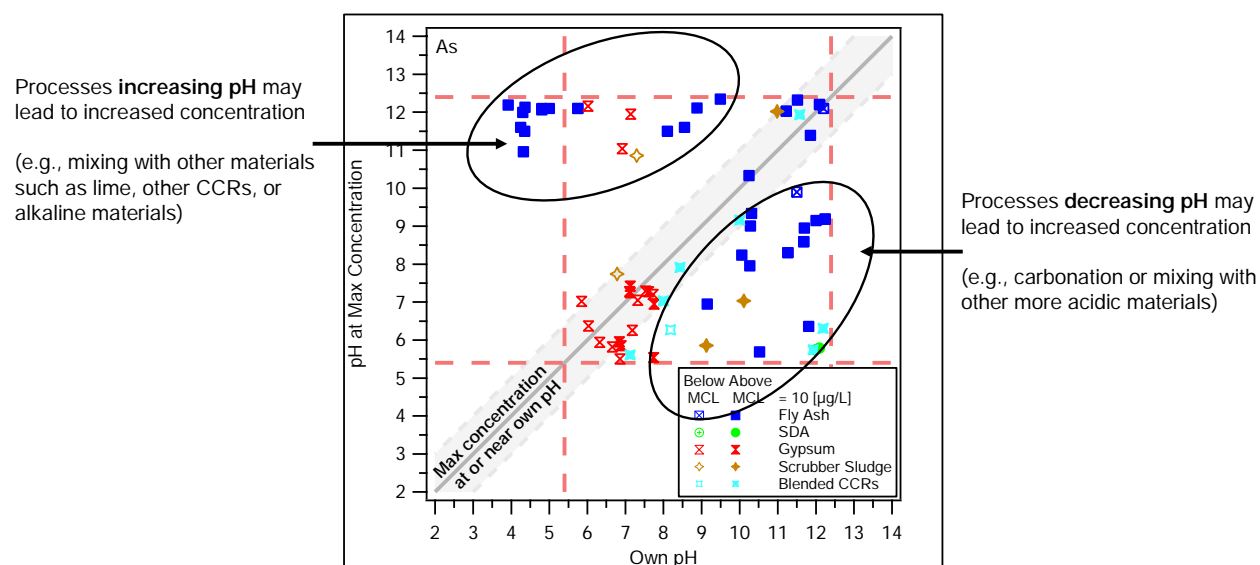


Figure 80. An example of pH identity plot. Dashed red lines are used to indicate the pH domain of 5.4 to 12.4.

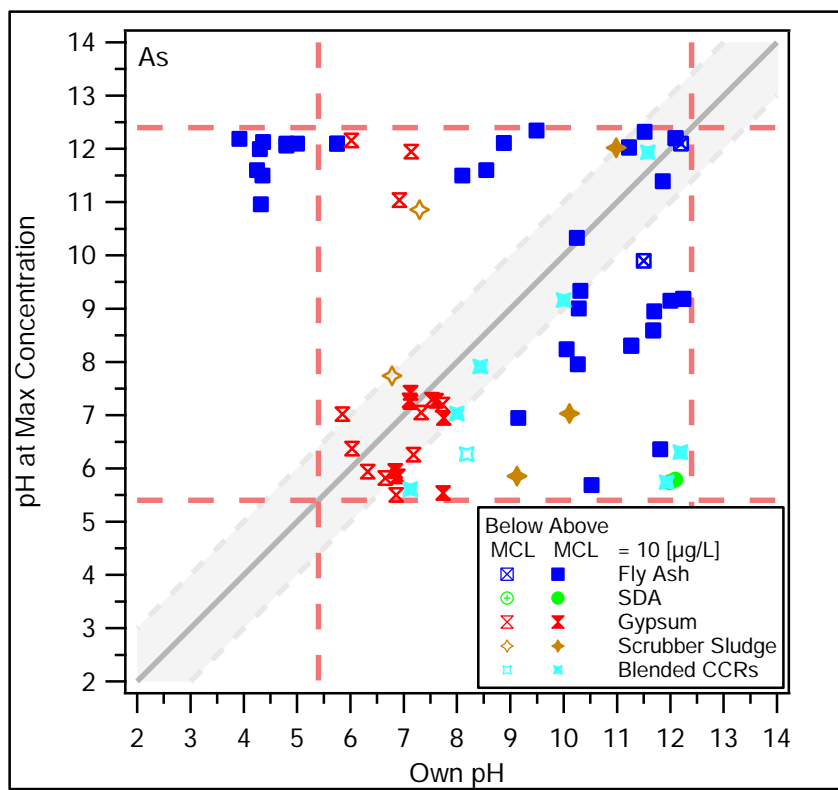
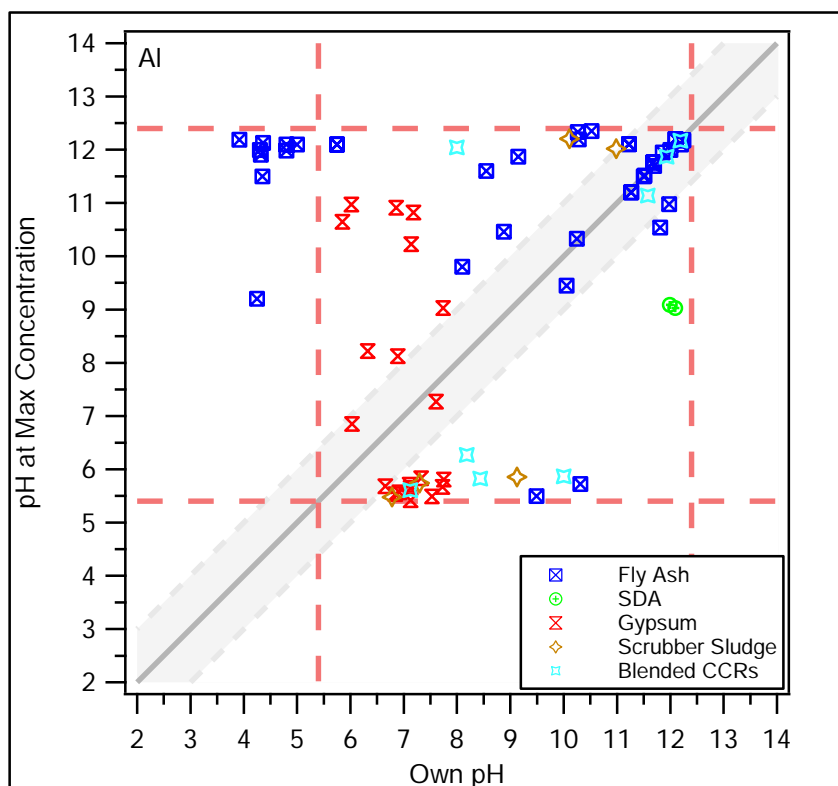


Figure 81 and Figure 82. Aluminum and Arsenic. pH identity plots.

Characterization of Coal Combustion Residues III

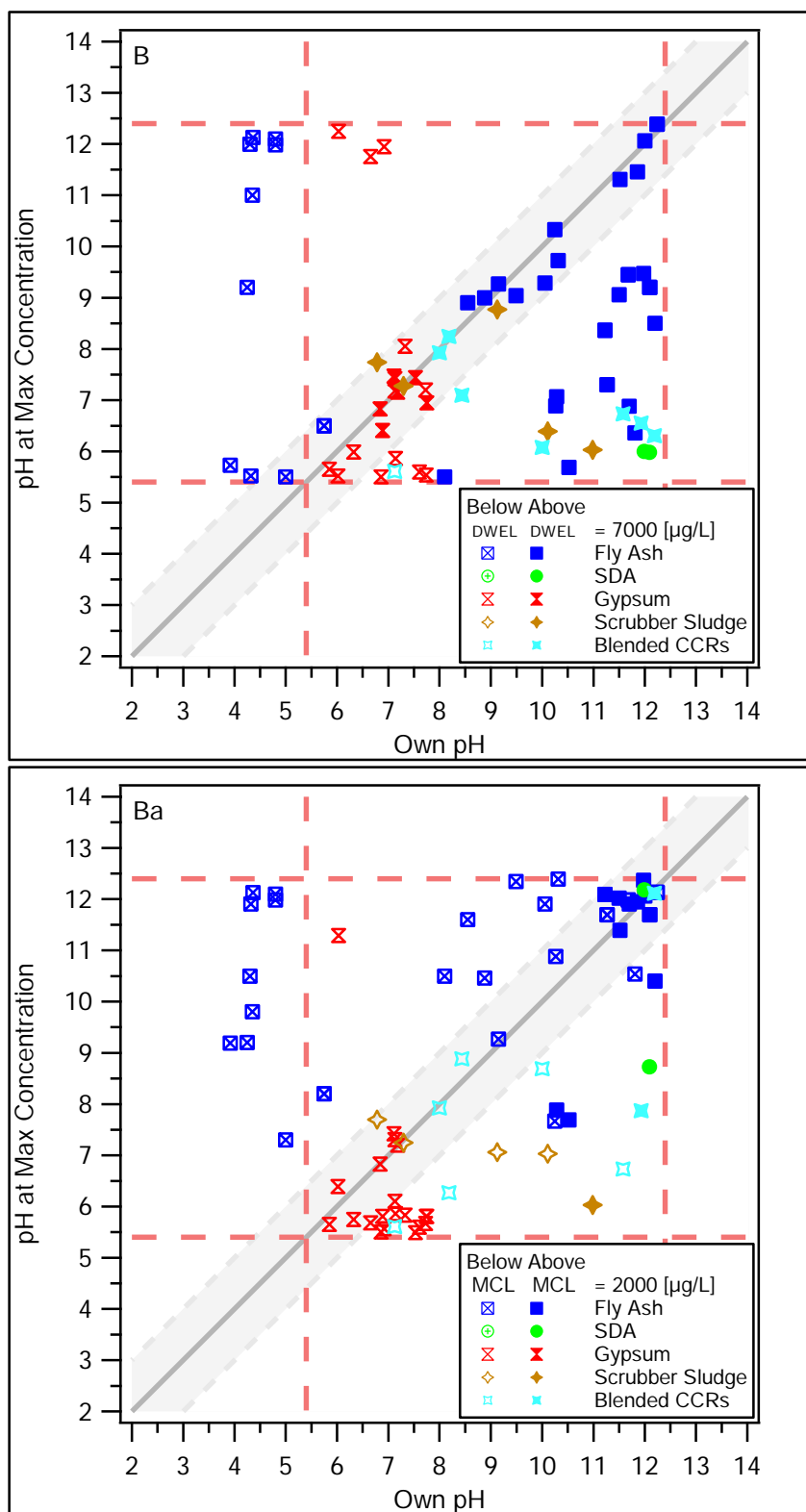


Figure 83 and Figure 84. Boron and Barium. pH identity plots.

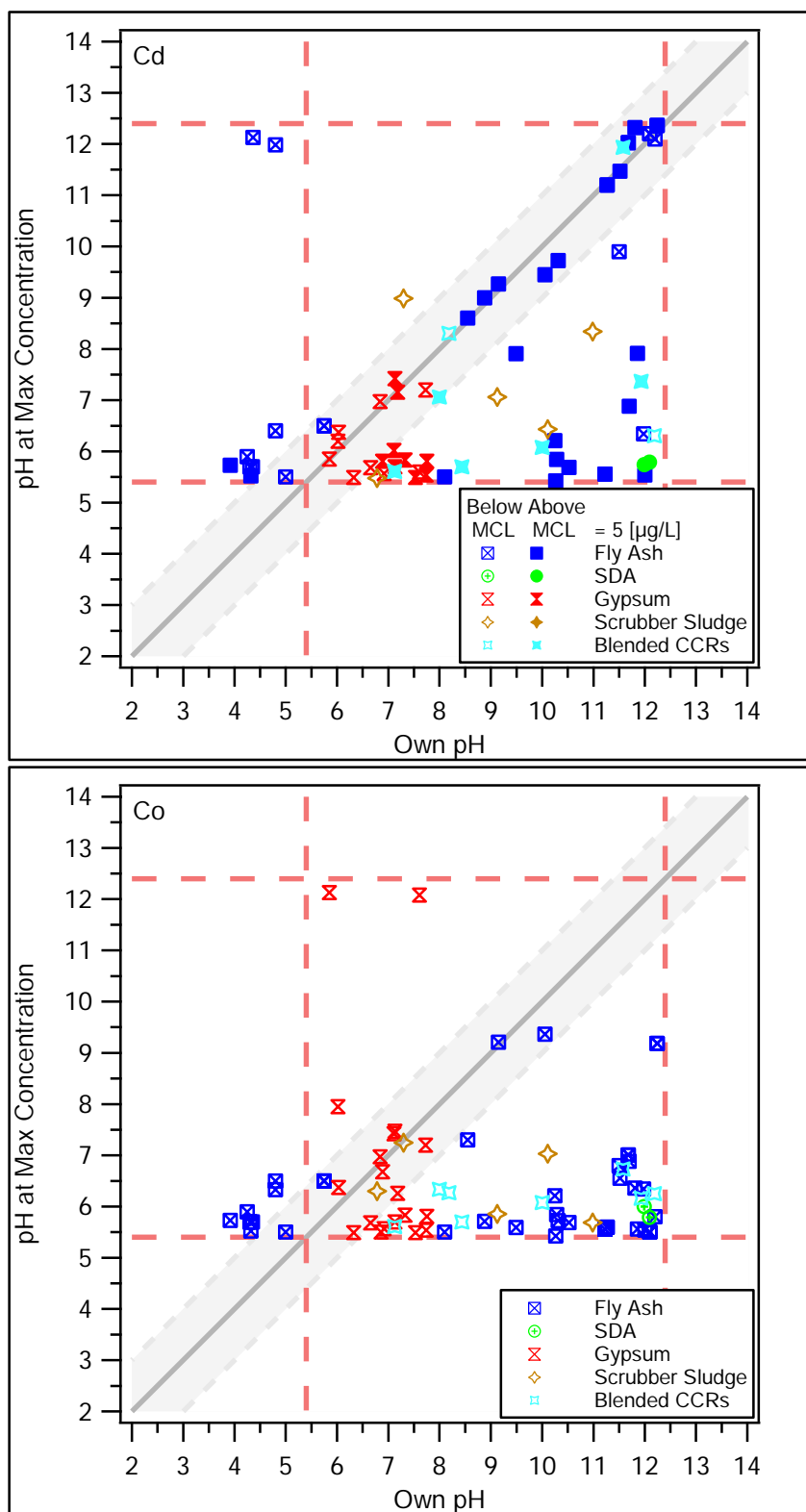


Figure 85 and Figure 86. Cadmium and Cobalt. pH identity plots.

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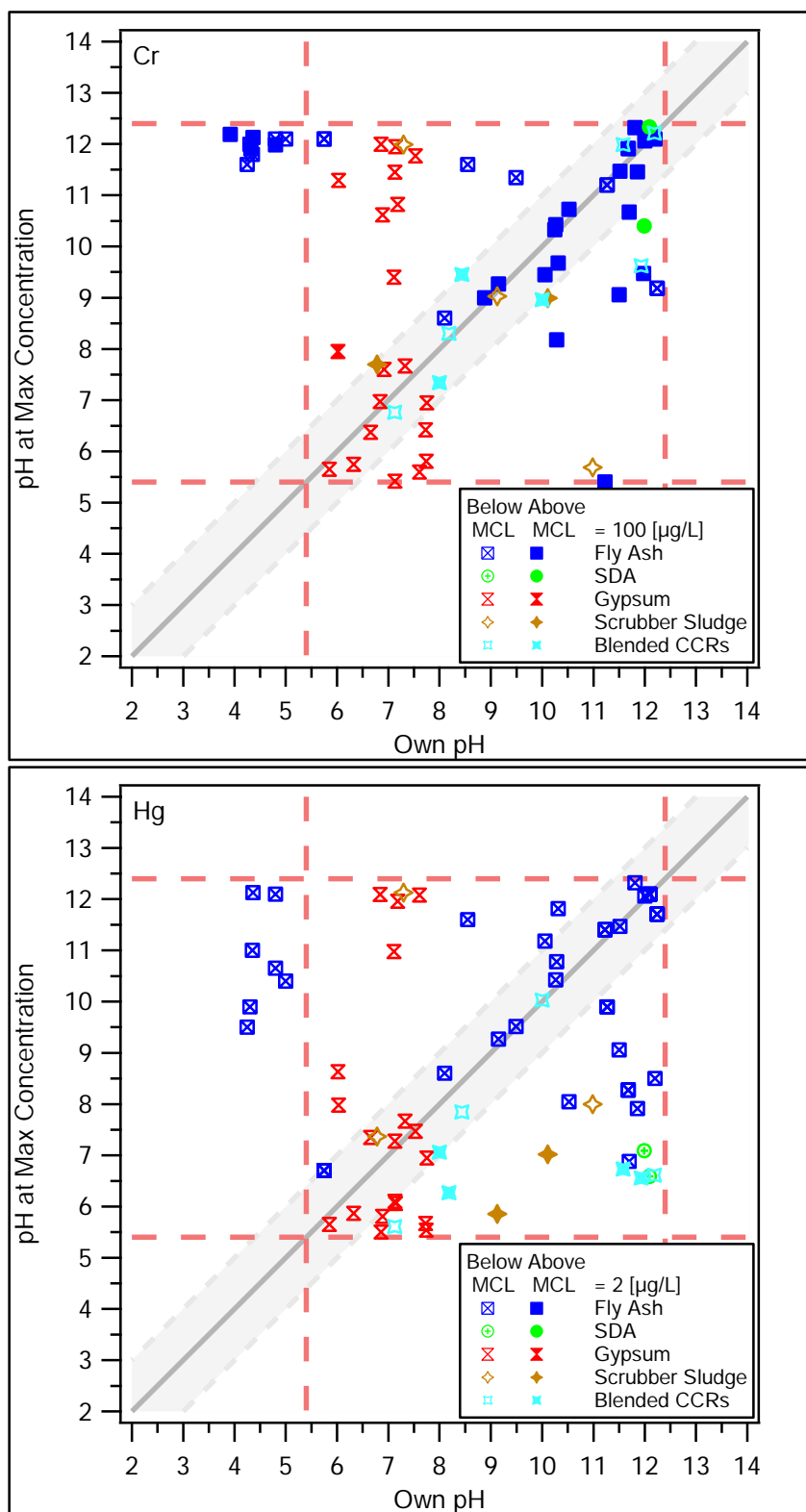


Figure 87 and Figure 88. Chromium and Mercury. pH identity plots.

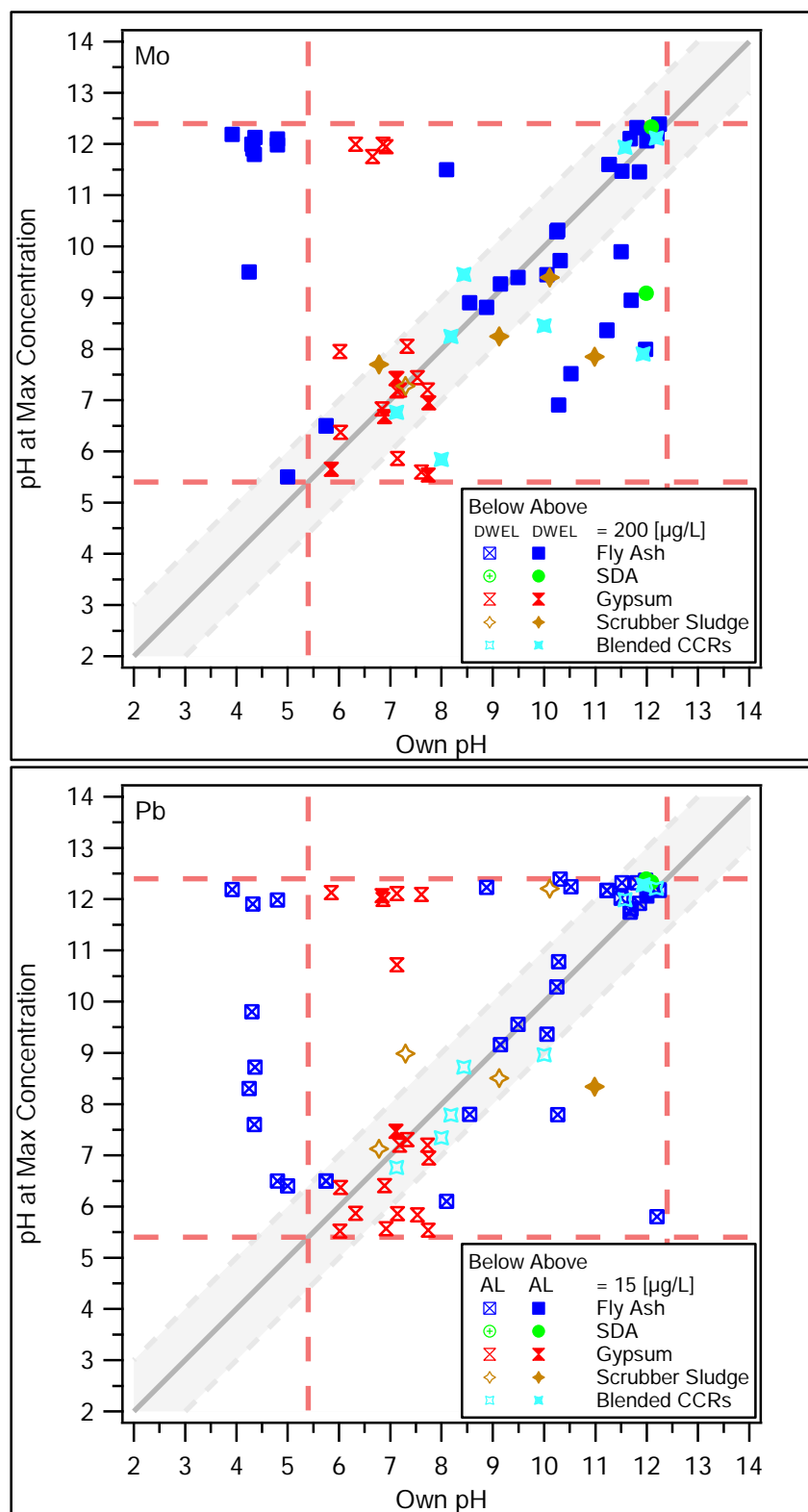


Figure 89 and Figure 90. Molybdenum and Lead. pH identity plots.

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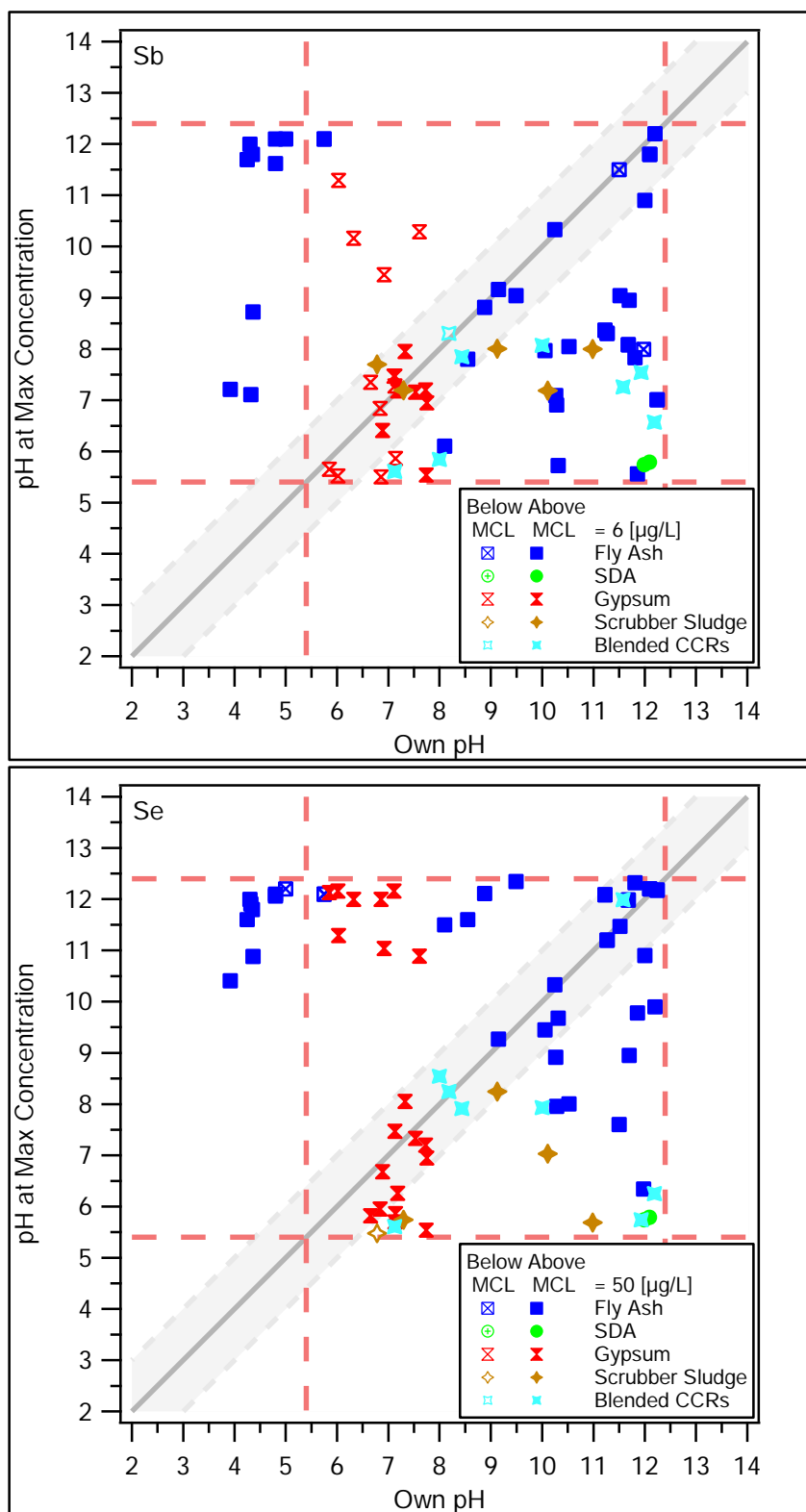


Figure 91 and Figure 92. Antimony and Selenium. pH identity plots.

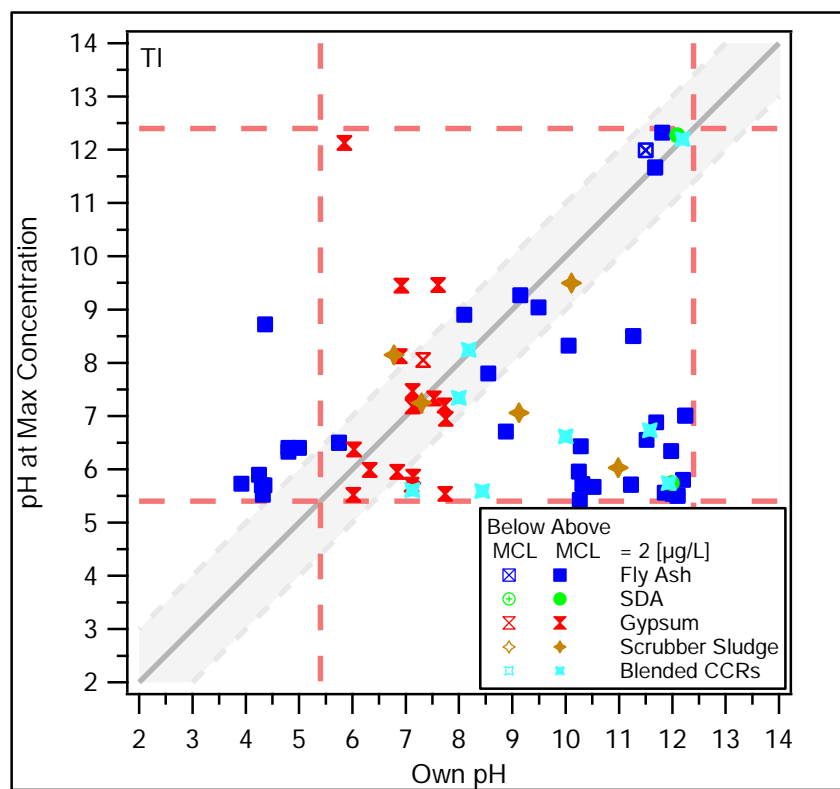


Figure 93. Thallium. pH identity plots.

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 $5.4 \leq \text{pH} \leq 12.4$, 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

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.

Characterization of Coal Combustion Residues III

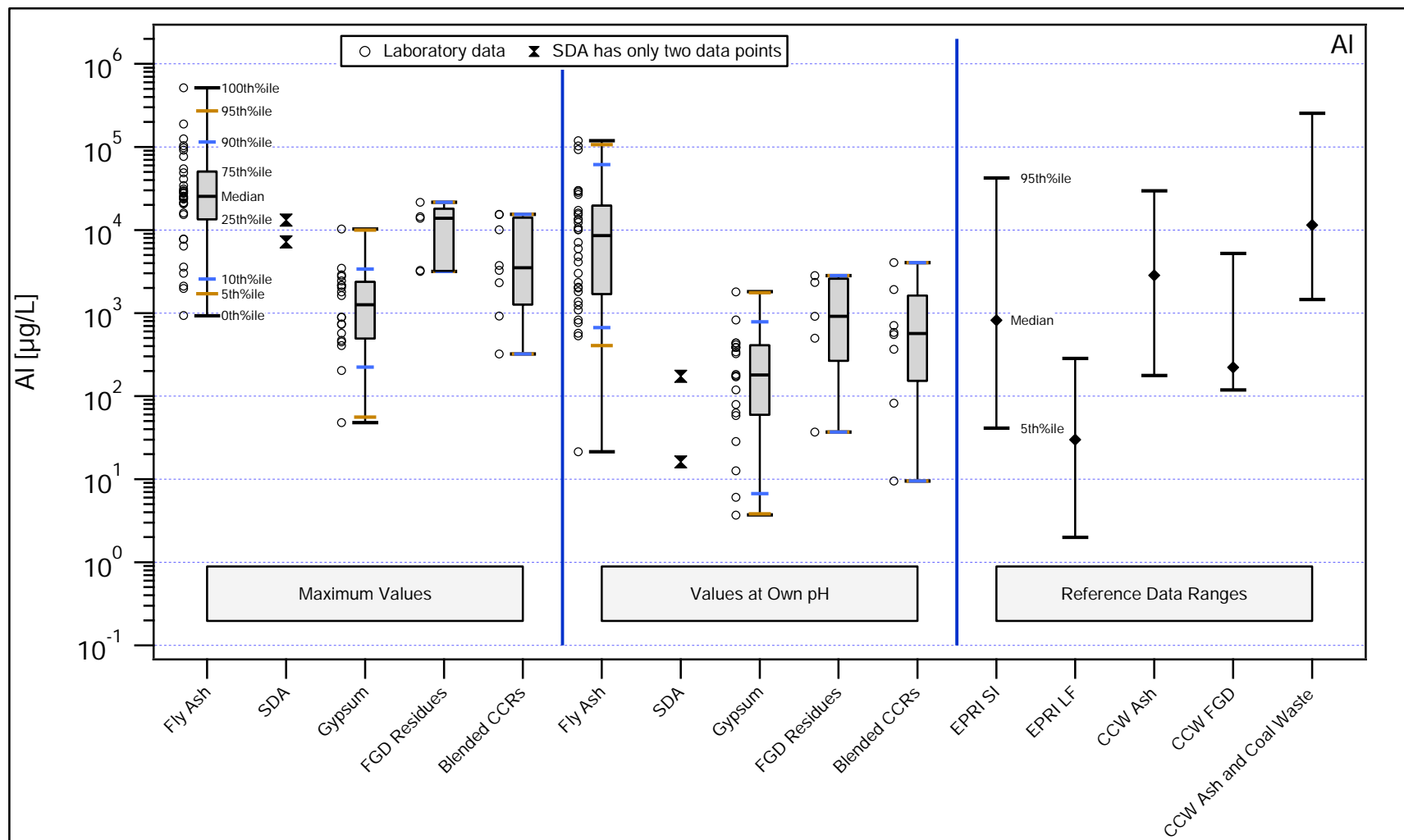


Figure 94. Aluminum. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

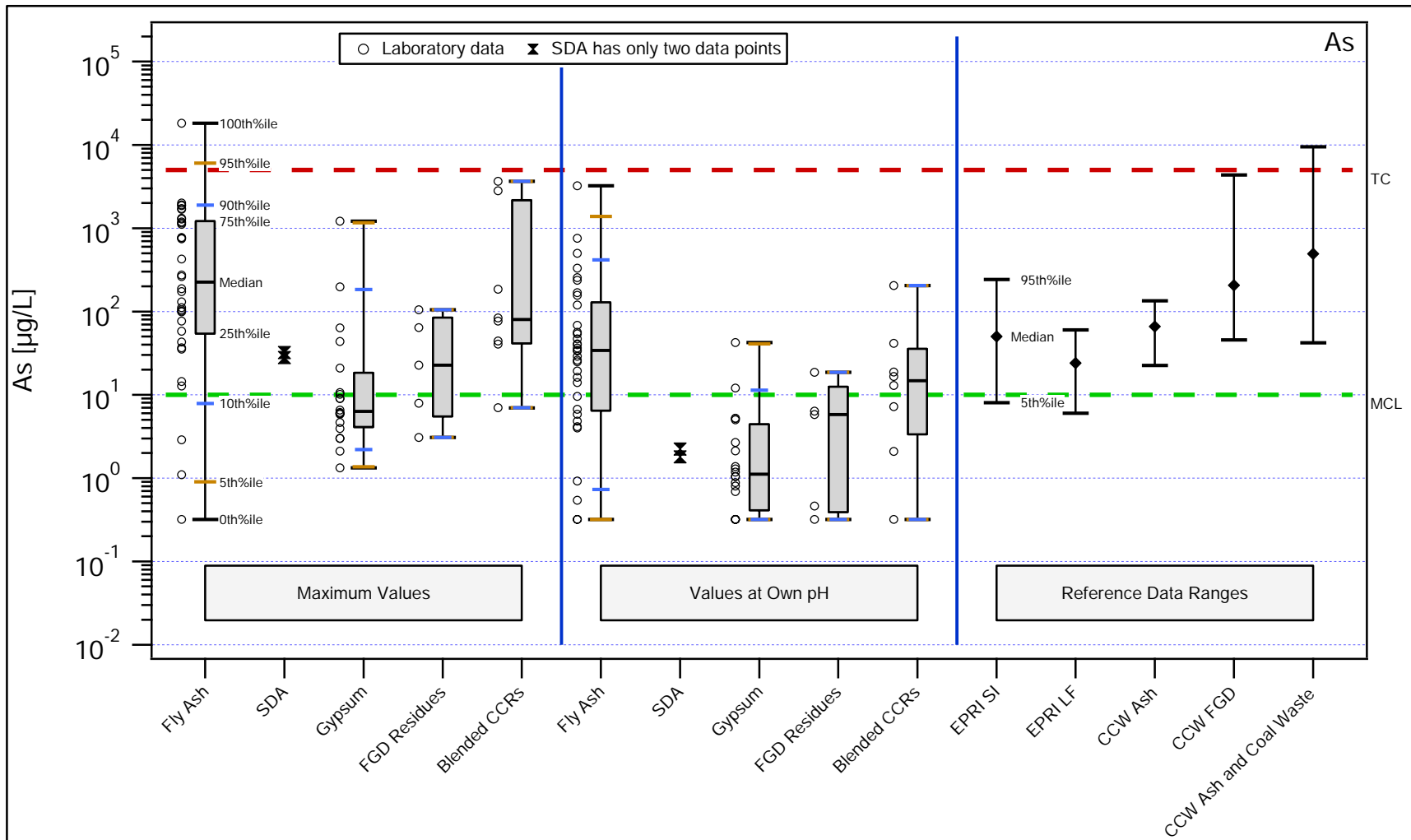


Figure 95. Arsenic. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

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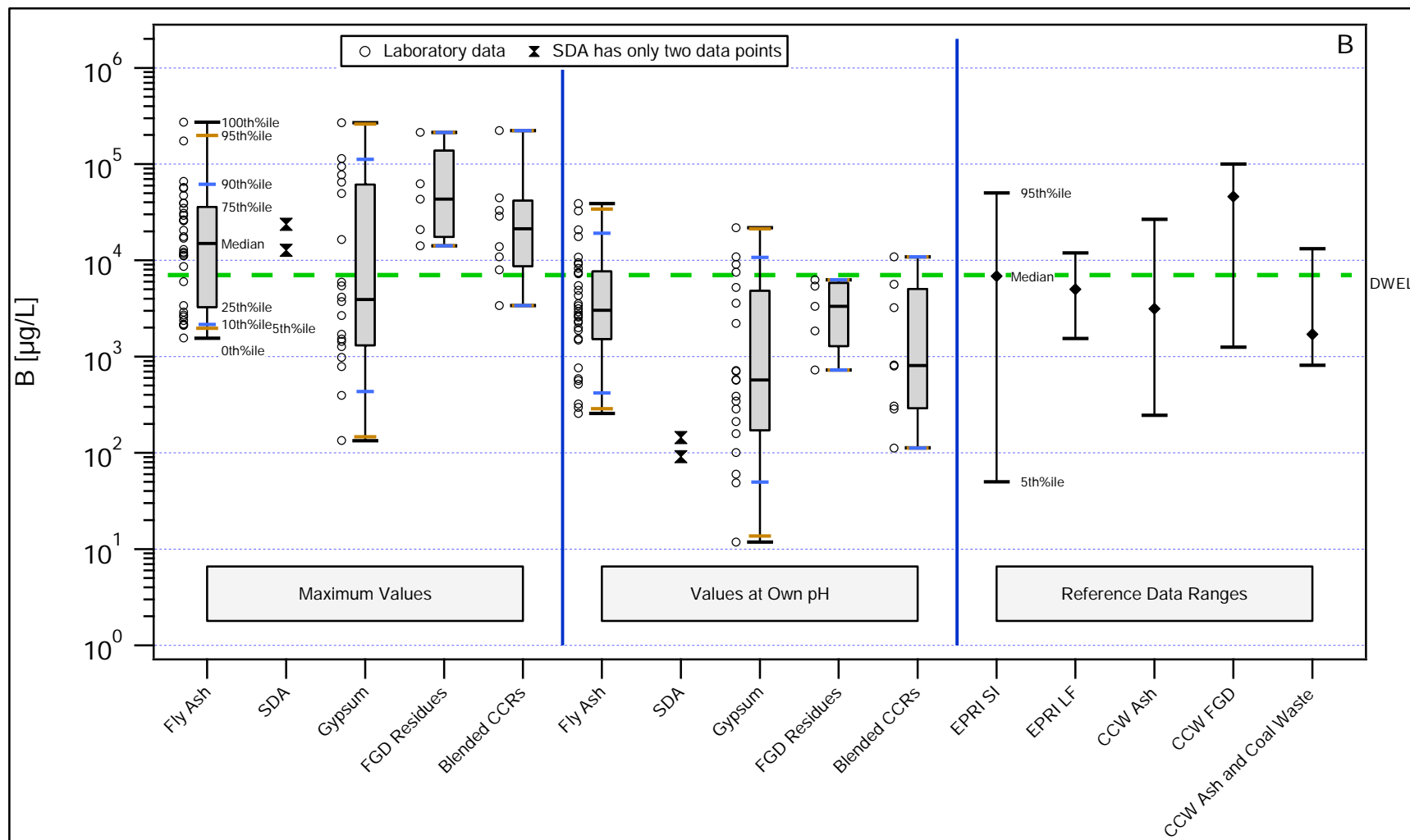


Figure 96. Boron. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations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

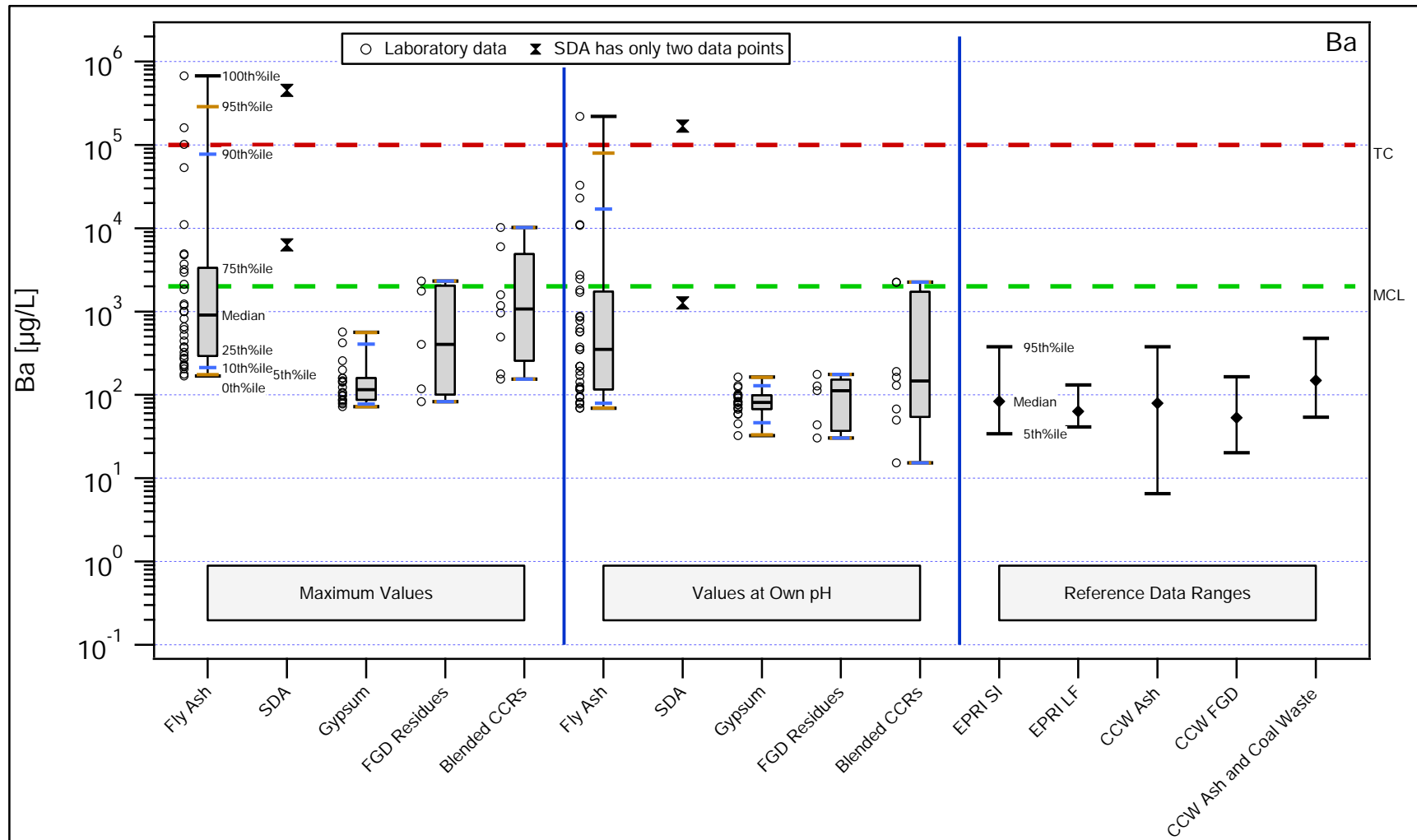


Figure 97. Barium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

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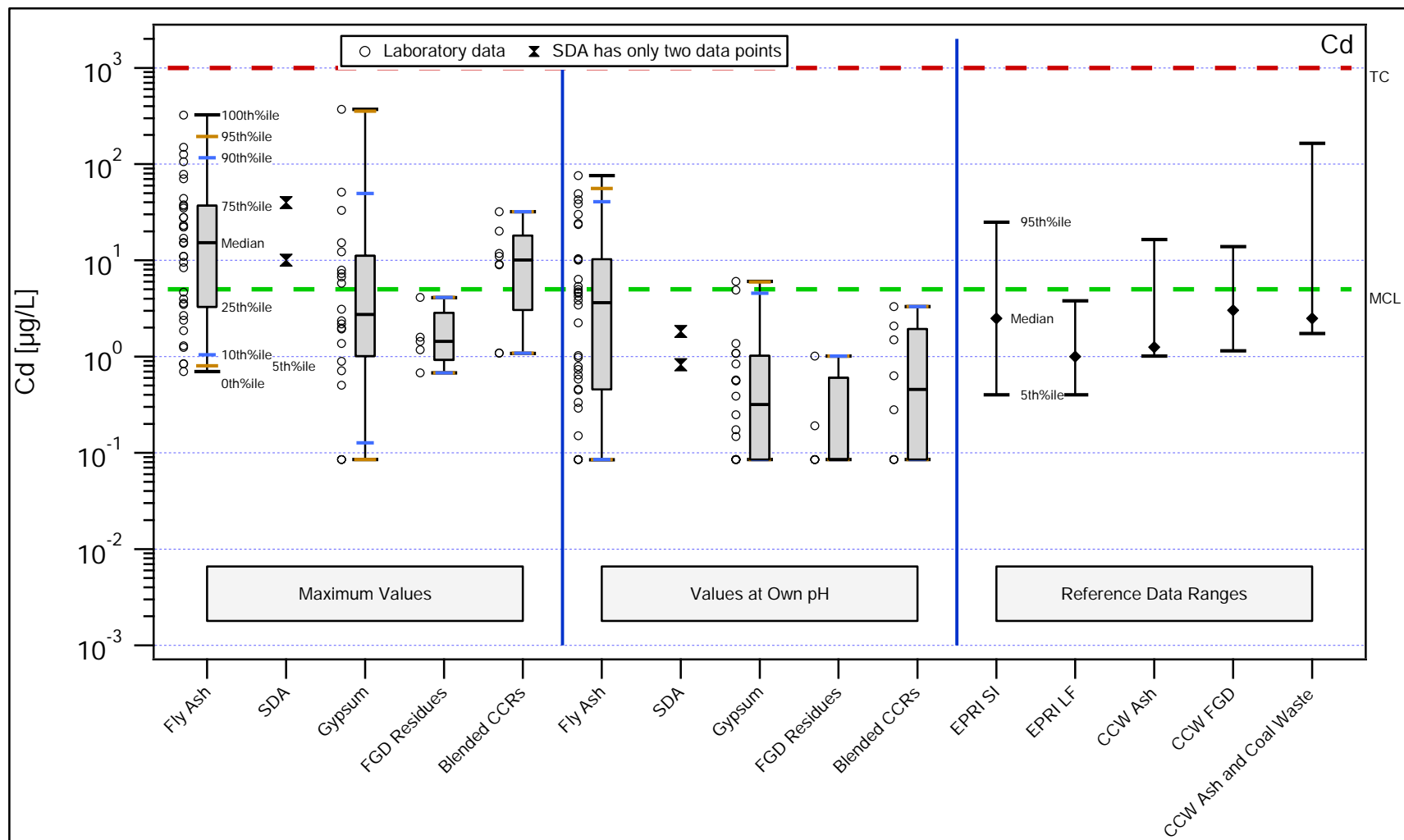


Figure 98. Cadmium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

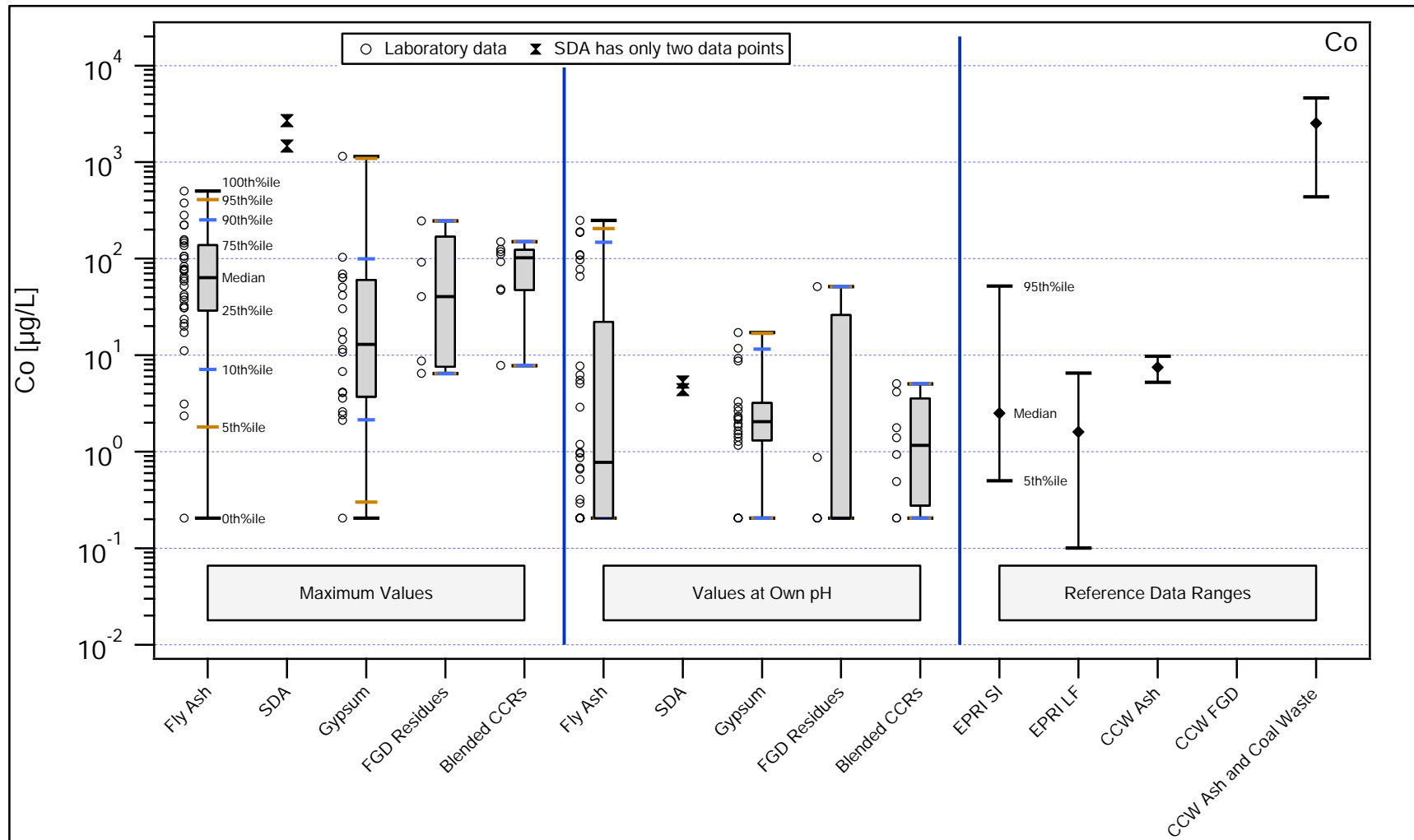


Figure 99. Cobalt. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

Characterization of Coal Combustion Residues III

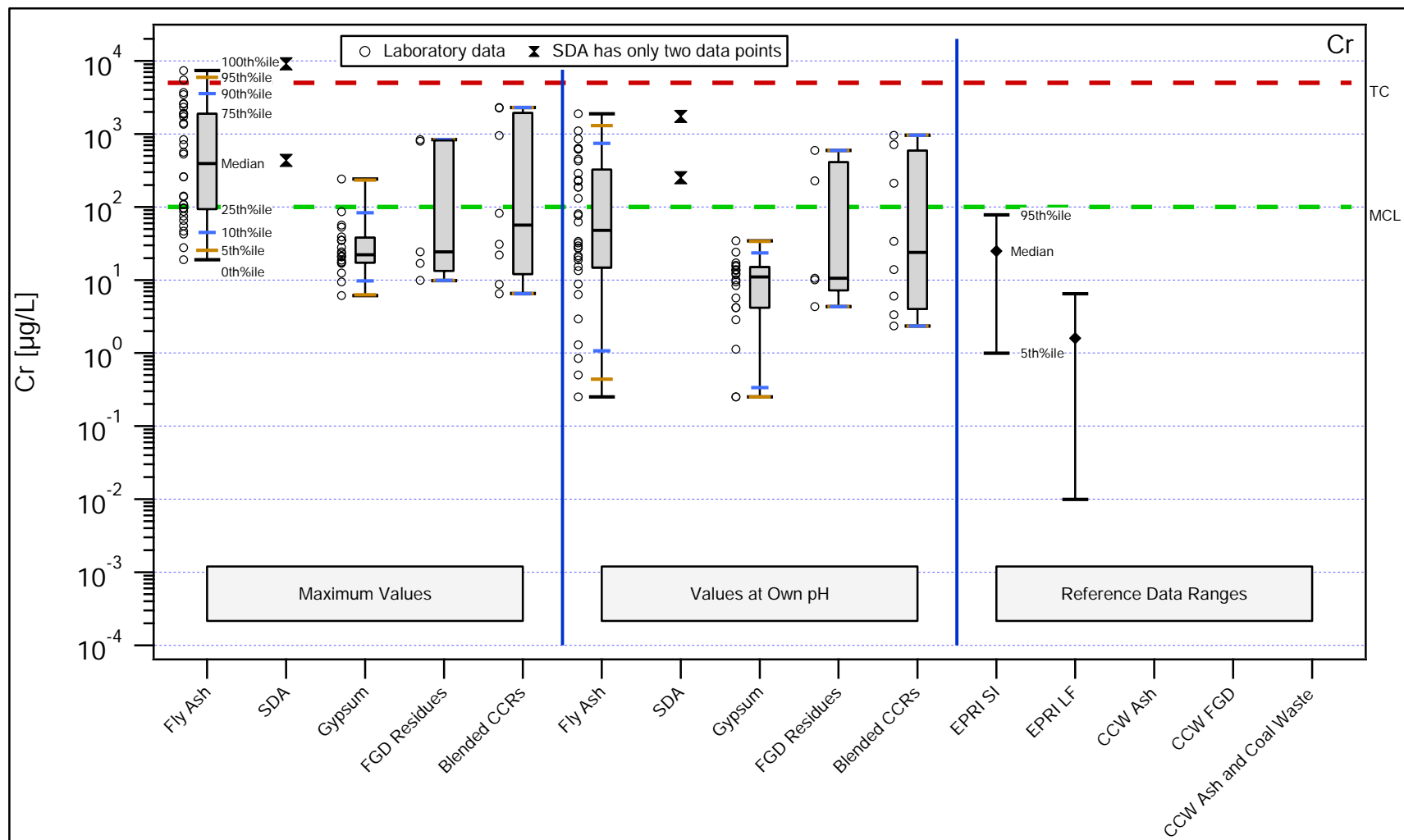


Figure 100. Chromium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations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

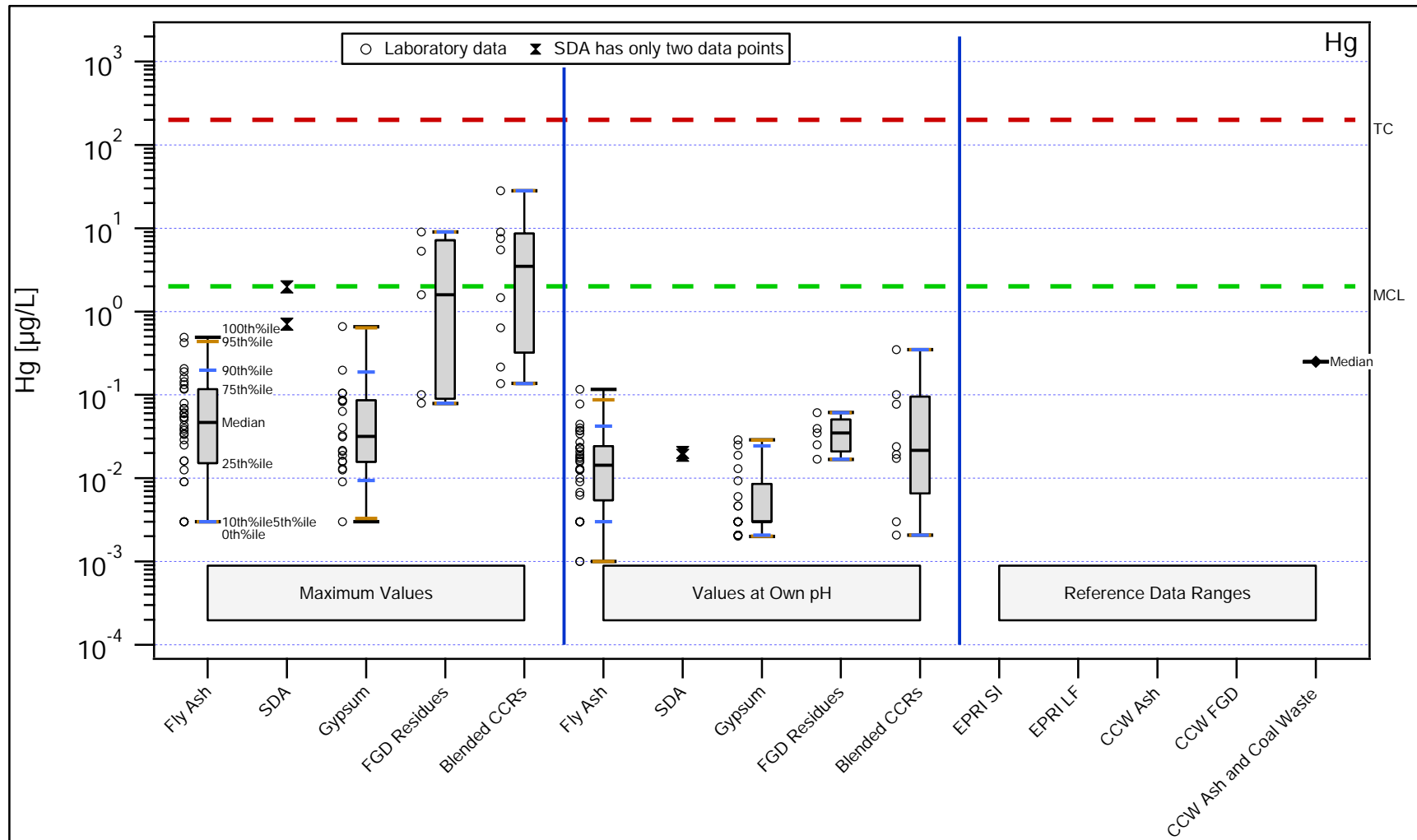


Figure 101. Mercury. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

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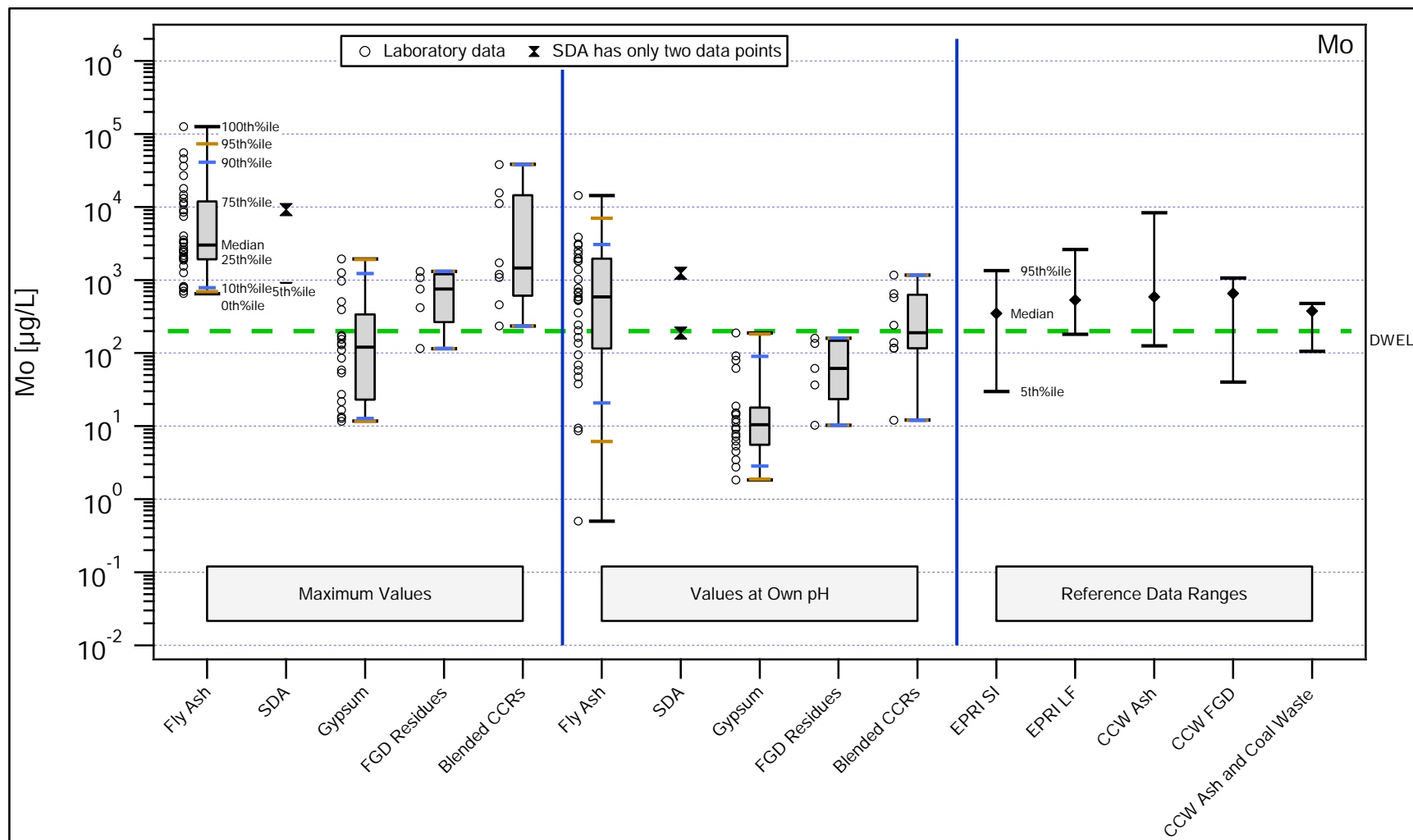


Figure 102. Molybdenum. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations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

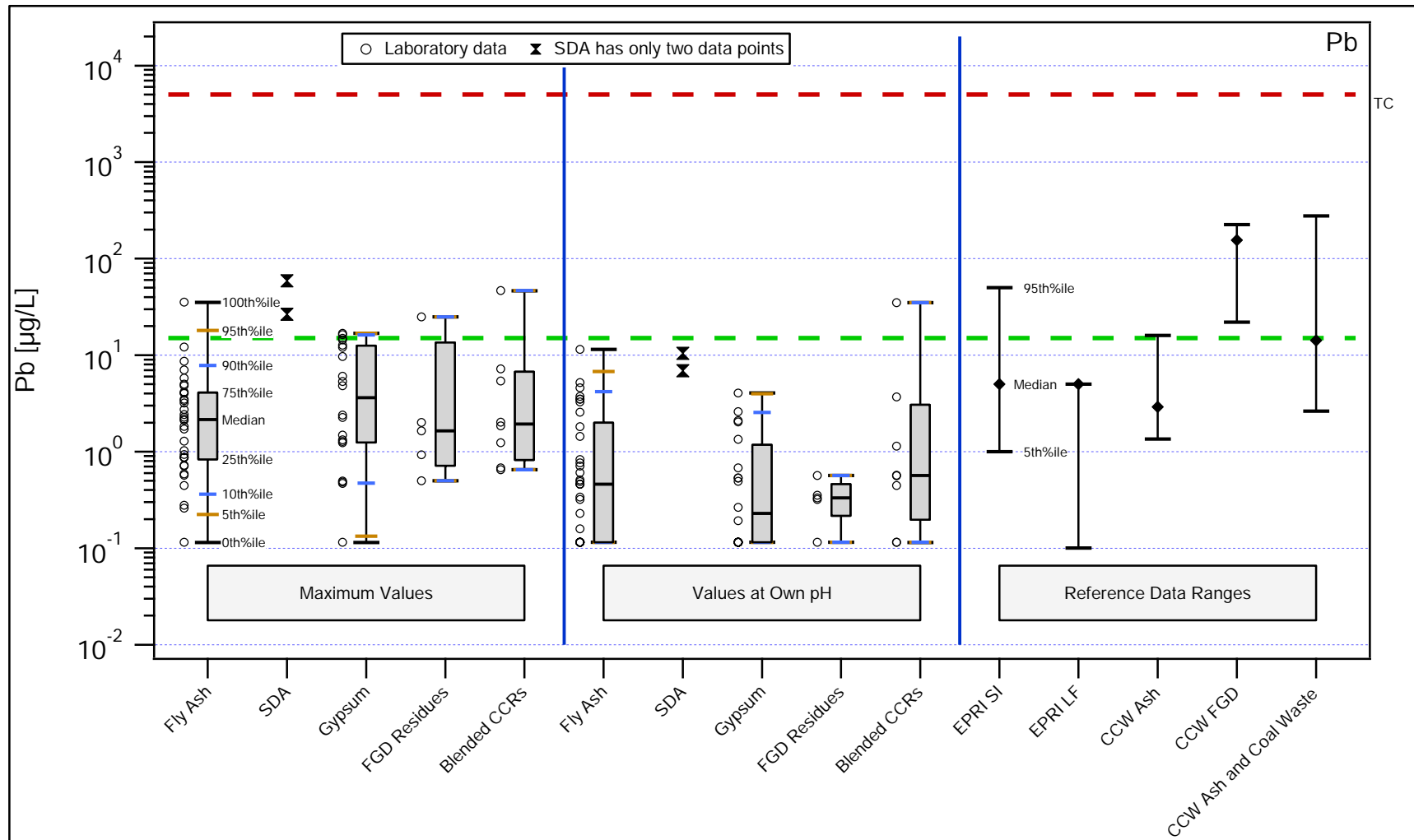


Figure 103. Lead. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at $\text{LS} = 10\text{mL/g}$, and reference data ranges derived from the EPRI database of field leachate and pore water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

Characterization of Coal Combustion Residues III

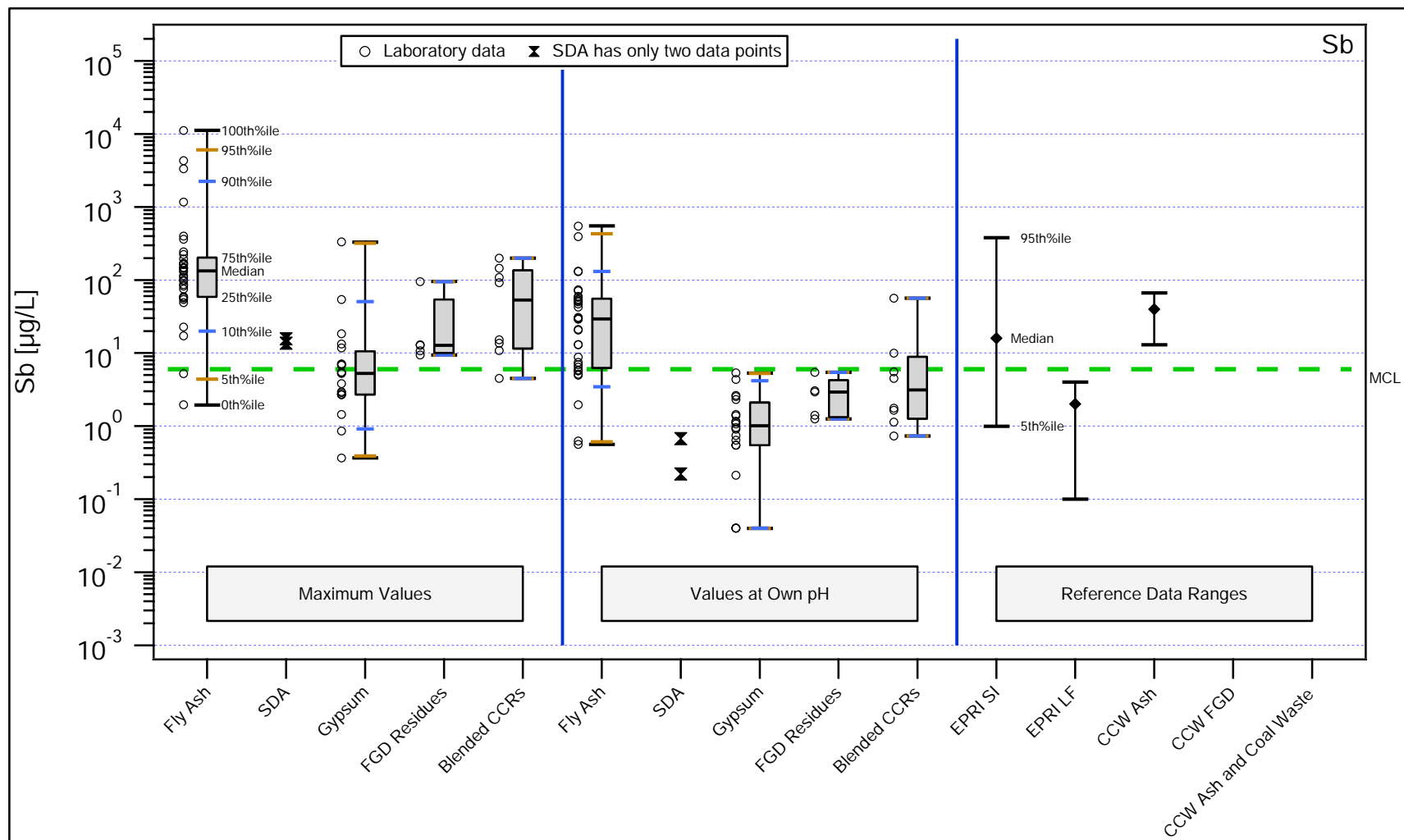


Figure 104. Antimony. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations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

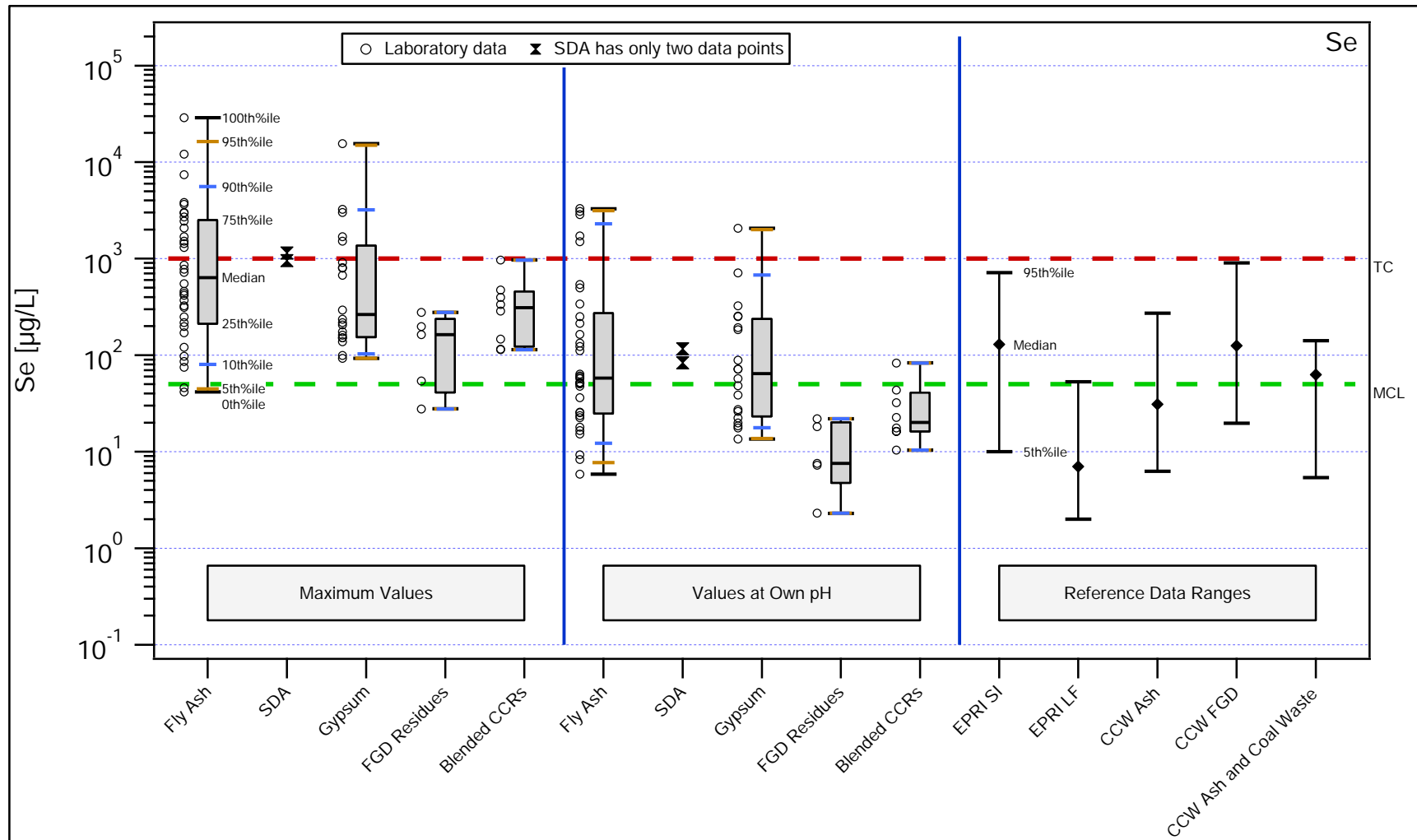


Figure 105. Selenium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations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

Characterization of Coal Combustion Residues III

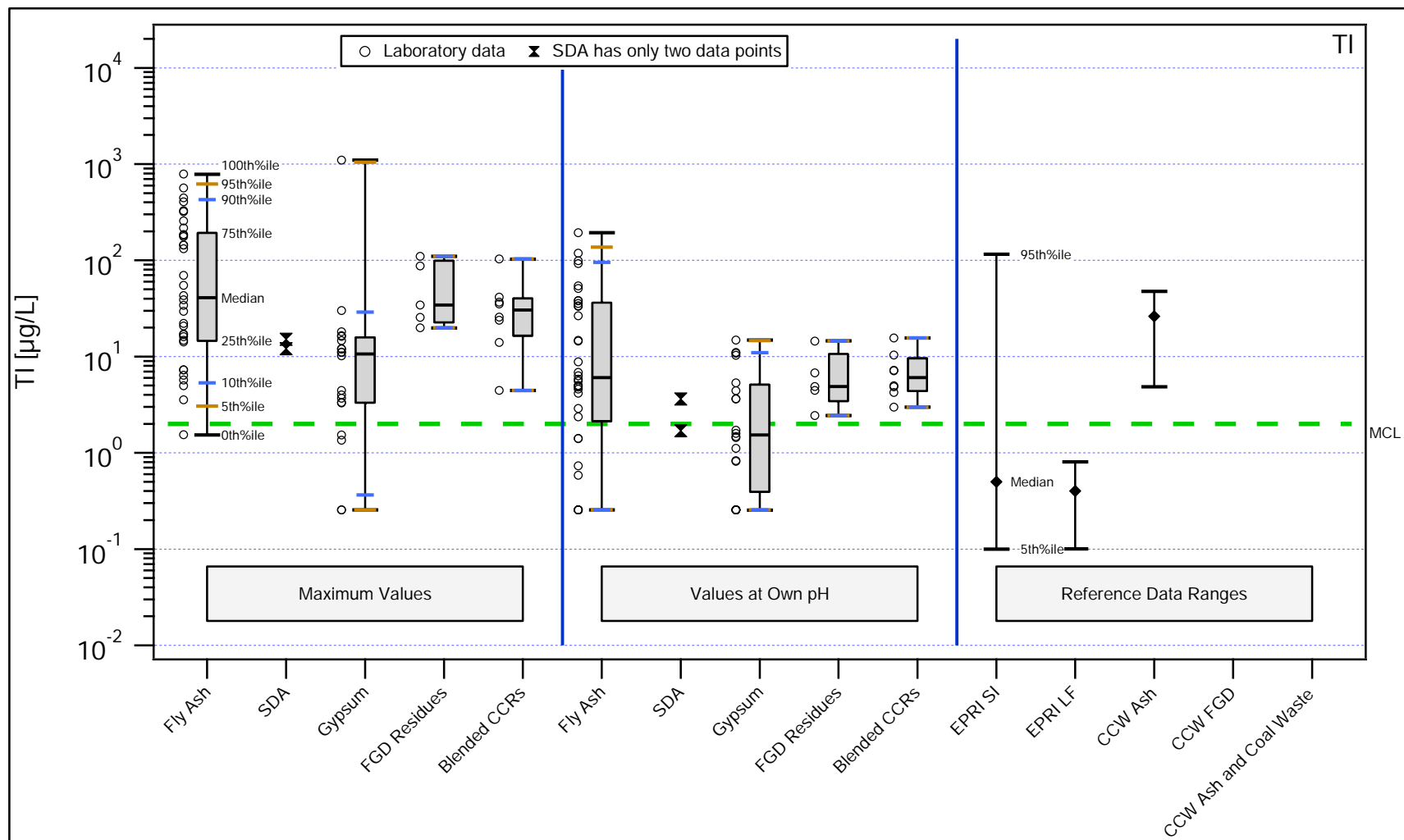


Figure 106. Thallium. Comparison of maximum concentrations observed in SR002.1 and SR003.1 eluates over the pH domain $5.4 \leq \text{pH} \leq 12.4$, own pH concentrations from SR002.1 at LS = 10mL/g, and reference data ranges derived from the EPRI database of field leachate and pore water concentrations (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.

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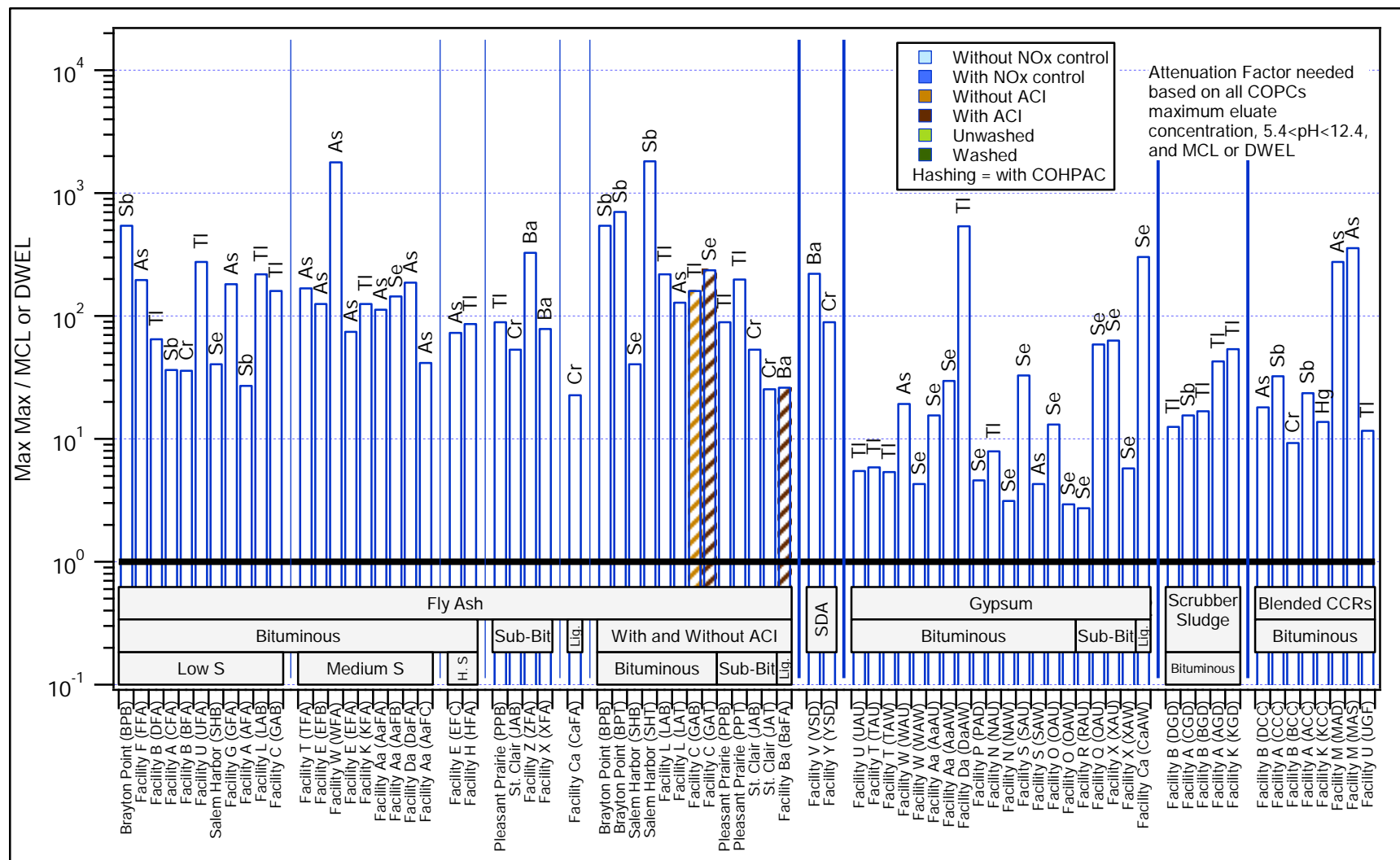


Figure 107. **Minimum attenuation factor** needed for the **maximum eluate concentration** ($5.4 \leq \text{pH} \leq 12.4$) to be reduced below the MCL or DWEL for all COPCs considered in this study. COPC requiring the greatest attenuation factor is indicated for each CCR.

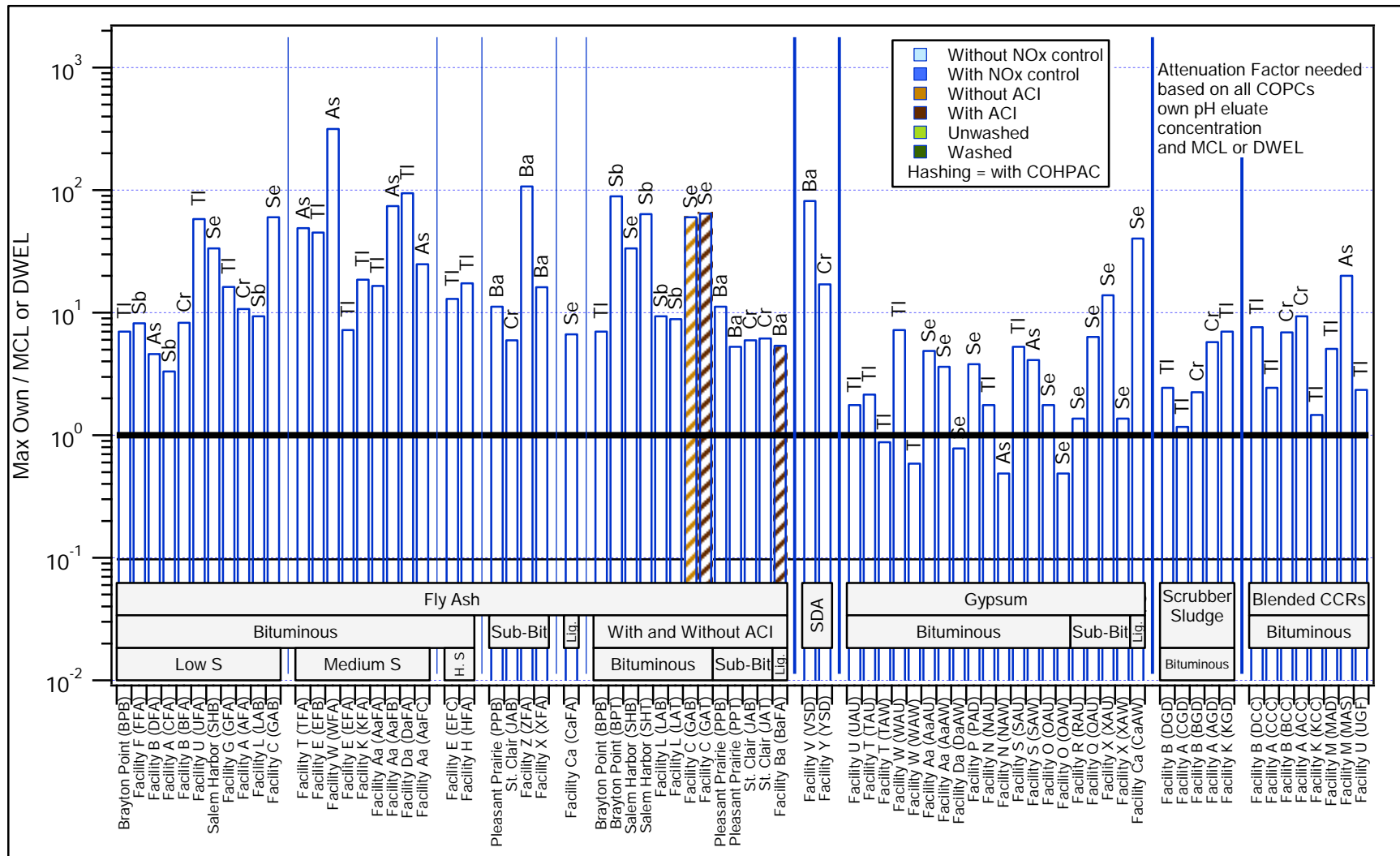


Figure 108. **Minimum attenuation factor** needed for **the own pH eluate concentration** to be reduced below the MCL or DWEL for all COPCs considered in this study. COPC requiring the greatest attenuation factor is indicated for each CCR.

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 SO₂ 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 SO₂ 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 12.4⁴³, 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.

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.

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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.

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Table 13. **Fly Ash** - Laboratory leach test eluate concentrations for $5.4 \leq \text{pH} \leq 12.4$ 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 $5.4 \leq \text{pH} \leq 12.4$ 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.

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Appendix A

Facility Descriptions and CCR Sample Locations

Facility Descriptions

<u>Brayton Point</u>	<u>A-1</u>
<u>Pleasant Prairie</u>	<u>A-1</u>
<u>Salem Harbor</u>	<u>A-2</u>
<u>Facility A</u>	<u>A-3</u>
<u>Facility B</u>	<u>A-3</u>
<u>Facility C</u>	<u>A-4</u>
<u>Facility E</u>	<u>A-4</u>
<u>Facility F</u>	<u>A-4</u>
<u>Facility G</u>	<u>A-5</u>
<u>Facility H</u>	<u>A-5</u>
<u>Facility J</u>	<u>A-5</u>
<u>Facility K</u>	<u>A-5</u>
<u>Facility L</u>	<u>A-6</u>
<u>Facility M</u>	<u>A-6</u>
<u>Facility N</u>	<u>A-7</u>
<u>Facility O</u>	<u>A-7</u>
<u>Facility P</u>	<u>A-8</u>
<u>Facility Q</u>	<u>A-8</u>
<u>Facility R</u>	<u>A-8</u>
<u>Facility S</u>	<u>A-9</u>
<u>Facility T</u>	<u>A-9</u>
<u>Facility U</u>	<u>A-9</u>
<u>Facility V</u>	<u>A-9</u>
<u>Facility W</u>	<u>A-10</u>
<u>Facility X</u>	<u>A-10</u>
<u>Facility Y</u>	<u>A-11</u>
<u>Facility Z</u>	<u>A-11</u>
<u>Facility Aa</u>	<u>A-11</u>
<u>Facility Ba</u>	<u>A-12</u>
<u>Facility Ca</u>	<u>A-12</u>
<u>Facility Da</u>	<u>A-12</u>

Facility Flow Diagrams

<u>Brayton Point</u>	<u>A-13</u>
<u>Pleasant Prairie</u>	<u>A-15</u>
<u>Salem Harbor</u>	<u>A-17</u>
<u>Facility A</u>	<u>A-19</u>
<u>Facility B</u>	<u>A-21</u>
<u>Facility C</u>	<u>A-23</u>
<u>Facility E</u>	<u>A-25</u>
<u>Facility F</u>	<u>A-28</u>
<u>Facility G</u>	<u>A-29</u>
<u>Facility H</u>	<u>A-30</u>
<u>Facility J</u>	<u>A-31</u>
<u>Facility K</u>	<u>A-33</u>
<u>Facility L</u>	<u>A-34</u>
<u>Facility M</u>	<u>A-36</u>
<u>Facility N</u>	<u>A-38</u>
<u>Facility O</u>	<u>A-39</u>
<u>Facility P</u>	<u>A-40</u>
<u>Facility Q</u>	<u>A-41</u>
<u>Facility R</u>	<u>A-42</u>
<u>Facility S</u>	<u>A-43</u>
<u>Facility T</u>	<u>A-44</u>
<u>Facility U</u>	<u>A-45</u>
<u>Facility V</u>	<u>A-47</u>
<u>Facility W</u>	<u>A-48</u>
<u>Facility X</u>	<u>A-49</u>
<u>Facility Y</u>	<u>A-50</u>
<u>Facility Z</u>	<u>A-51</u>
<u>Facility Aa</u>	<u>A-52</u>
<u>Facility Ba</u>	<u>A-54</u>
<u>Facility Ca</u>	<u>A-55</u>
<u>Facility Da</u>	<u>A-56</u>

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 $156 \text{ ft}^2 / 1000 \text{ acfm}$. 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 $403 \text{ ft}^2 / 1000 \text{ acfm}$. Total SCA for the unit is $559 \text{ ft}^2 / 1000 \text{ acfm}$. The precipitator inlet gas temperature is nominally 280°F 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 study¹ was collected before processing for carbon separation because not all facilities do this processing. 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 °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 ft²/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 ft²/1000 acfm. The precipitator inlet gas temperature is nominally 255 °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 SO₂ 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 SO₂ 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 (SO_fA) 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 SO₂ 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 absorber¹ 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 May 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 SO₂ 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.

¹ Dibasic acid (DBA) is a commercial mixture of glutaric, succinic, and adipic acids: HOOC(CH₂)₂₋₄COOH.

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 SO₂ 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 SO₂ 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 SO₂ 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 SO₂ 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.

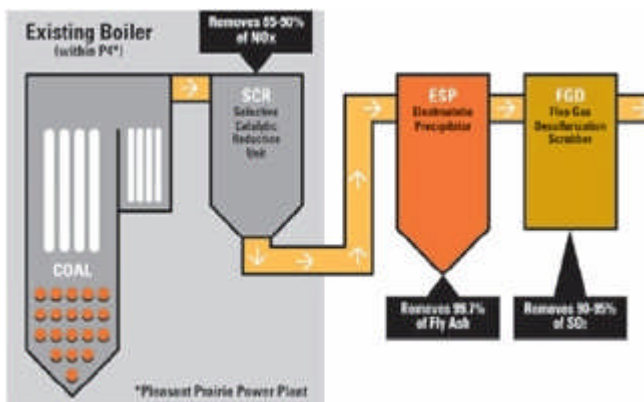
Samples were collected as follows: dry FGD gypsum after water wash (WAW), moist FGD gypsum before the water wash (WAU), wastewater treatment system filter cake (WFC), and dry fly ash (WFA). Five gallon buckets of each of the samples were collected by plant personnel on 11/20/08. Samples were delivered 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 presence of a catalyst. The forced oxidation FGD system uses wet-limestone as a sorbent for SO₂ 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 SO₂ 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.

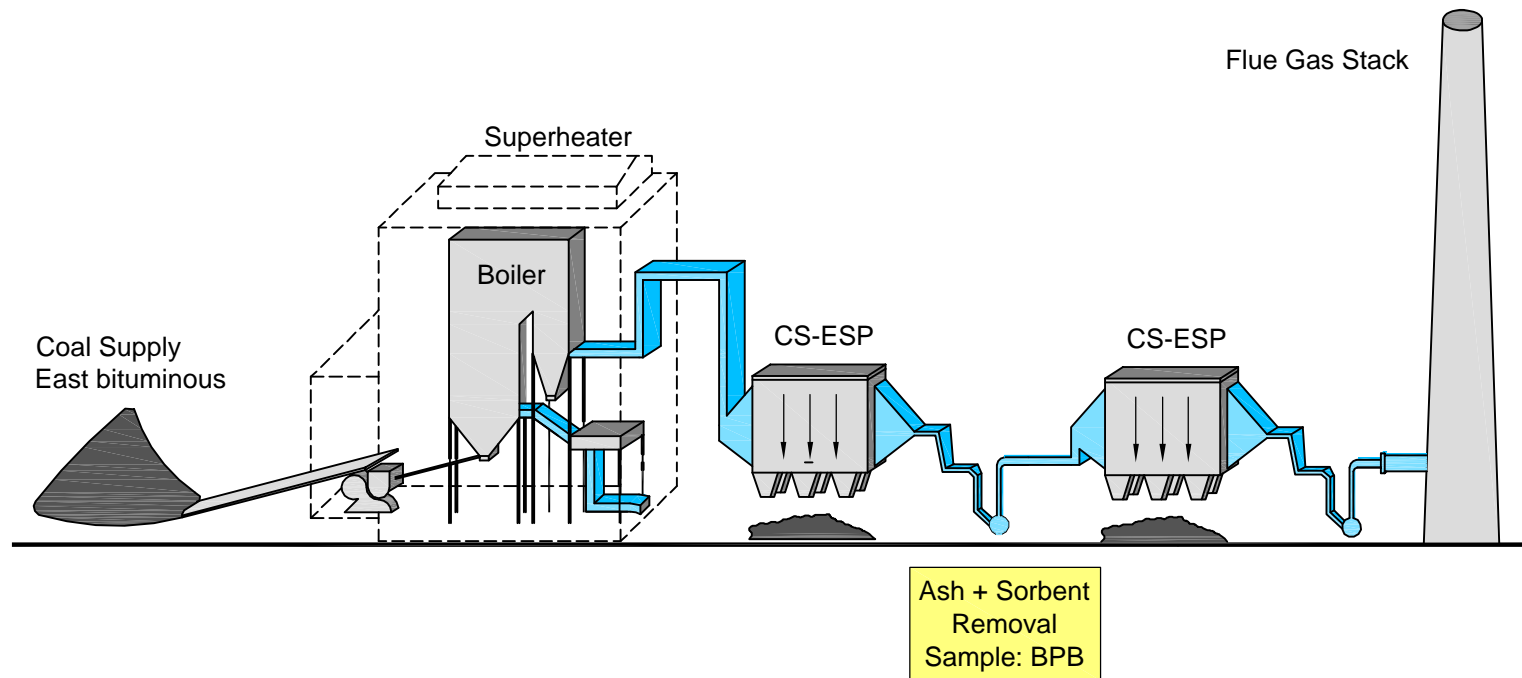
One five gallon bucket of the fly ash material (CaFA) and one five gallon bucket of washed FGD gypsum (CaAW) were collected by plant personnel November 6, 2008.

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 FGD system uses wet-limestone as a sorbent for SO₂ control. A dry handling system is used to collect the fly ash from the ESPs.

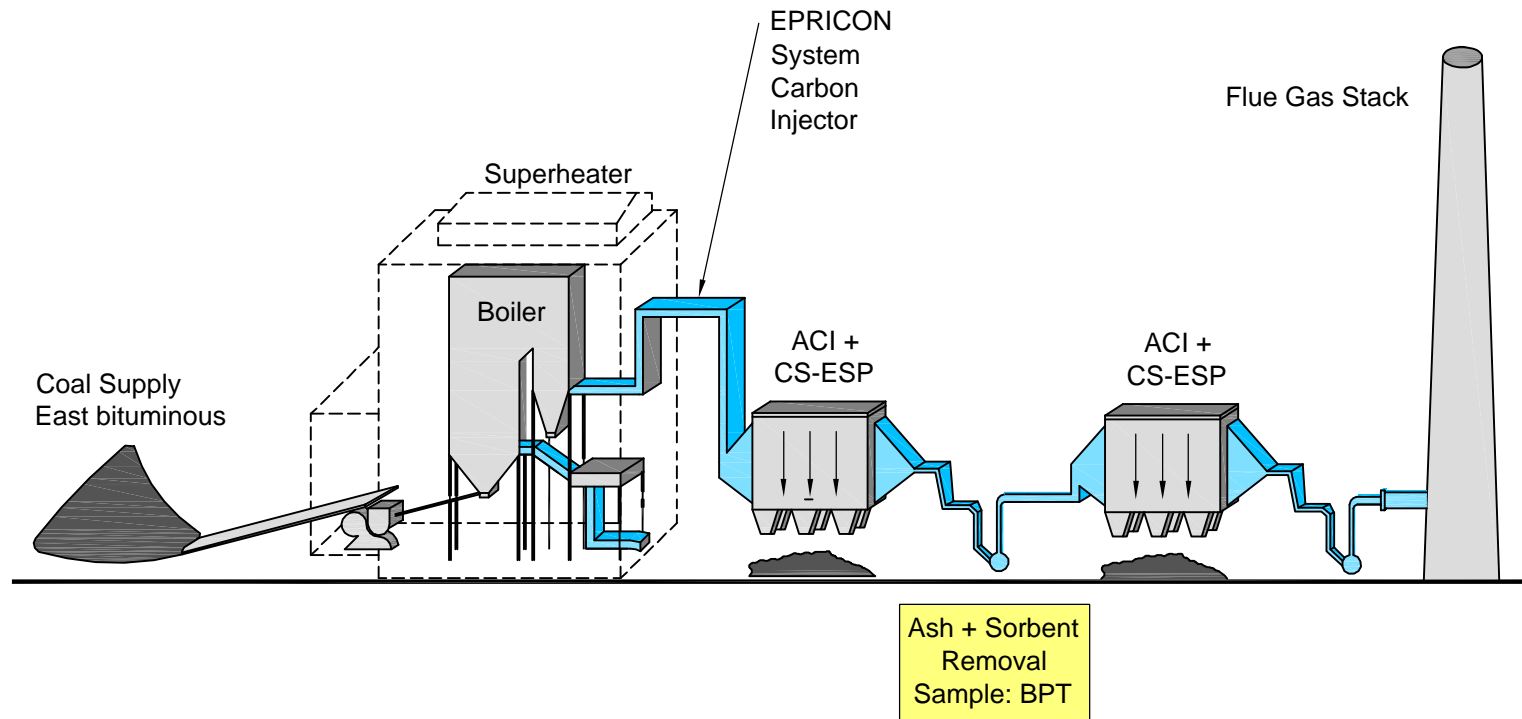
One five gallon bucket each of fly ash (DaFA), washed gypsum (DaAW), and FGD waste water treatment plant filter cake (DaFC) were collected by plant personnel. Samples were received by ARCADIS on 12/12/2008.

Facility: Brayton Point



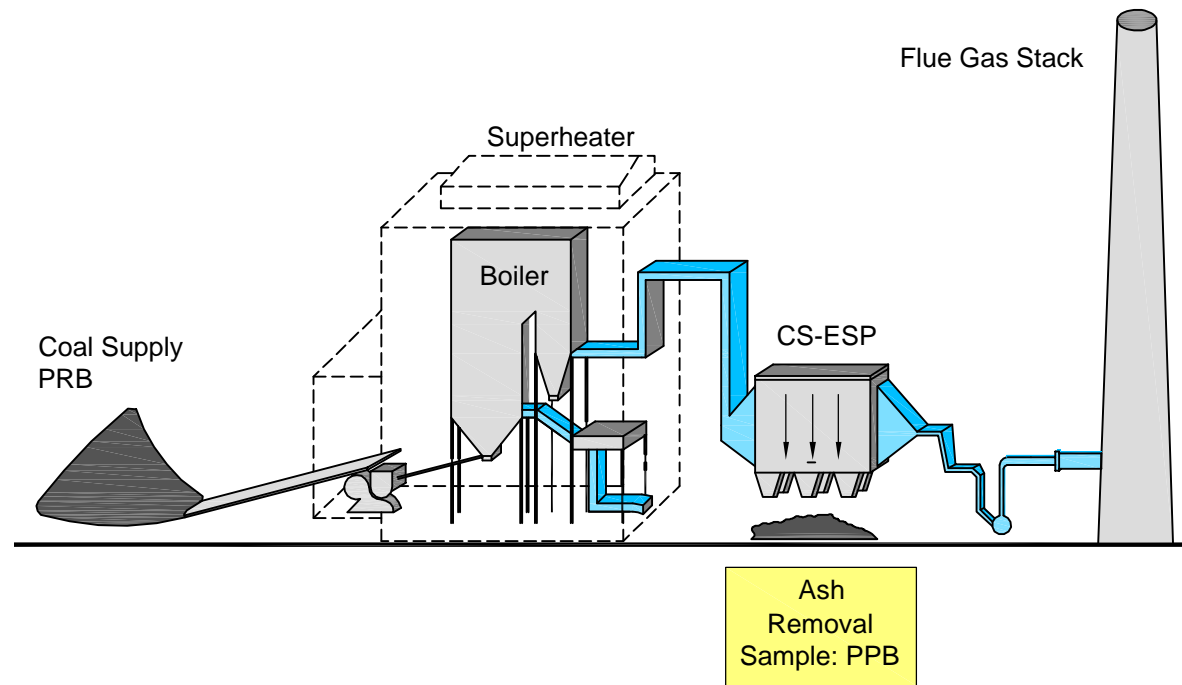
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Brayton Point with ACI



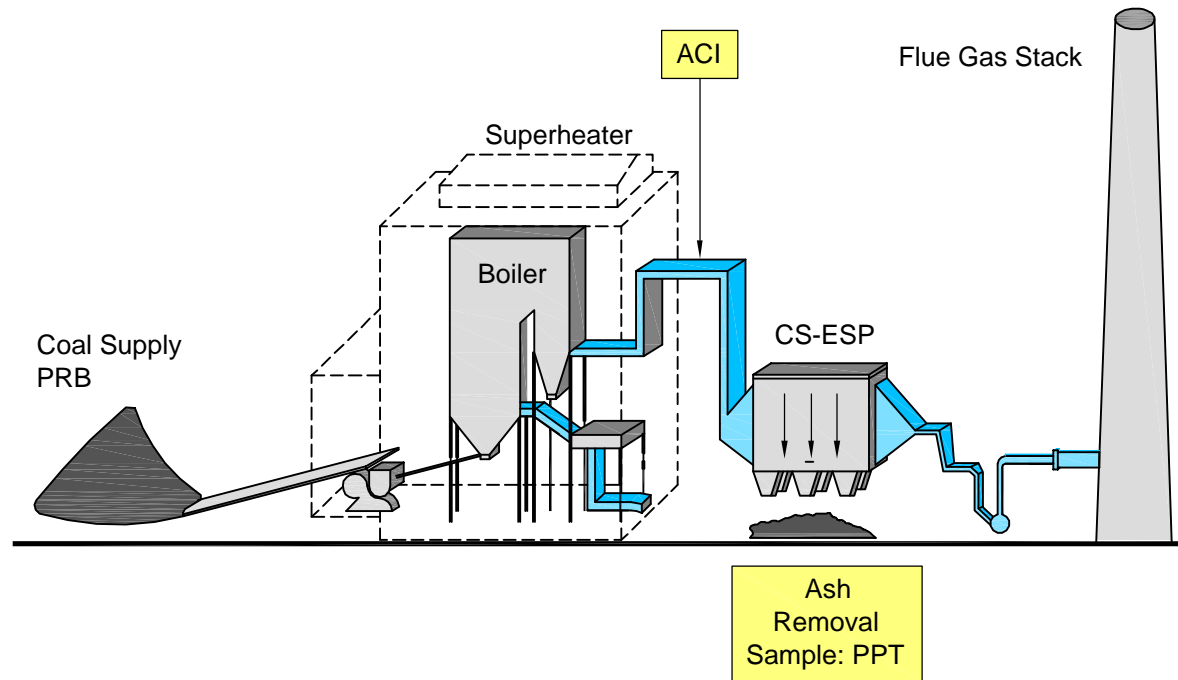
ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Pleasant Prairie



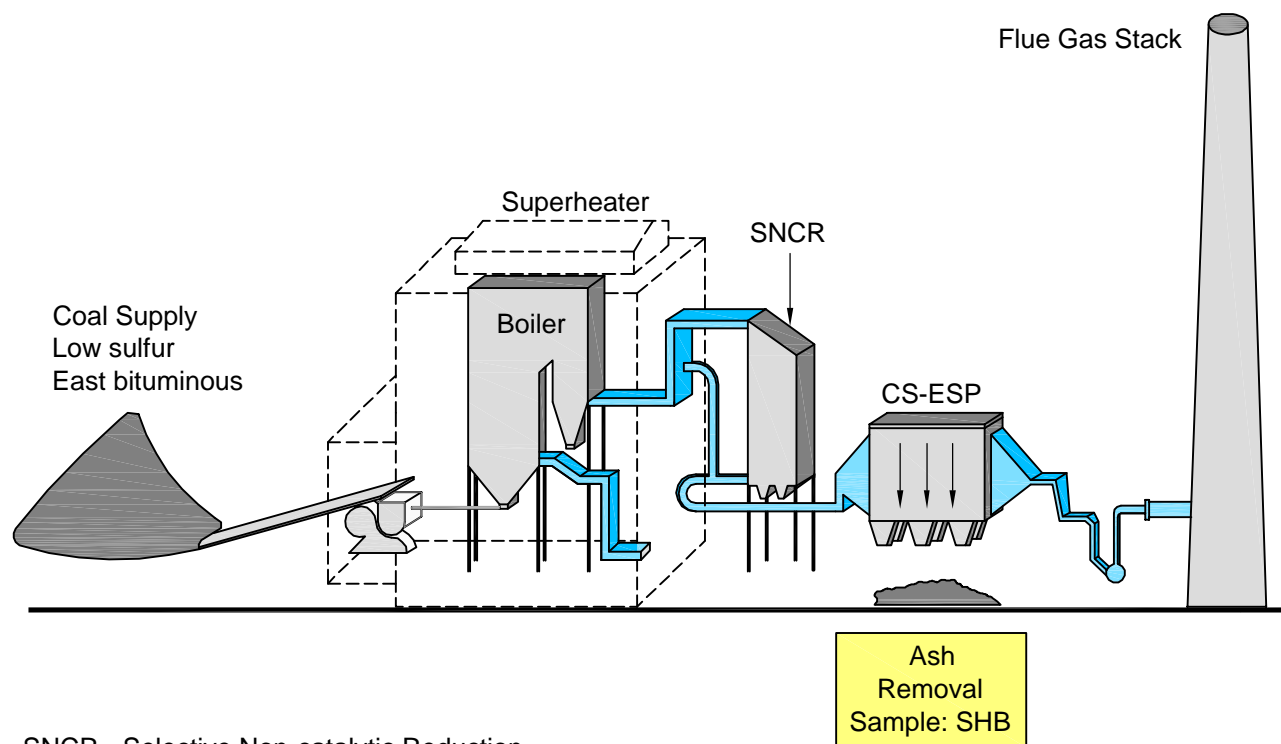
PRB - Powder River Basin
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Pleasant Prairie with ACI



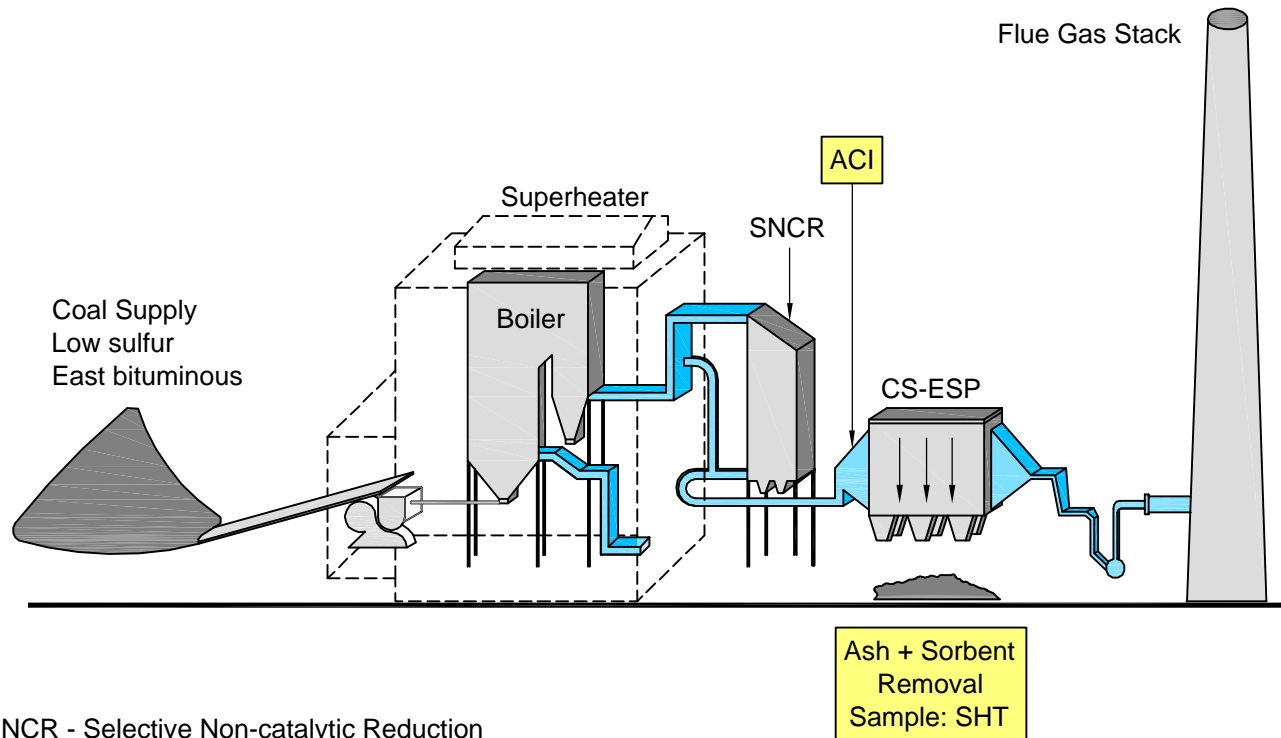
ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Salem Harbor



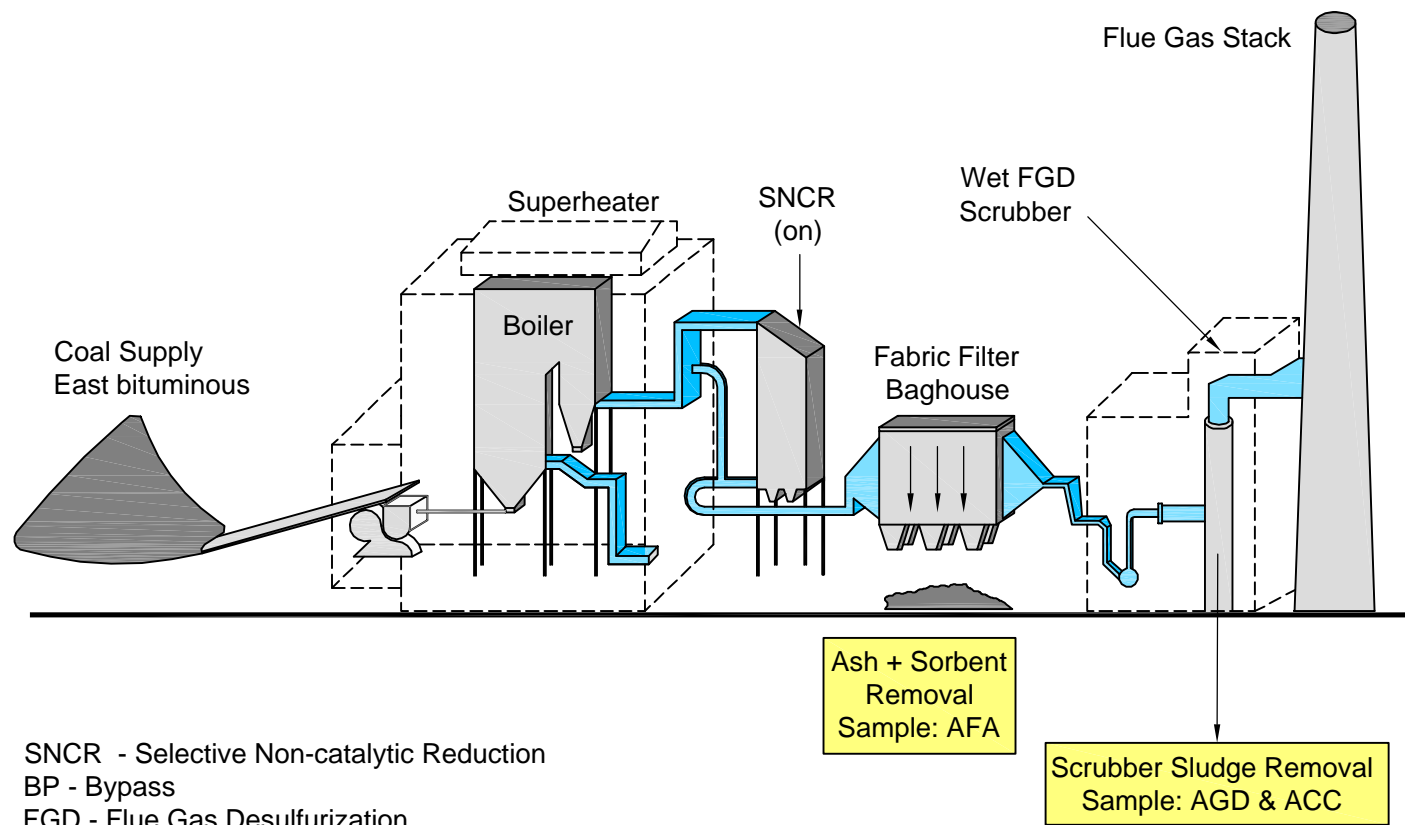
SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Salem Harbor with ACI

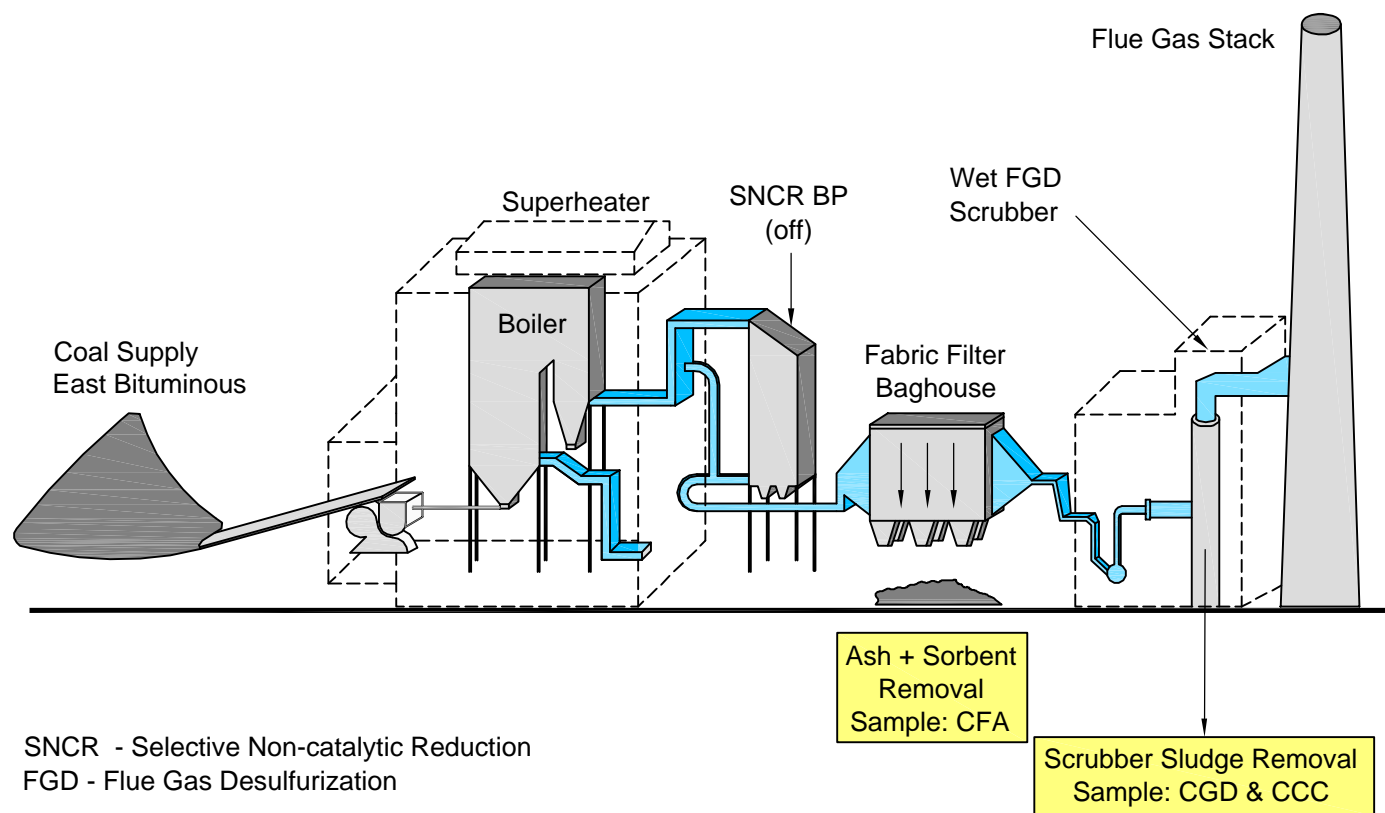


SNCR - Selective Non-catalytic Reduction
ACI - Activated Carbon Injector
CS-ESP - Cold Side-Electrostatic Precipitator

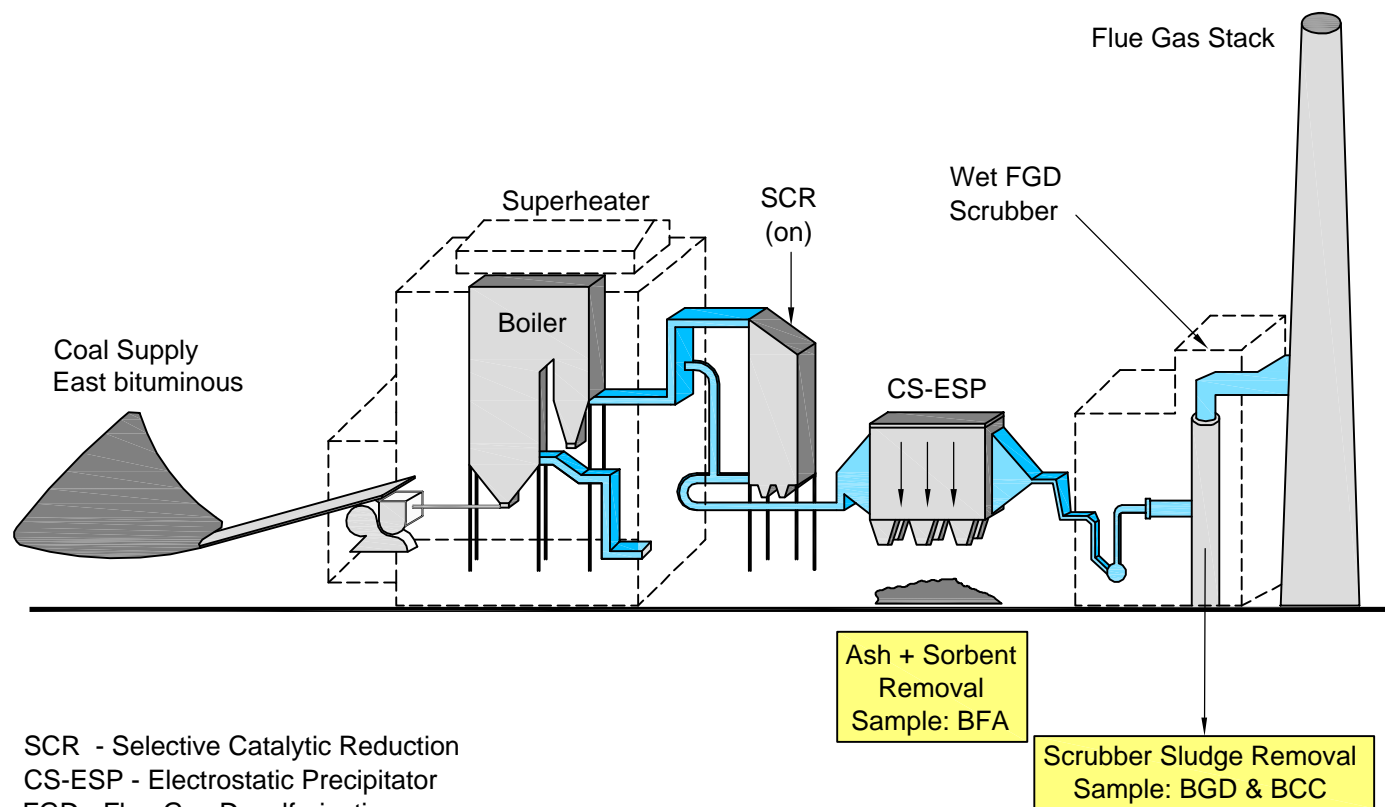
Facility: A



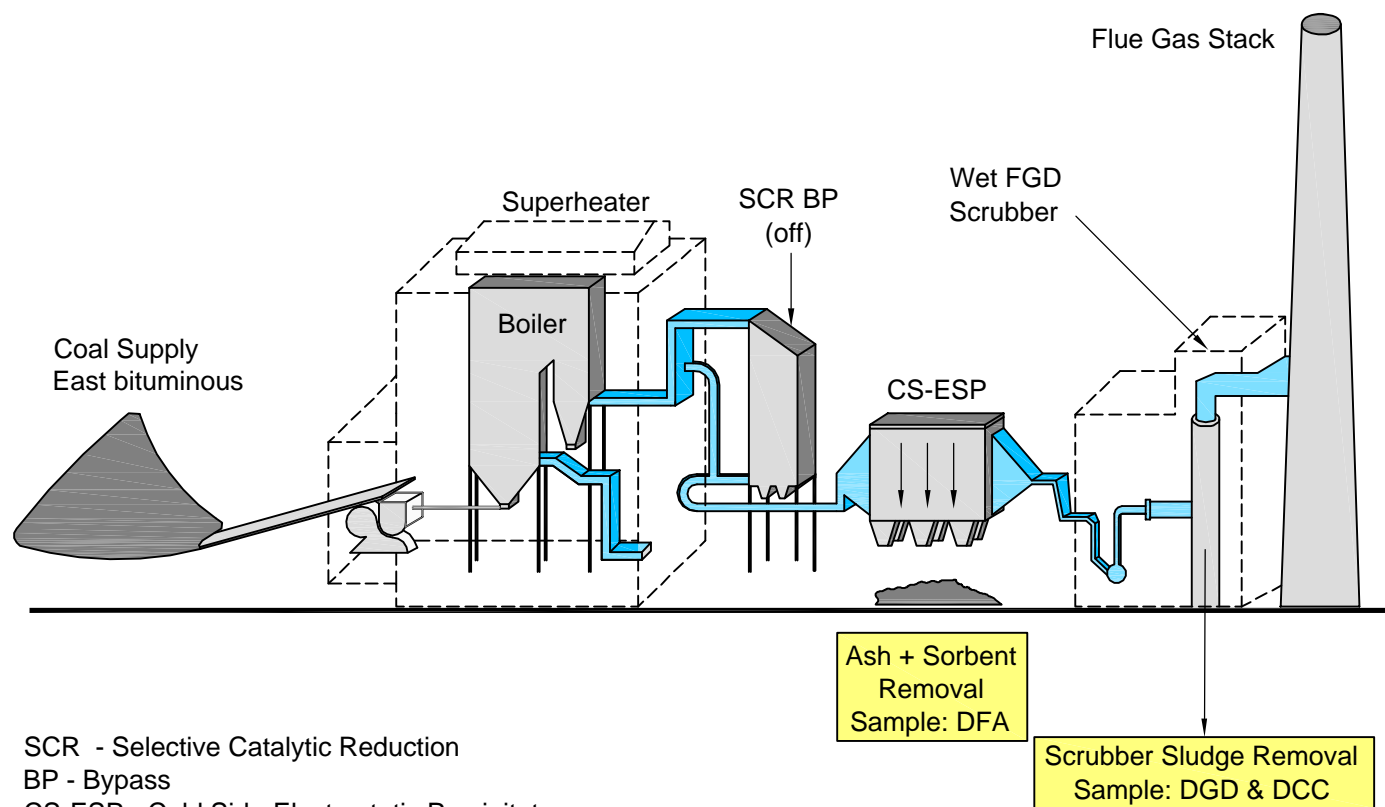
Facility: C



Facility: B SCR on

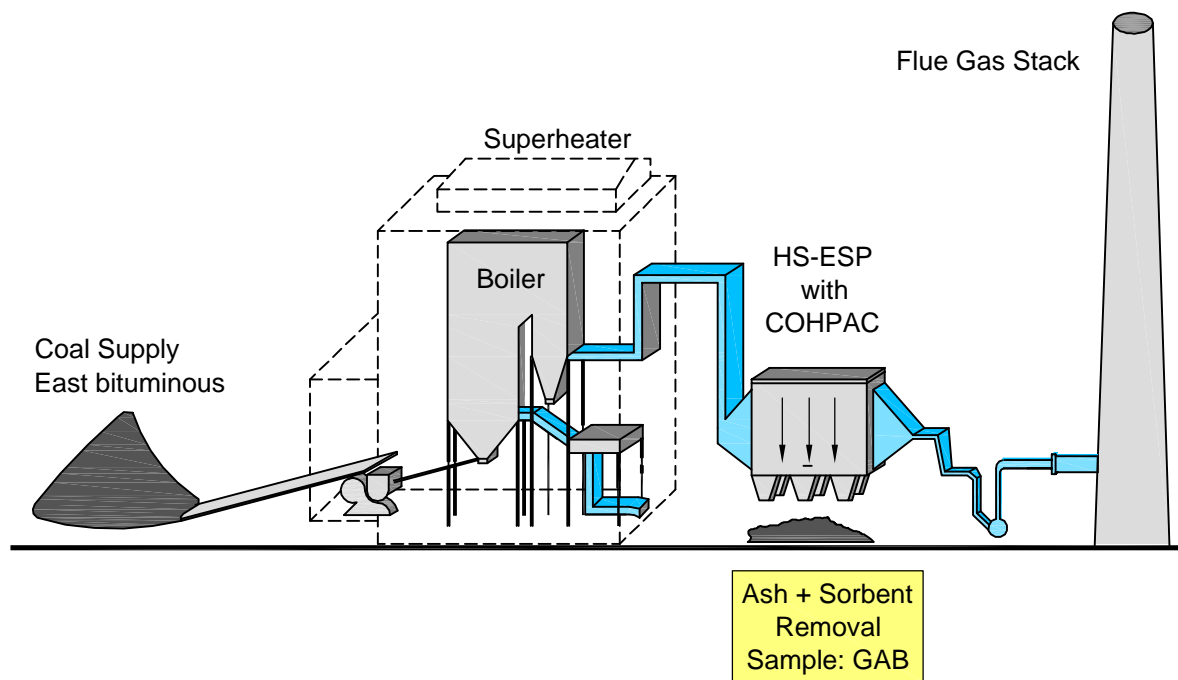


Facility: B SCR off



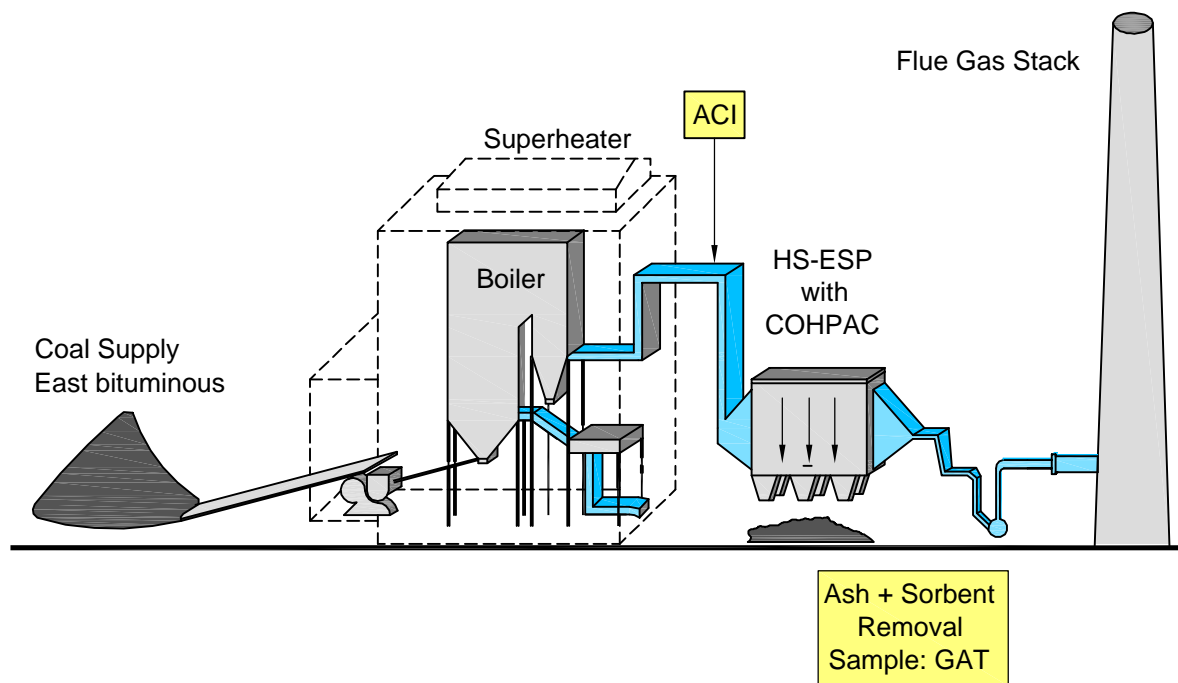
SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: C



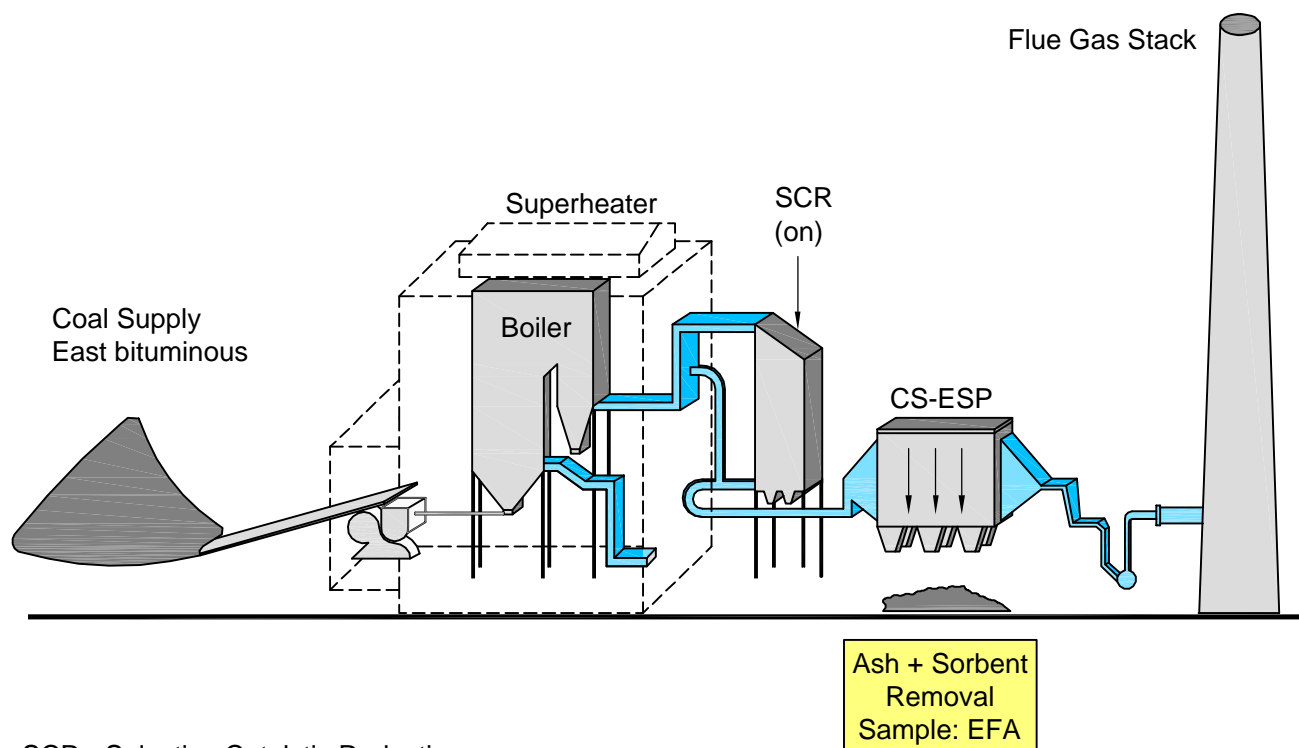
HC-ESP - Hot Side-Electrostatic Precipitator
COHPAC - Compact Hybrid Particulate Collector

Facility: C with ACI



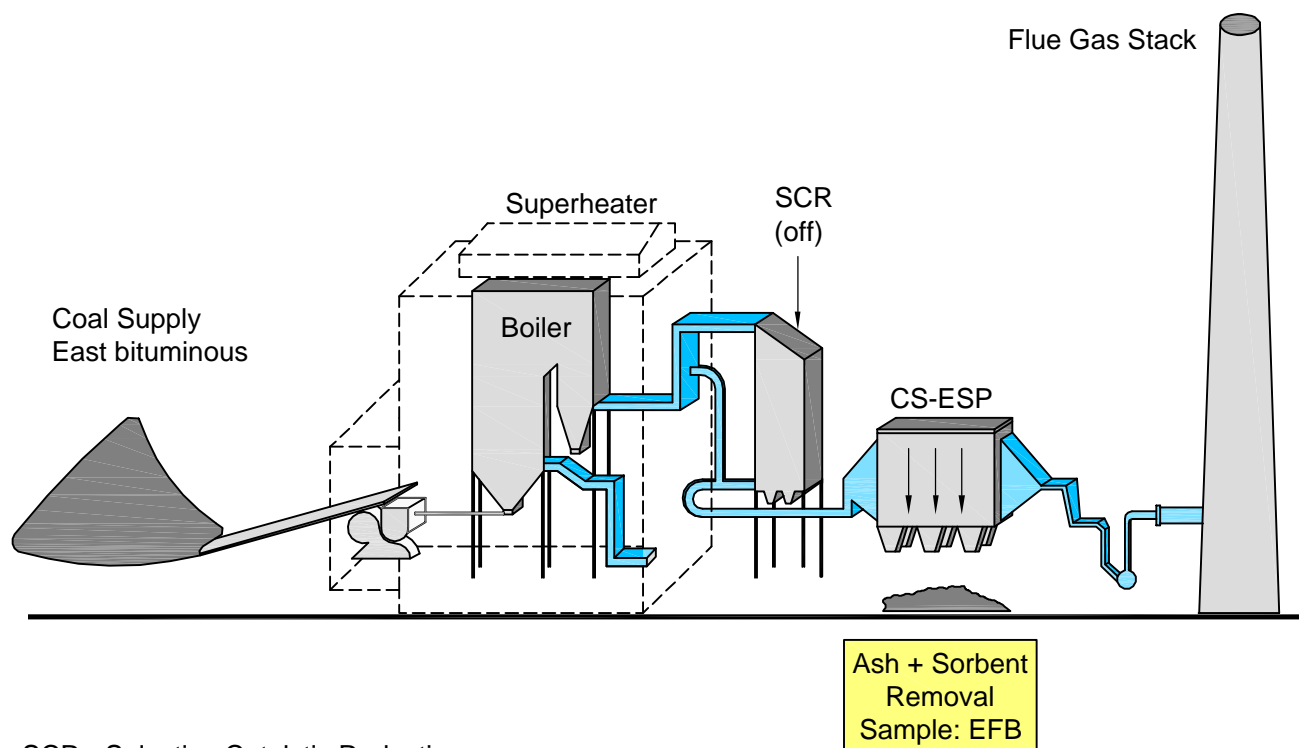
ACI - Activated carbon Injector
HS-ESP - Hot Side-Electrostatic Precipitator
COHPAC - Compact Hybrid Particulate Collector

Facility: E SCR on



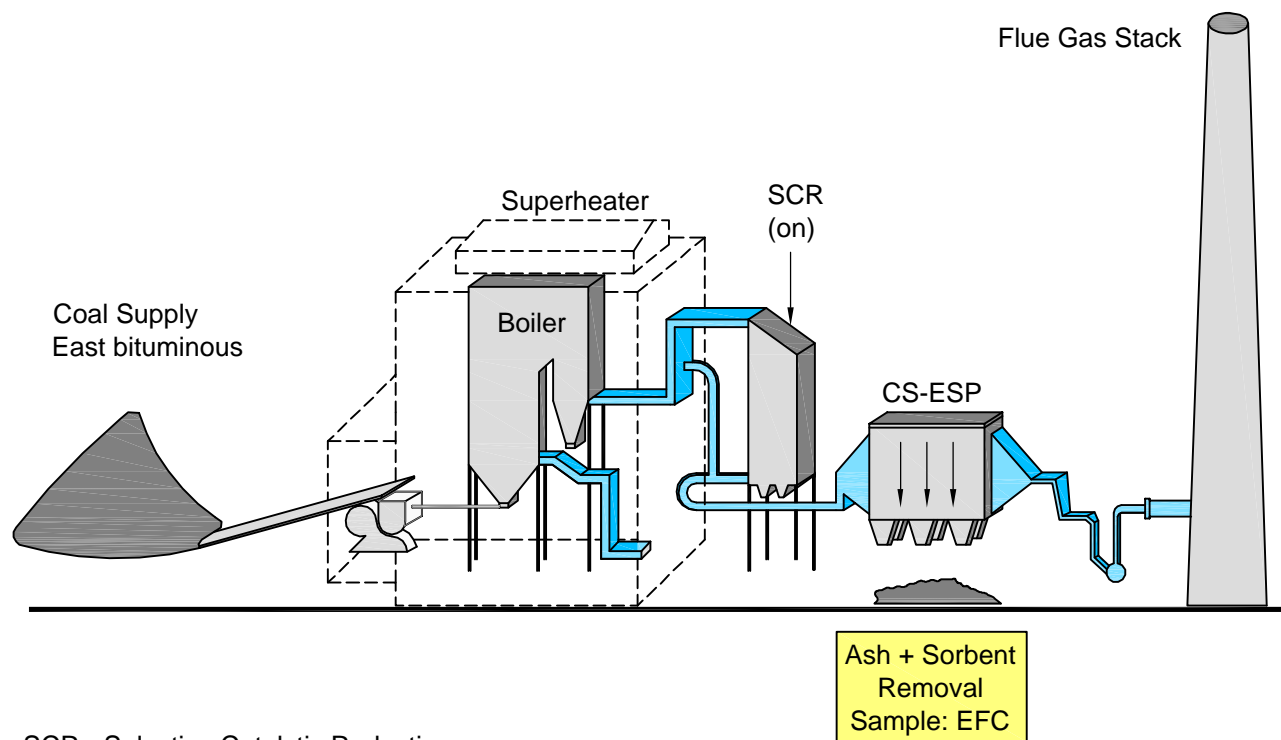
SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

Facility: E SCR off



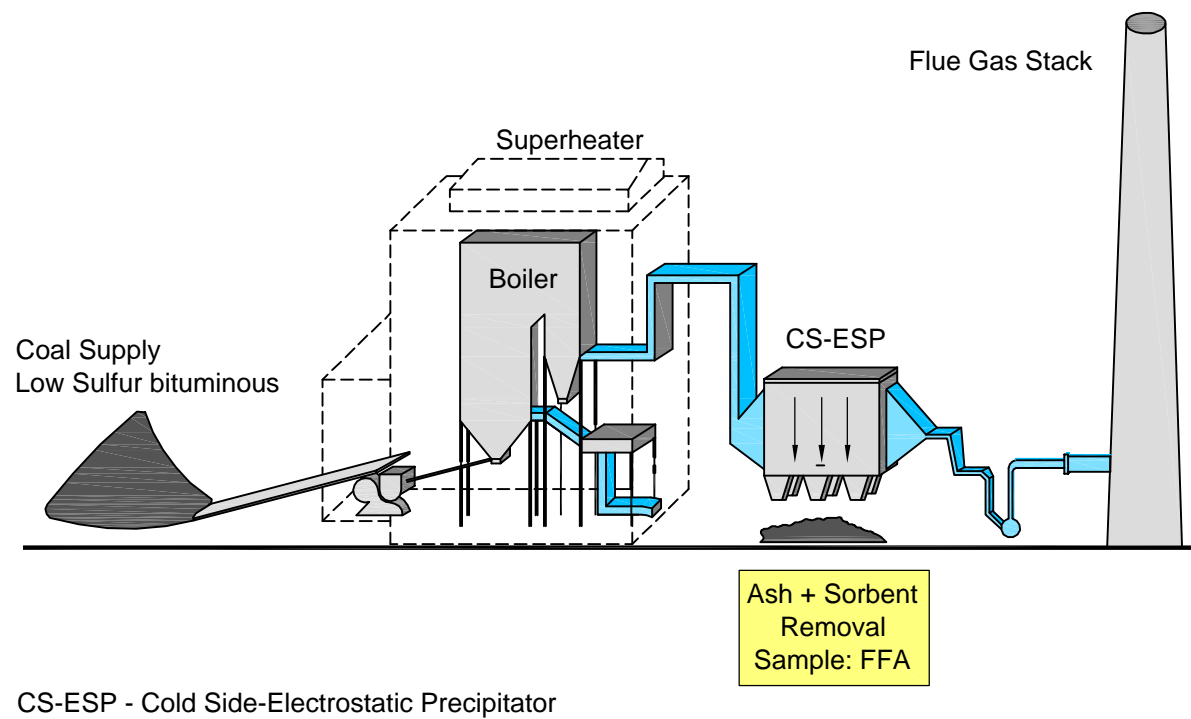
SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

Facility: E SCR on

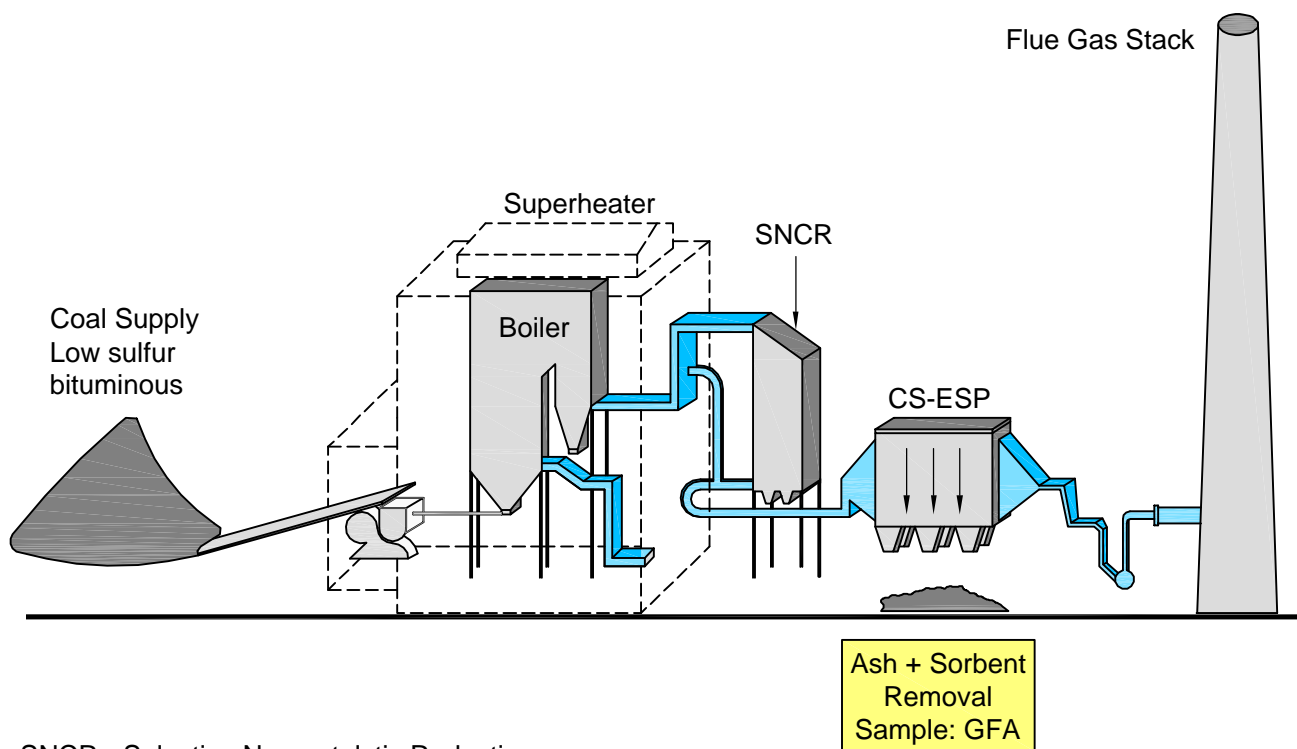


SCR - Selective Catalytic Reduction
CS-ESP - Electrostatic Precipitator

Facility: F

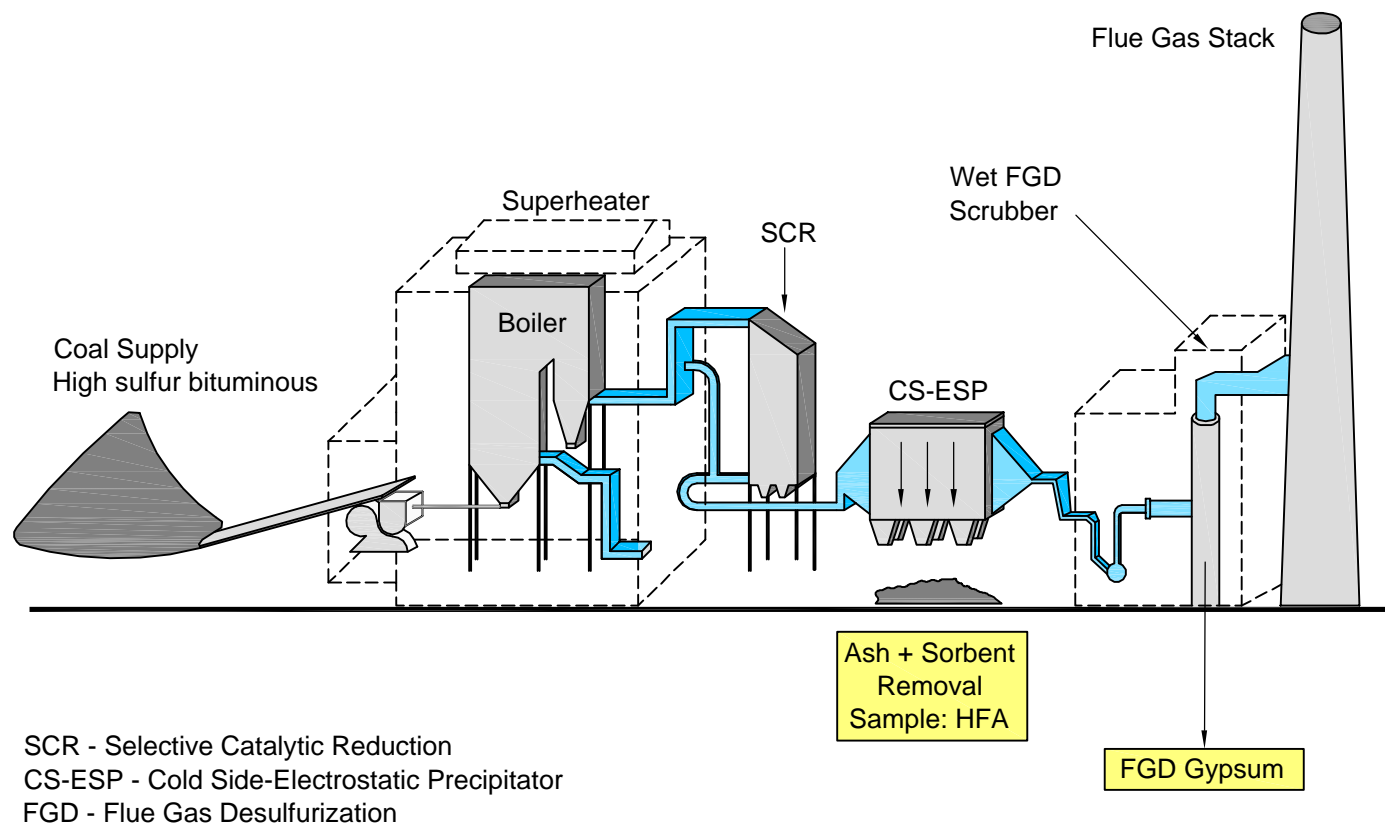


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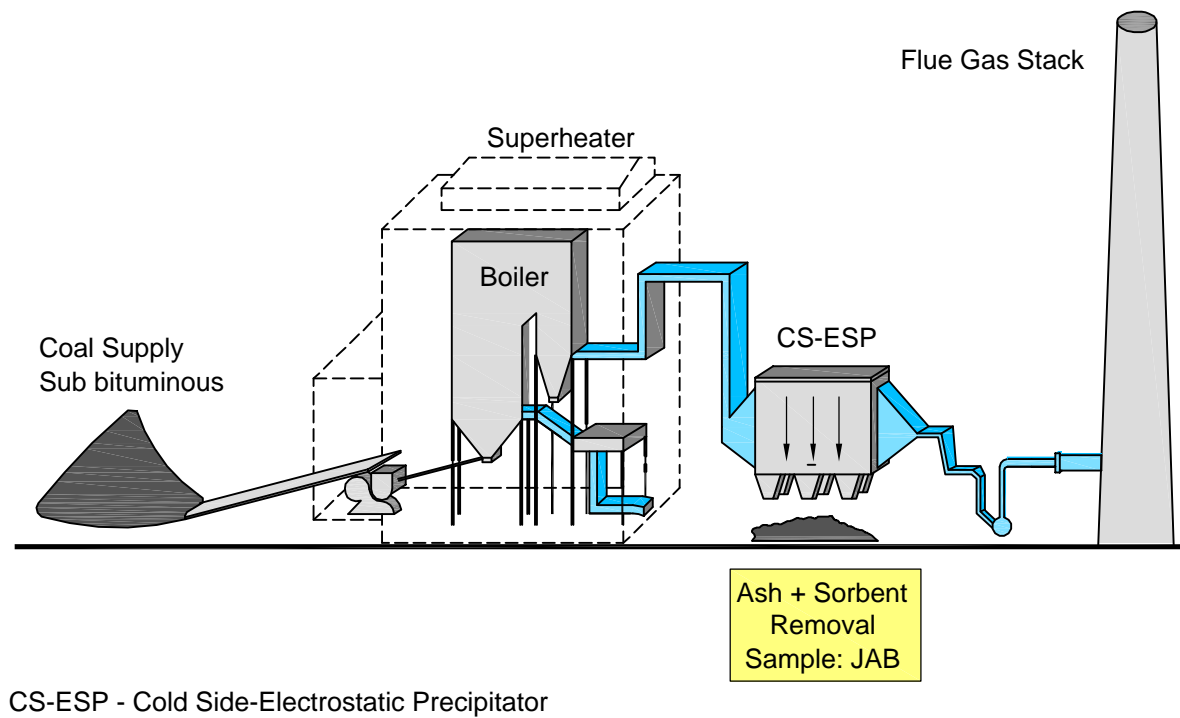


SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator

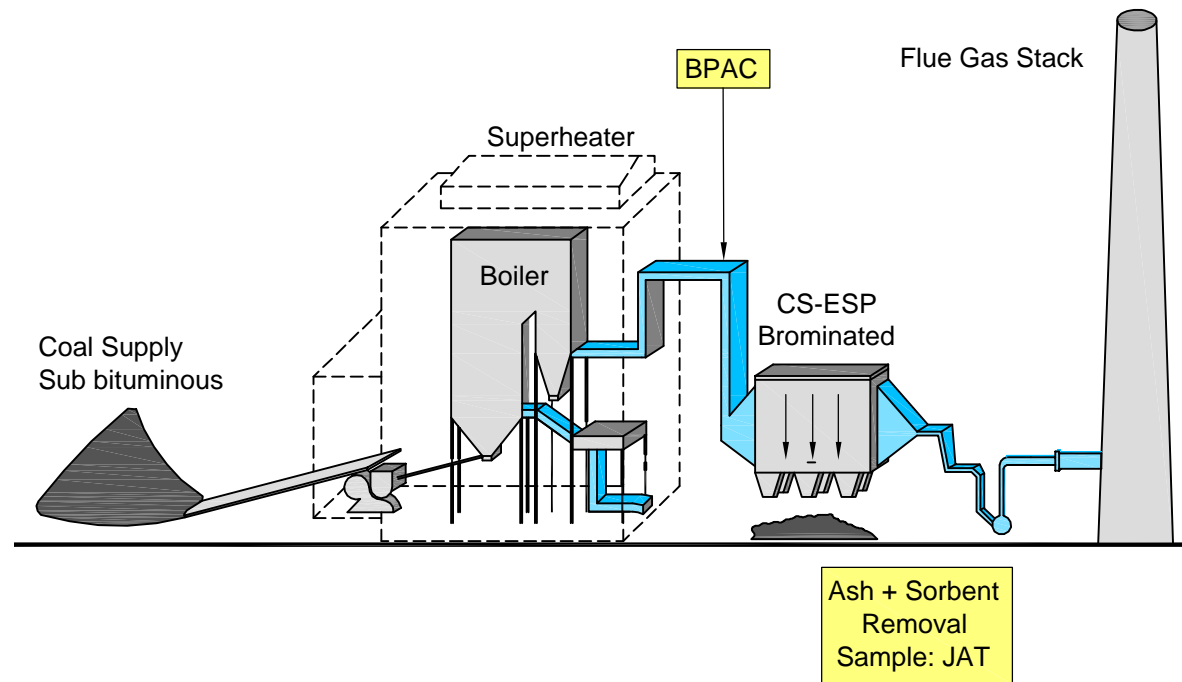
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Facility: J

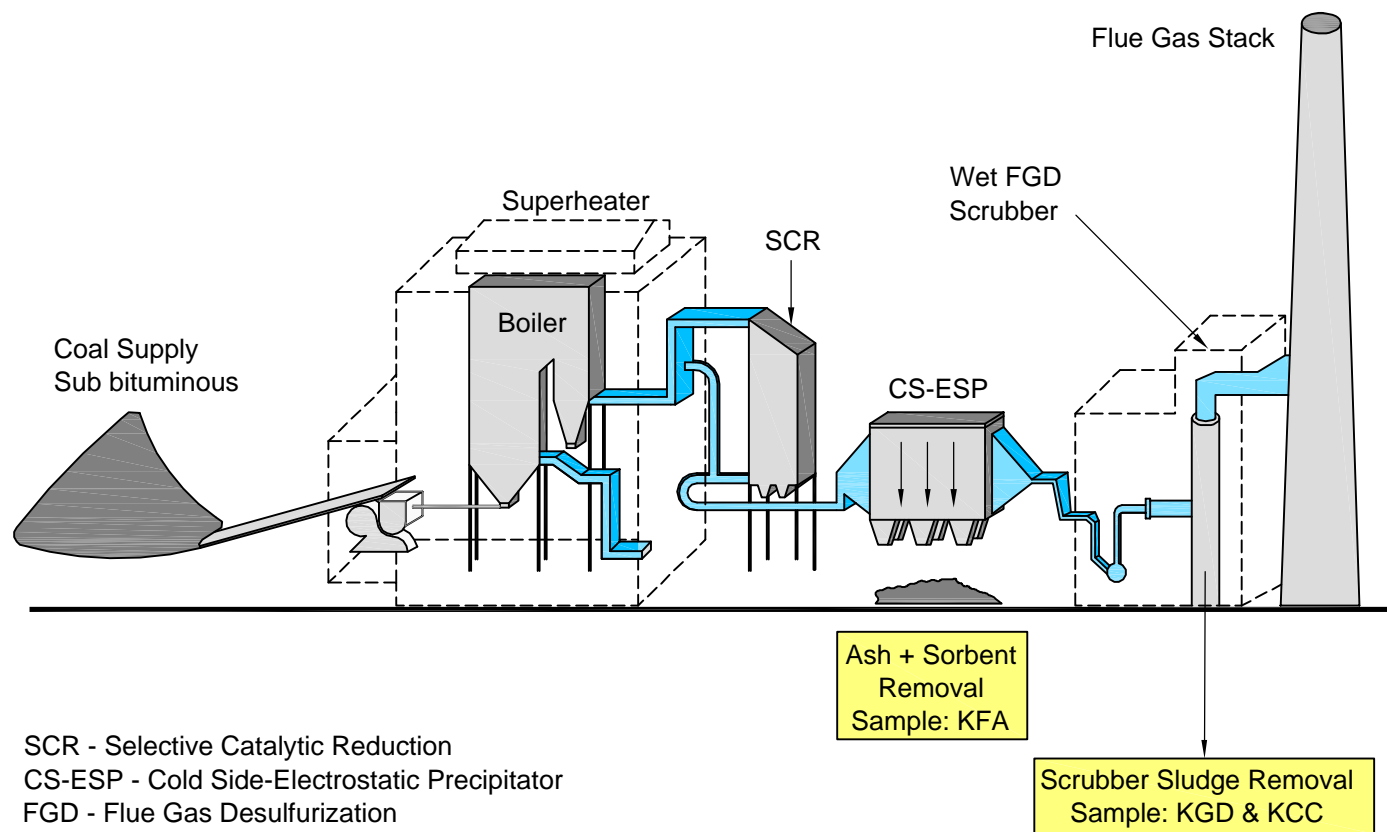


Facility: J with BPAC

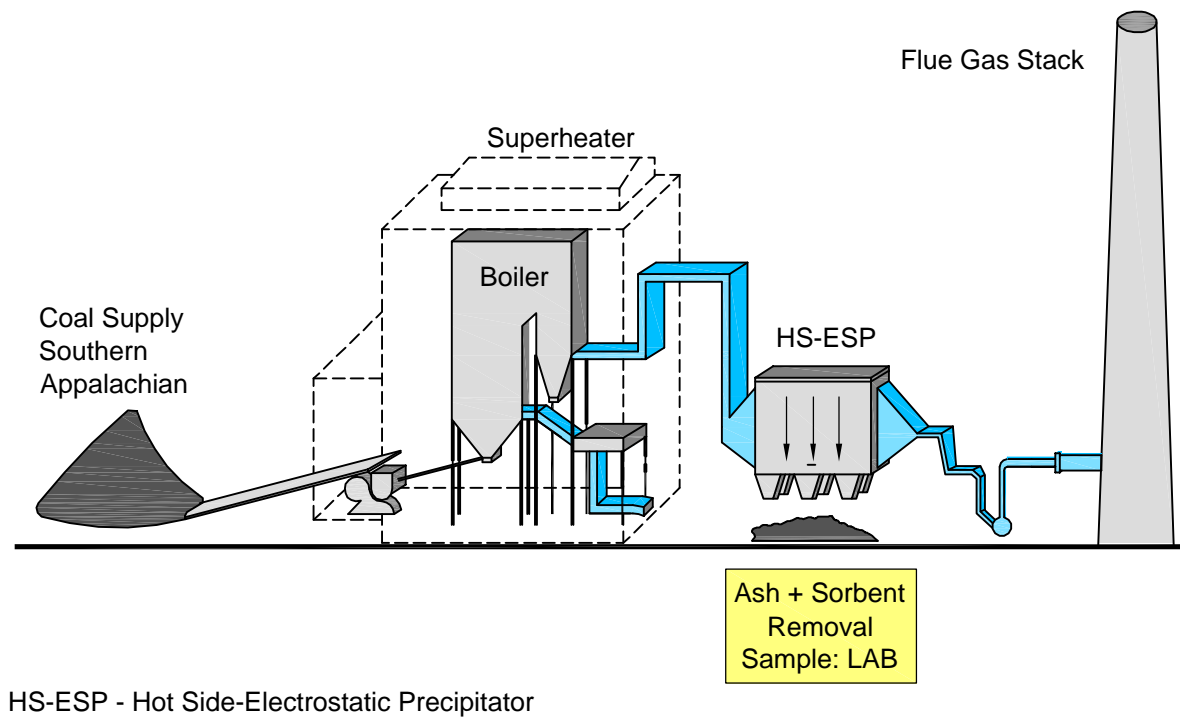


BPAC - Biominated Powder Activated Carbon
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

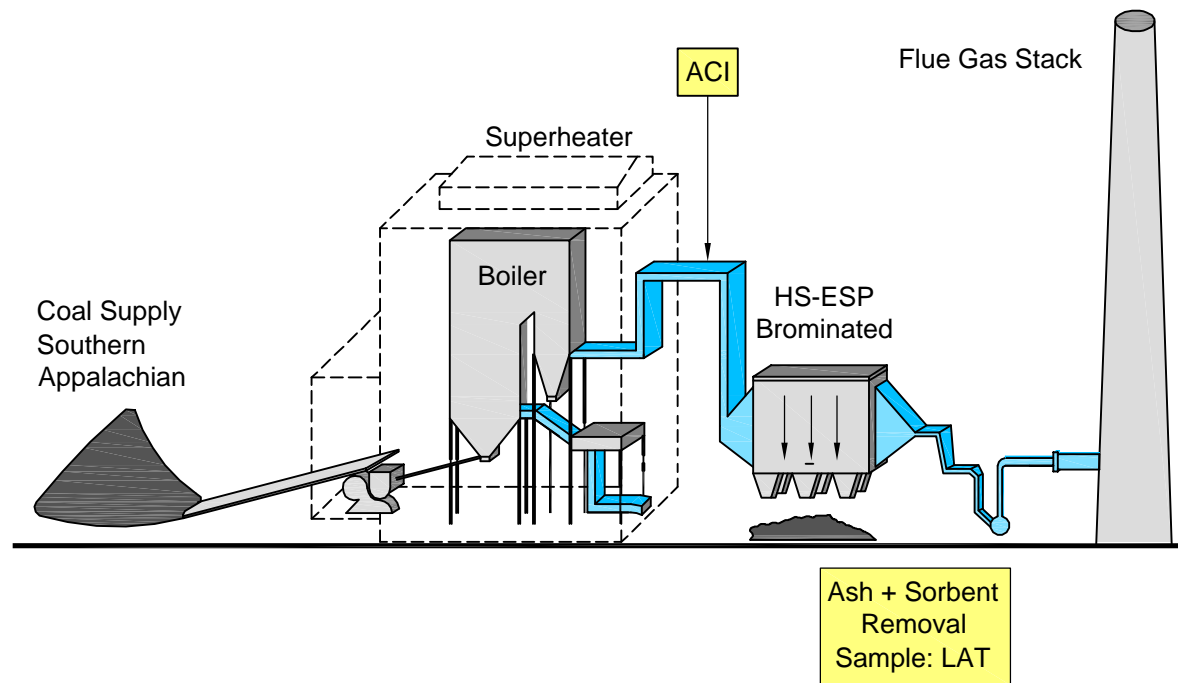
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Facility: L

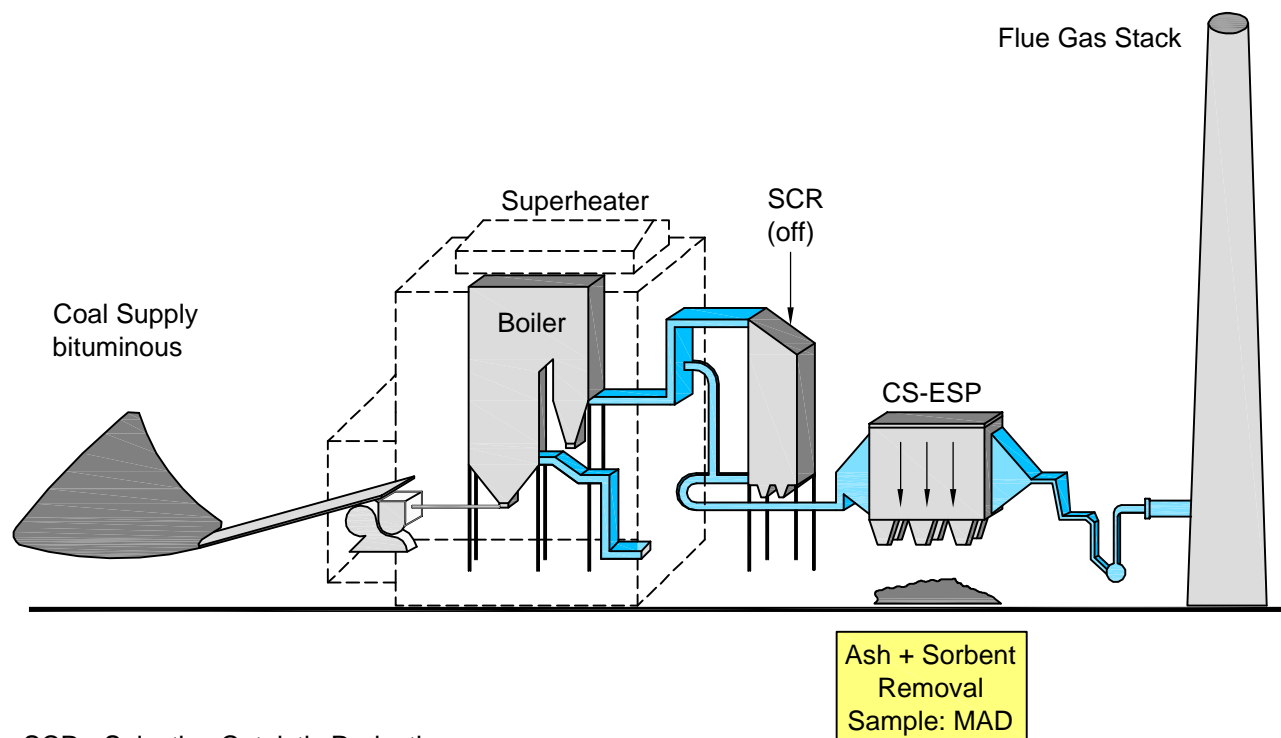


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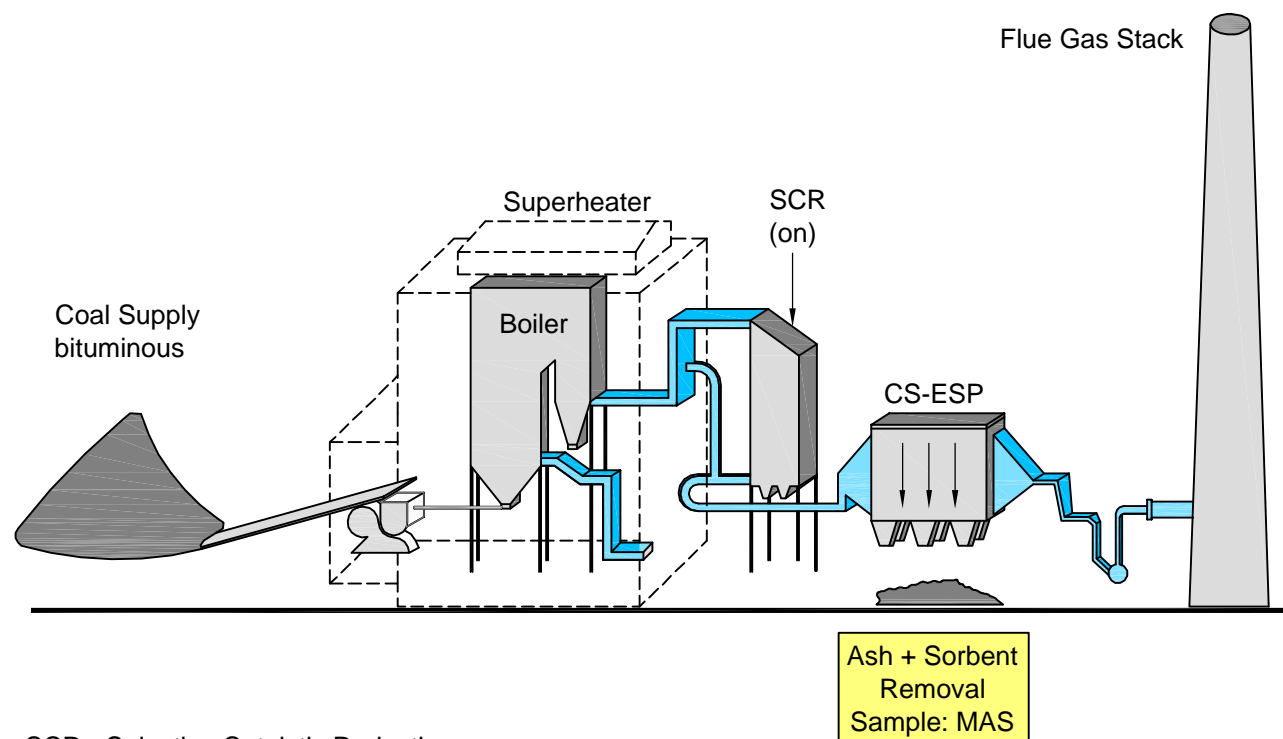
ACI - Activated Carbon Injector
HS-ESP - Hot Side-Electrostatic Precipitator

Facility: M SCR off



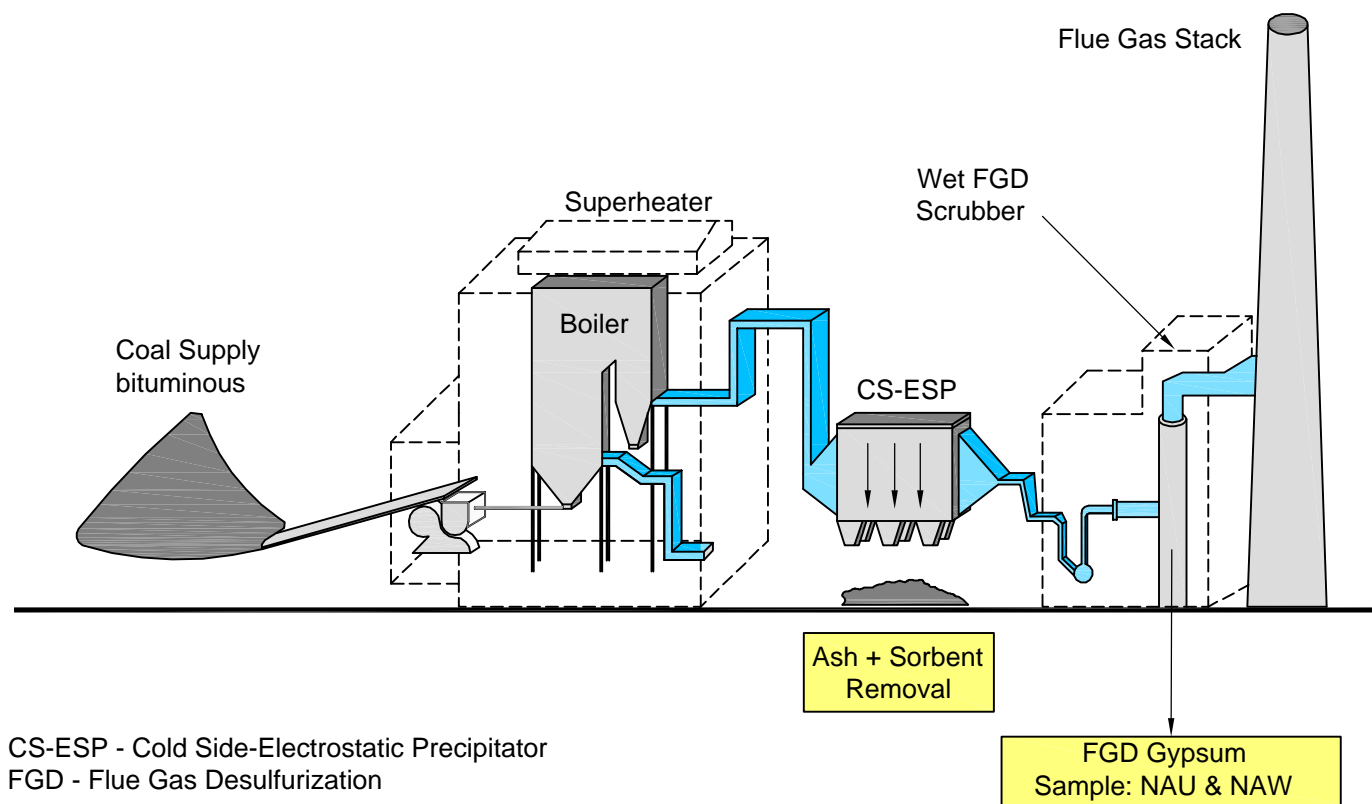
SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: M SCR on

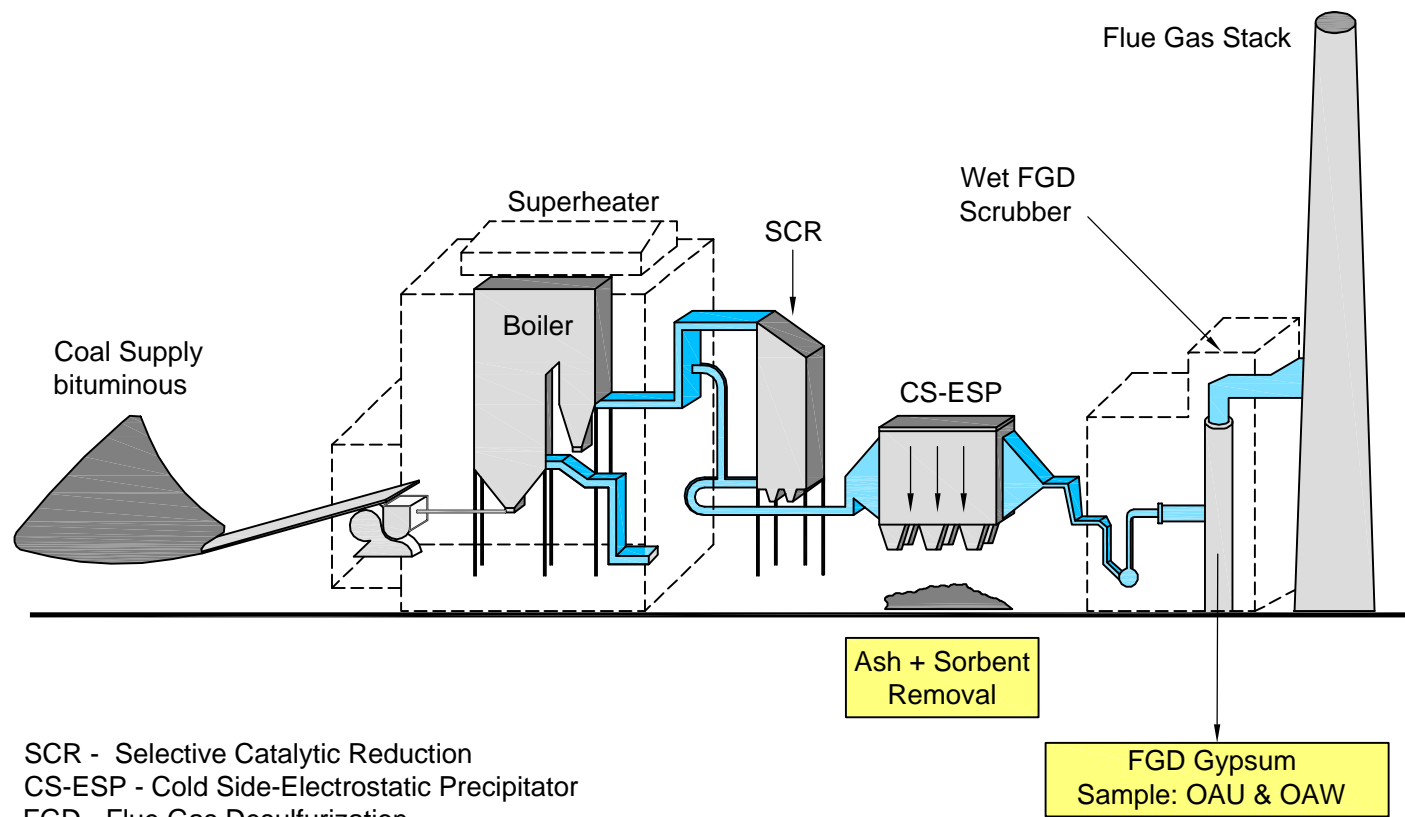


SCR - Selective Catalytic Reduction
BP - Bypass
CS-ESP - Cold Side-Electrostatic Precipitator

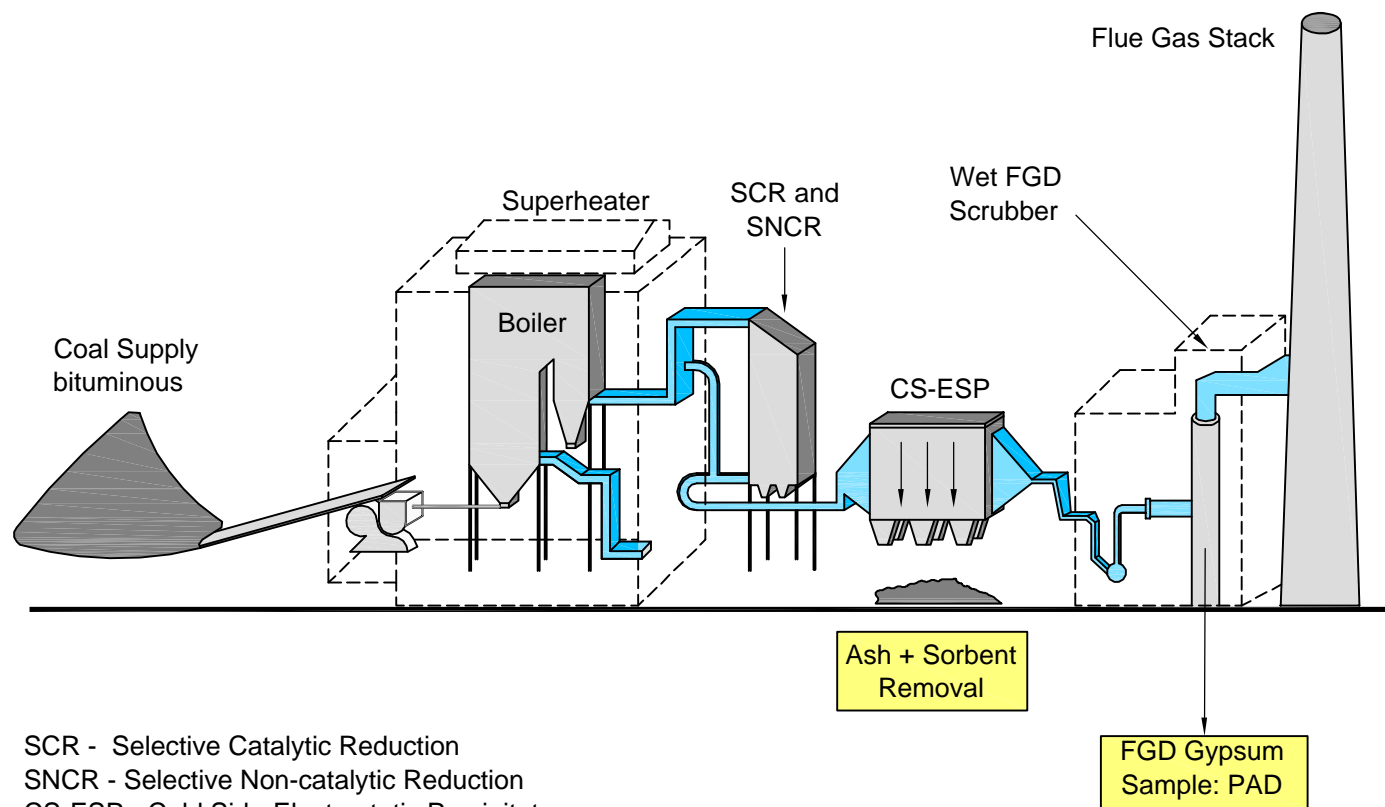
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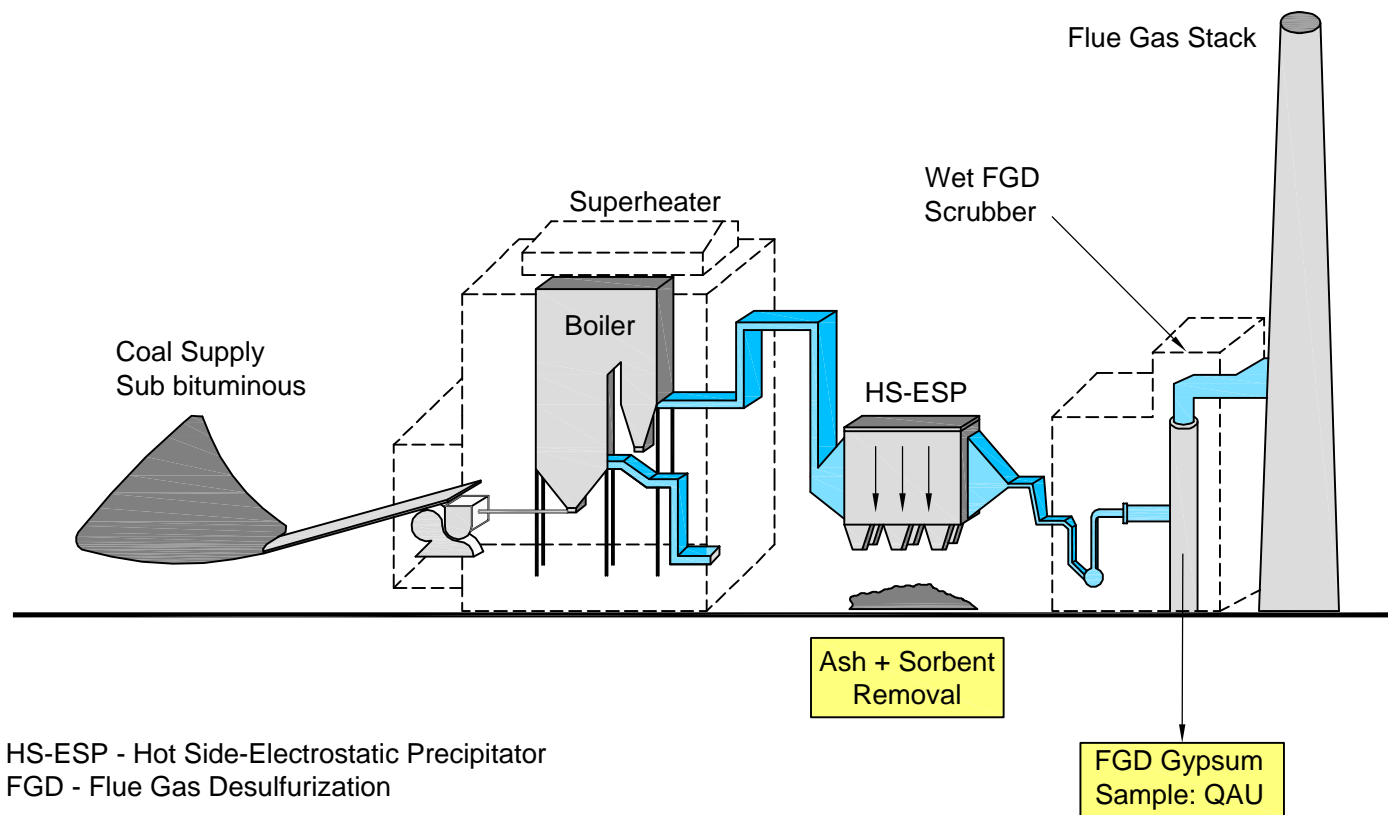


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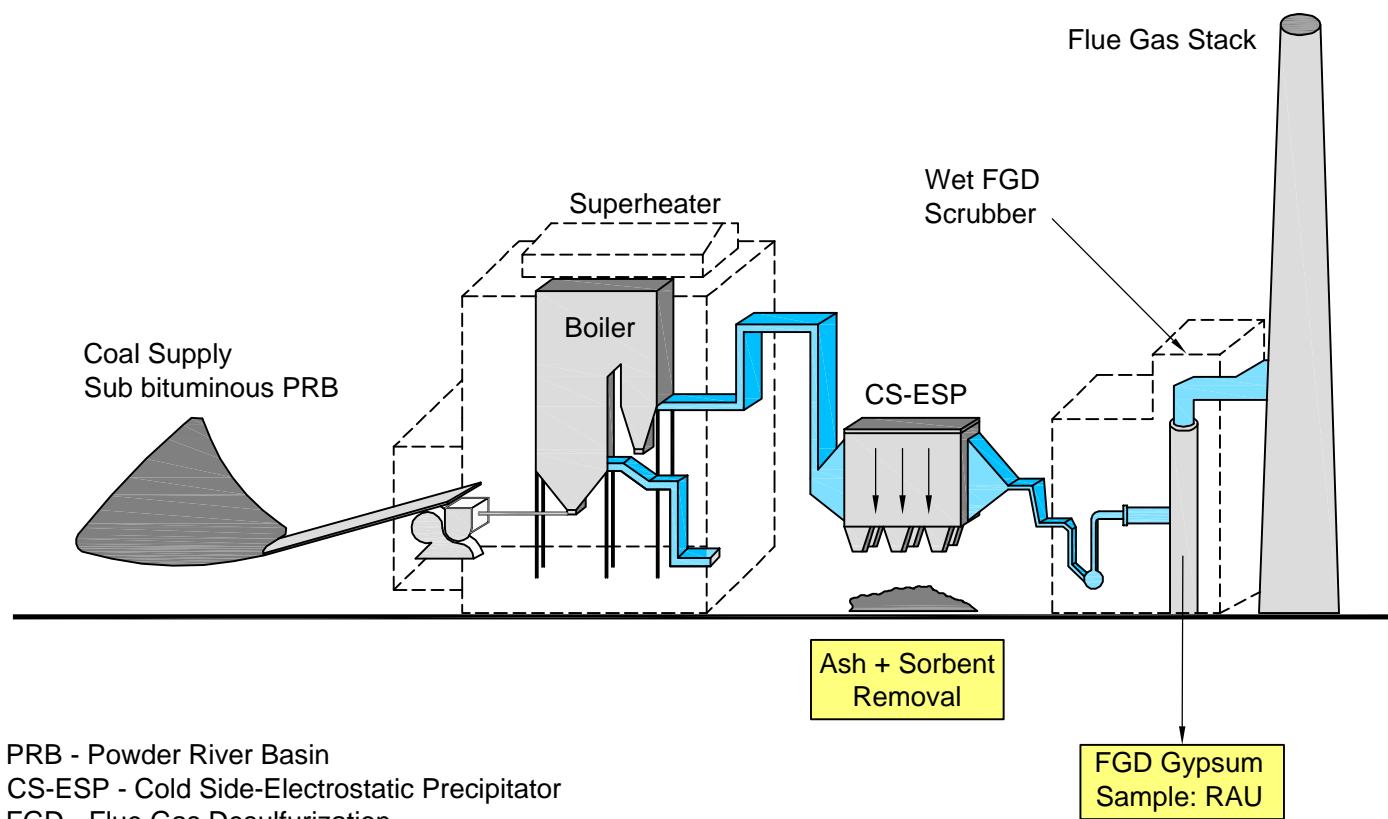


SCR - Selective Catalytic Reduction
SNCR - Selective Non-catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

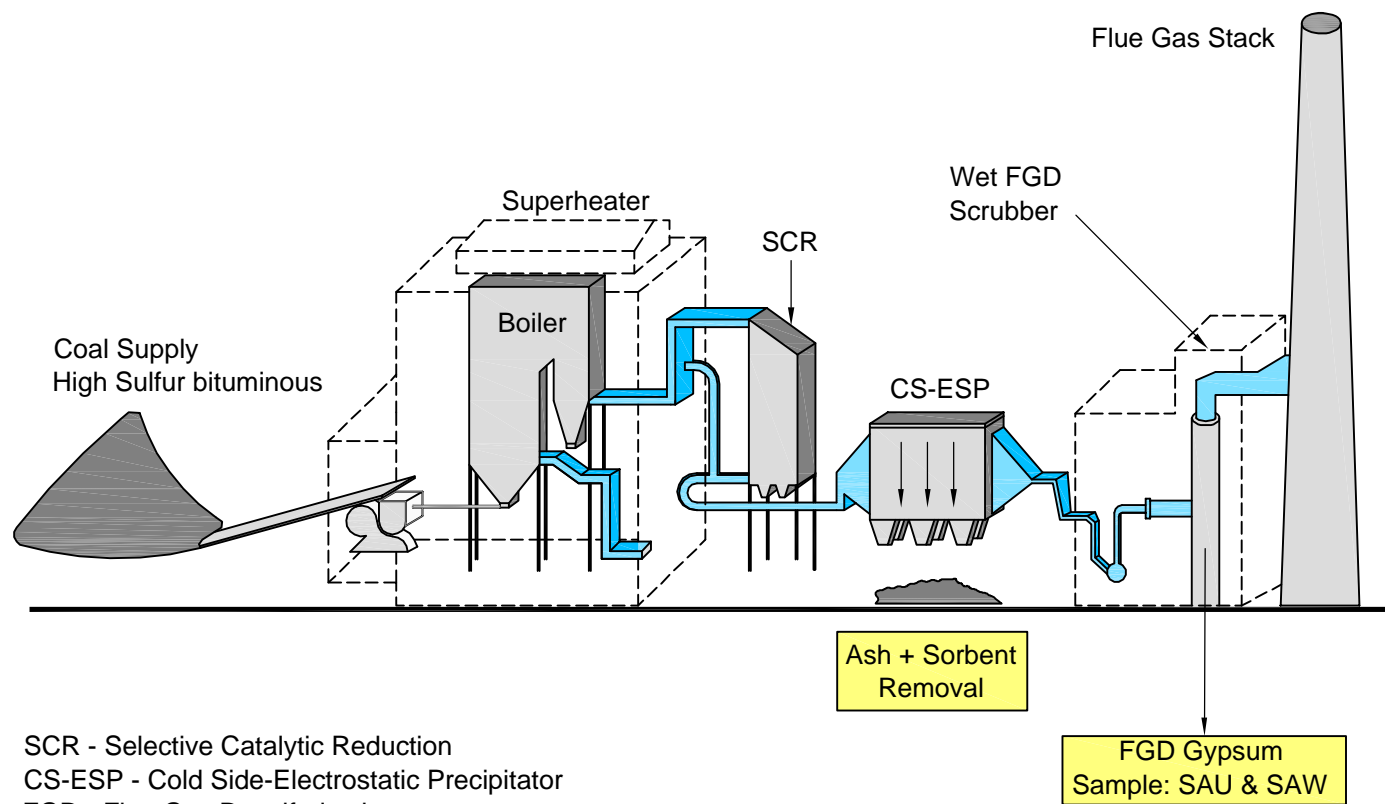
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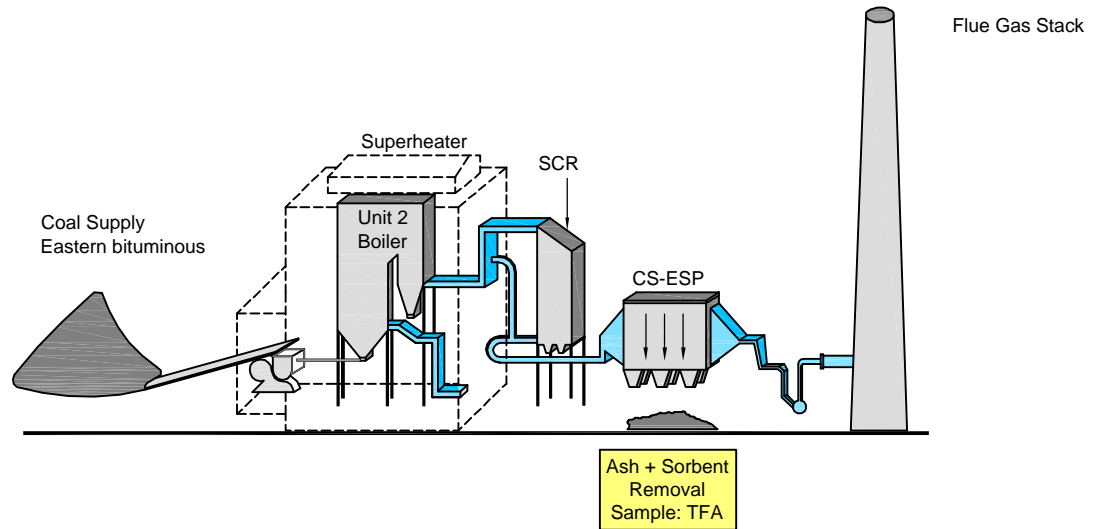
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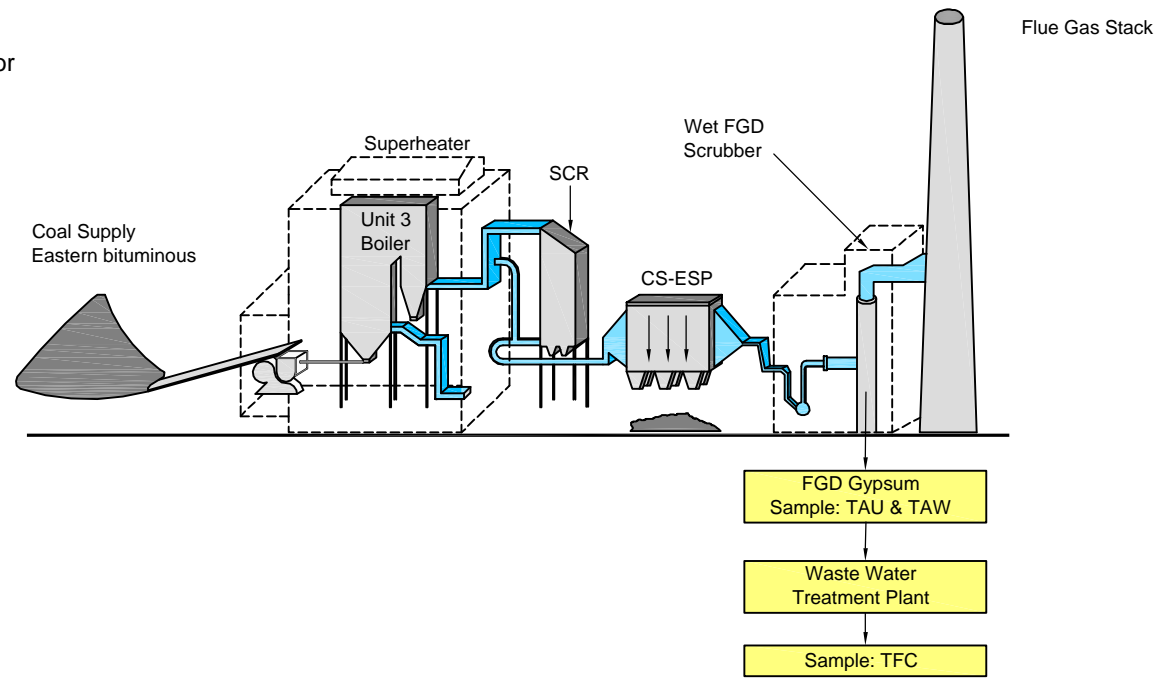
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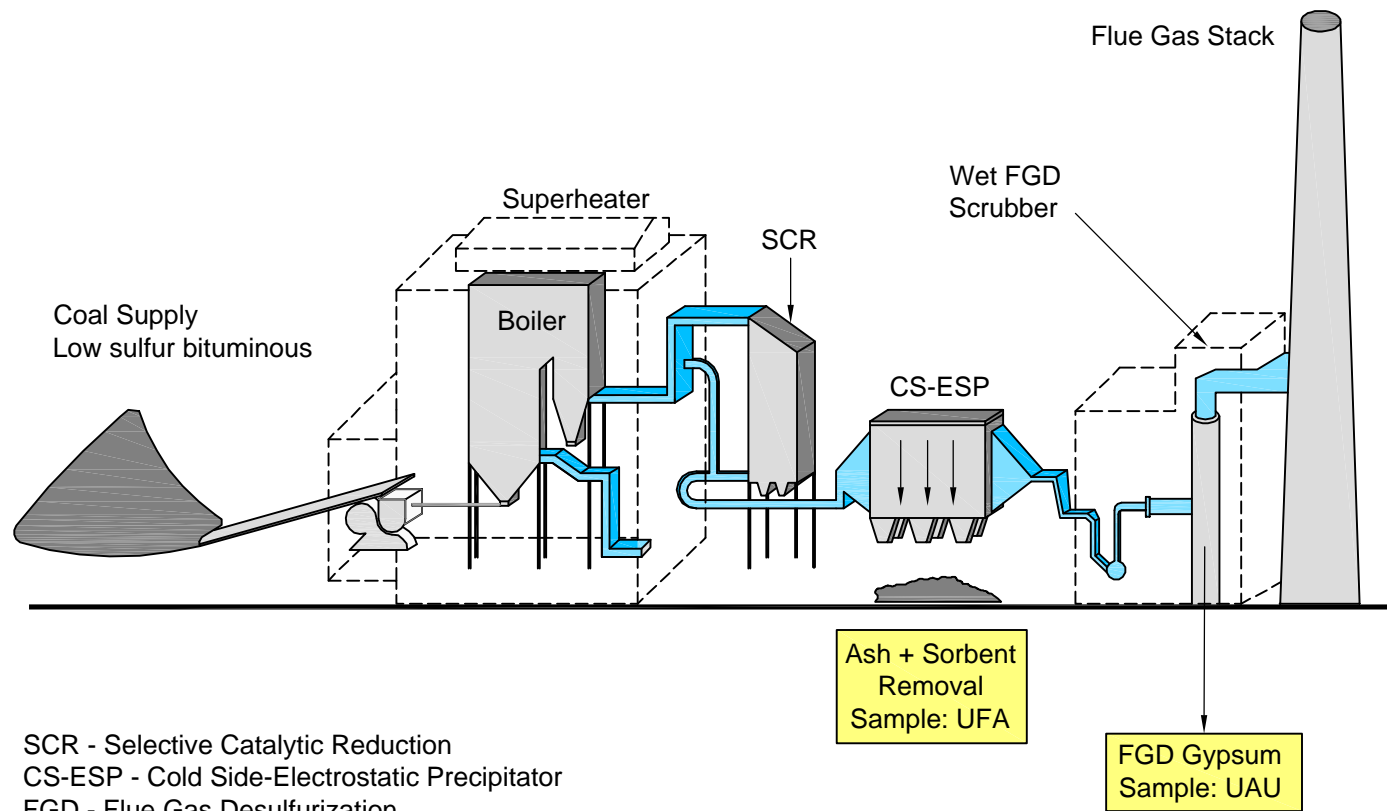
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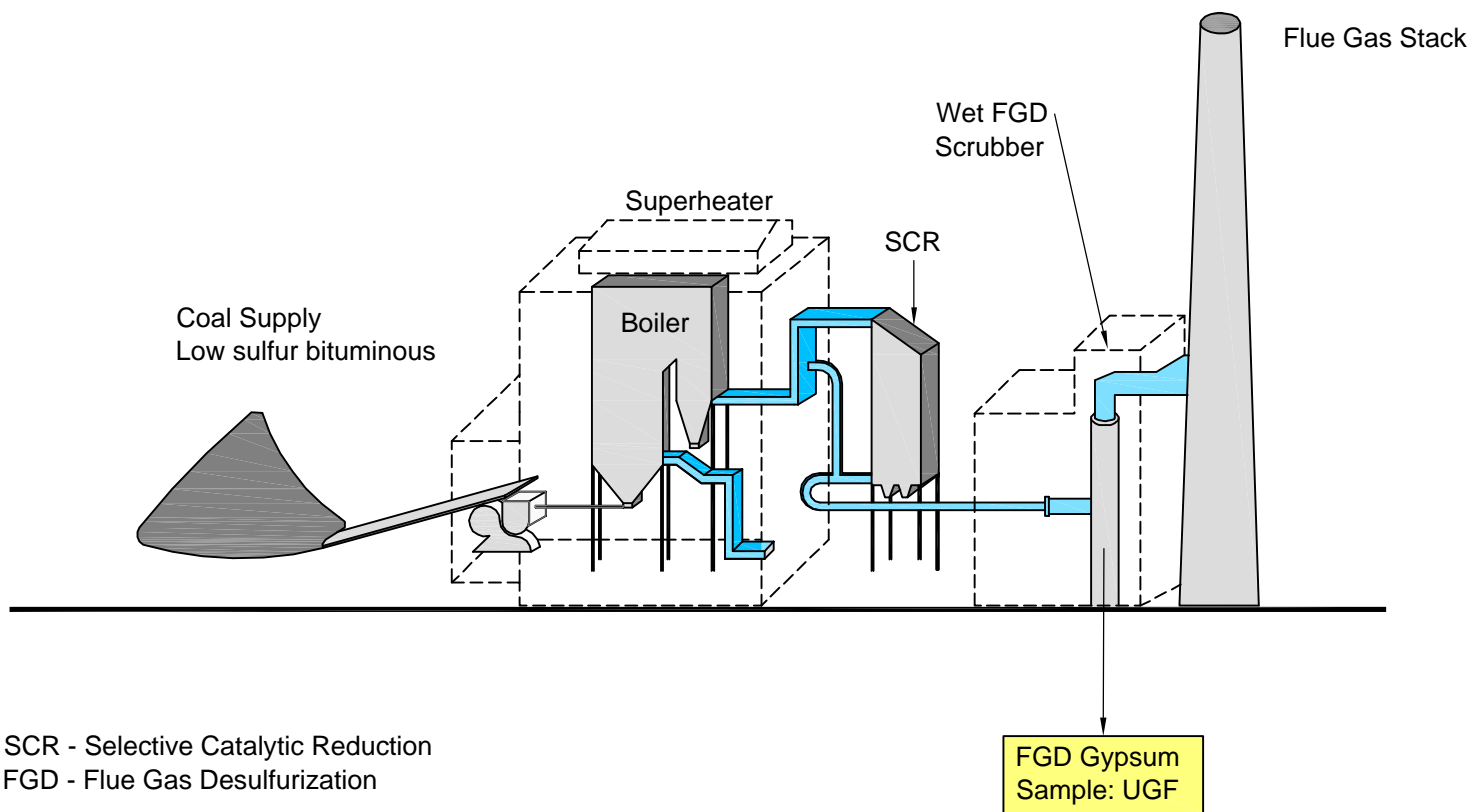
SCR - Selective Catalytic Reduction
 CS-ESP - Cold Side-Electrostatic Precipitator
 FGD - Flue Gas Desulfurization



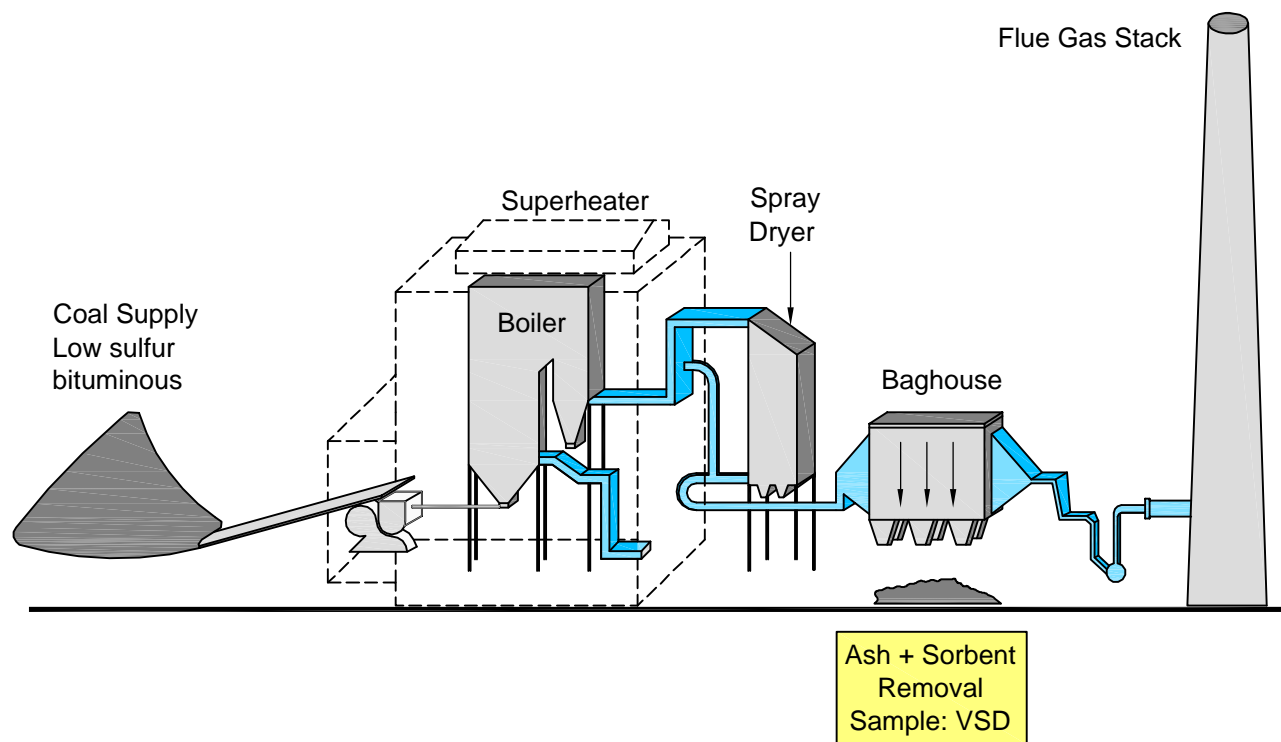
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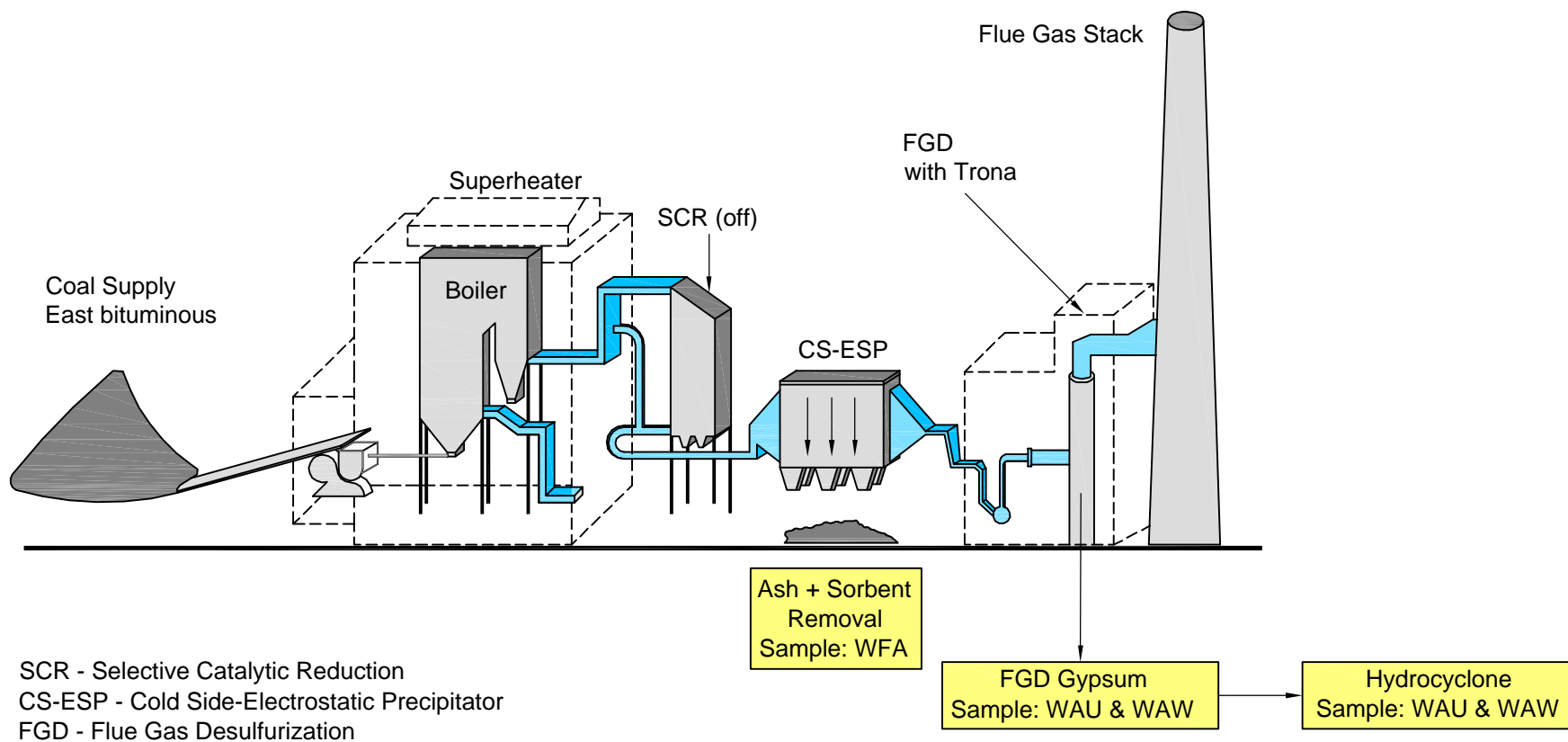
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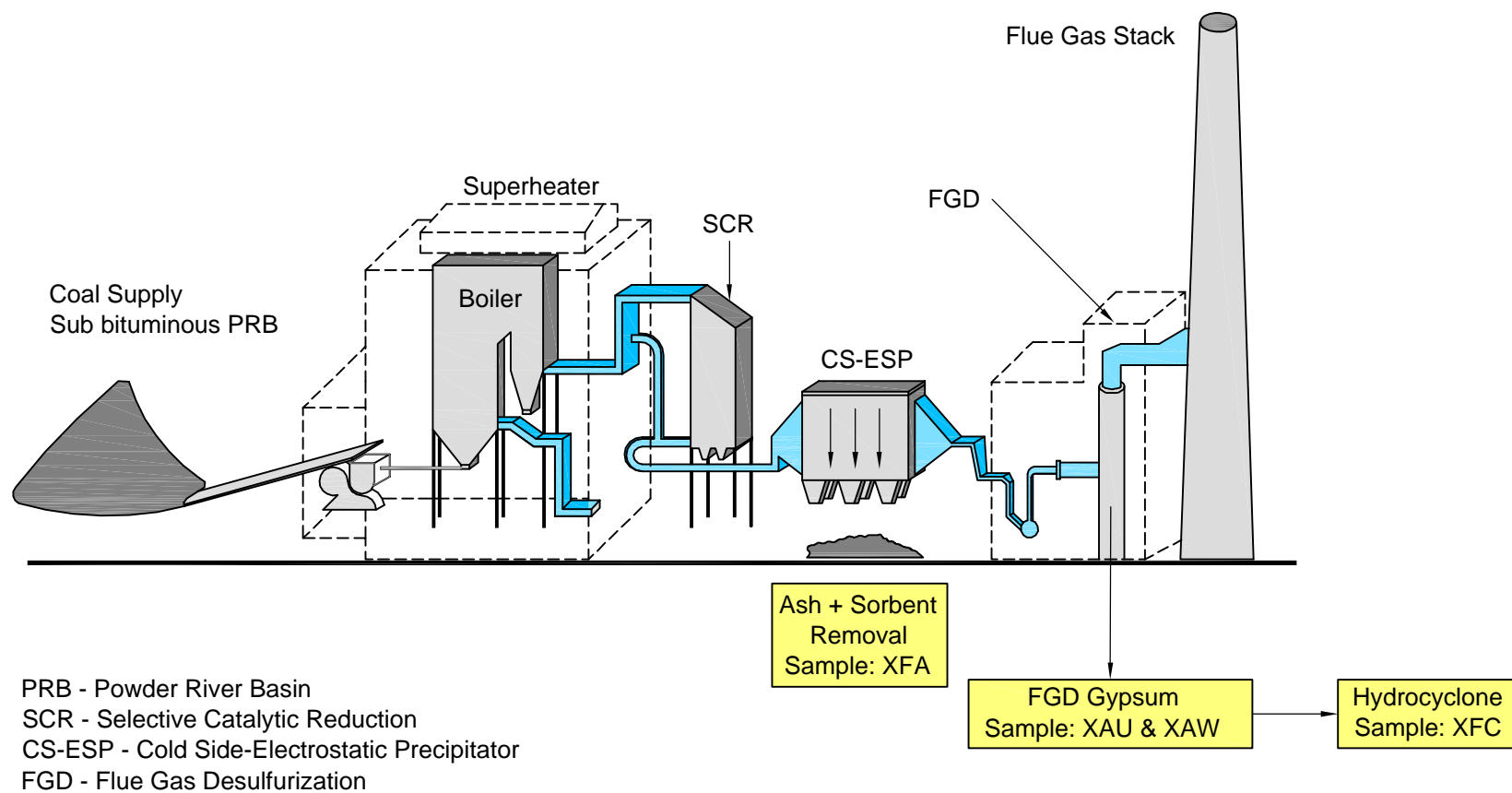
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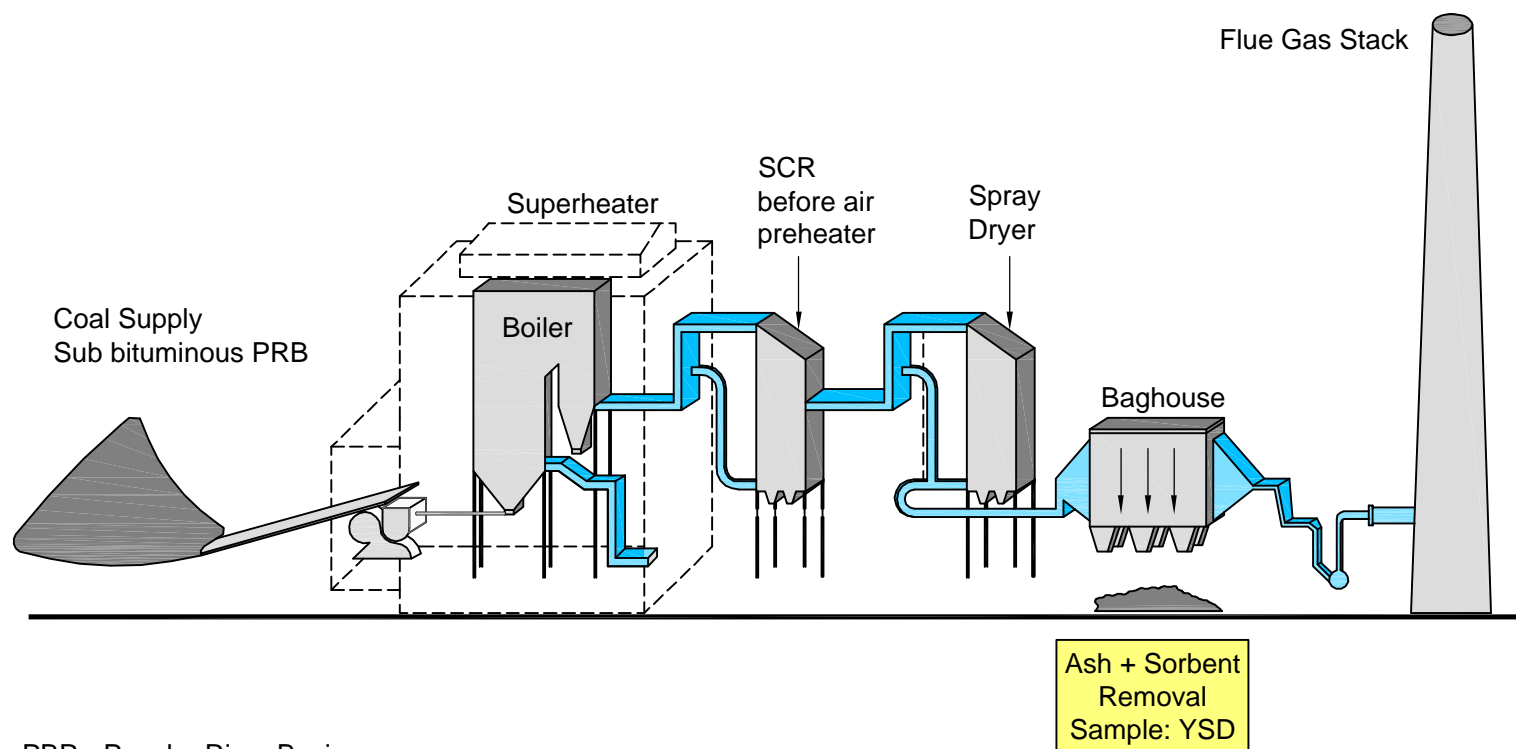
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Facility: X

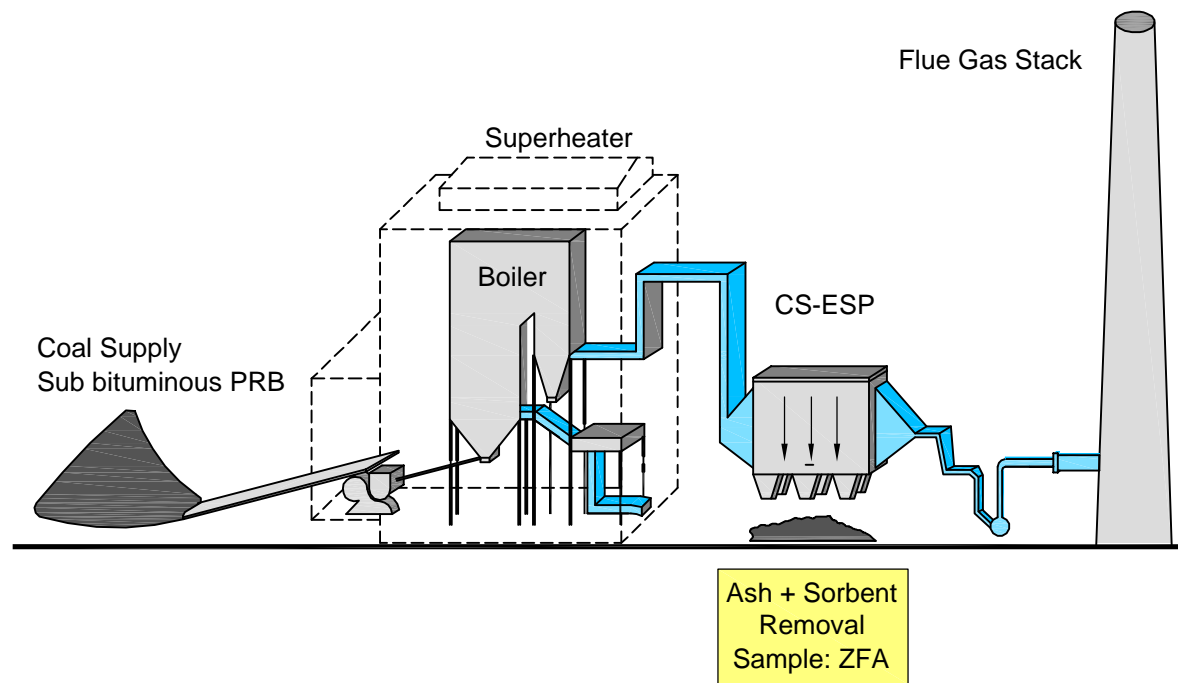


Facility: Y



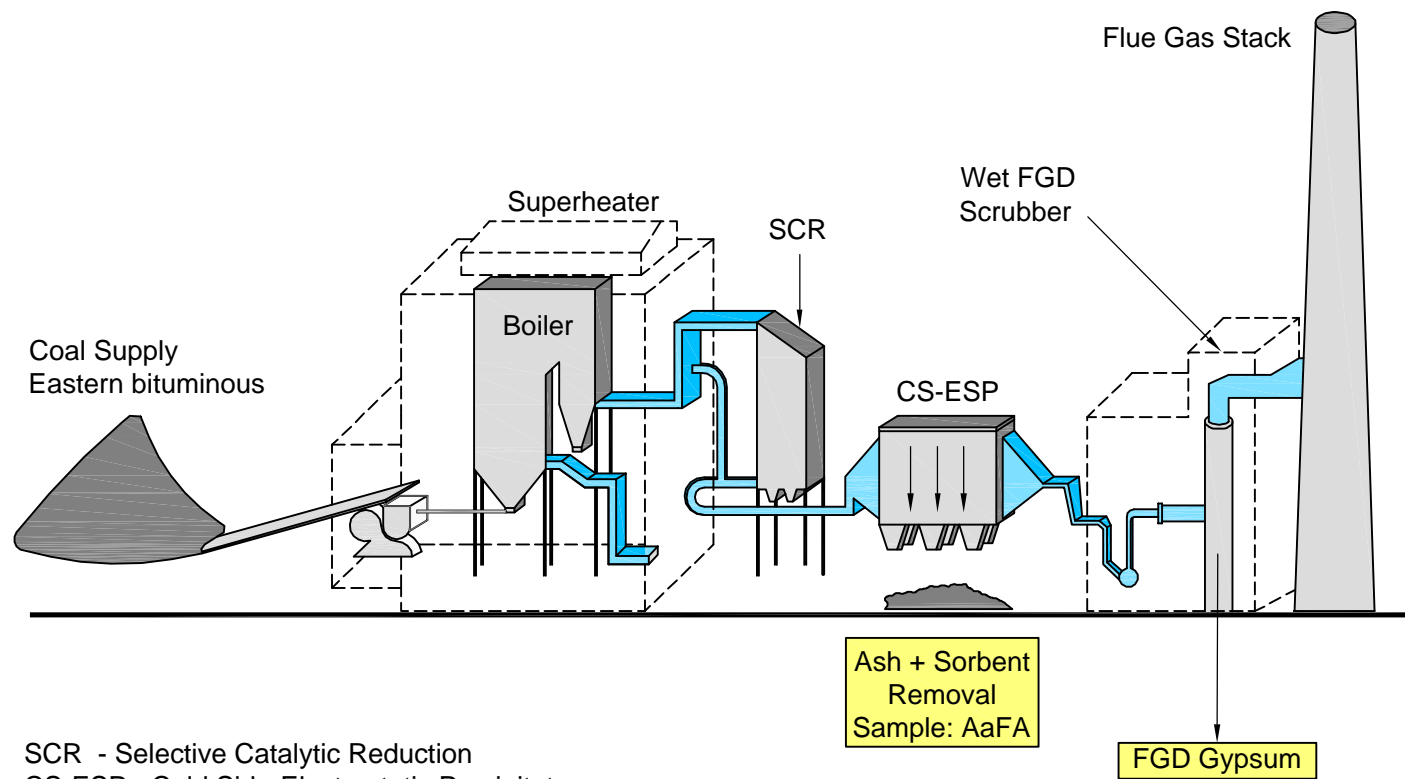
PBR - Powder River Basin
SCR - Selective Catalytic Reduction

Facility: Z



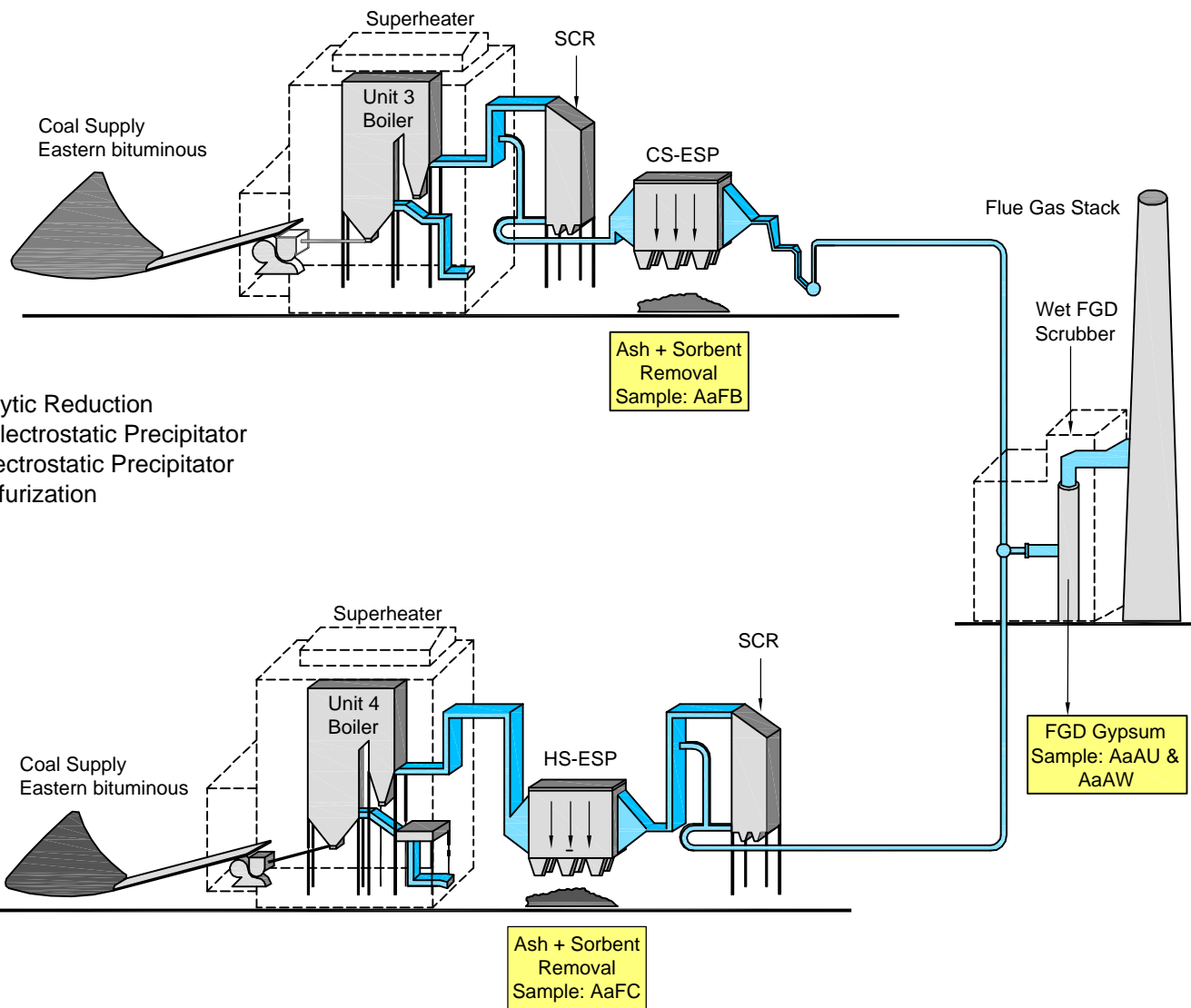
PRB - Powder River Basin
CS-ESP - Cold Side-Electrostatic Precipitator

Facility: Aa Unit 1



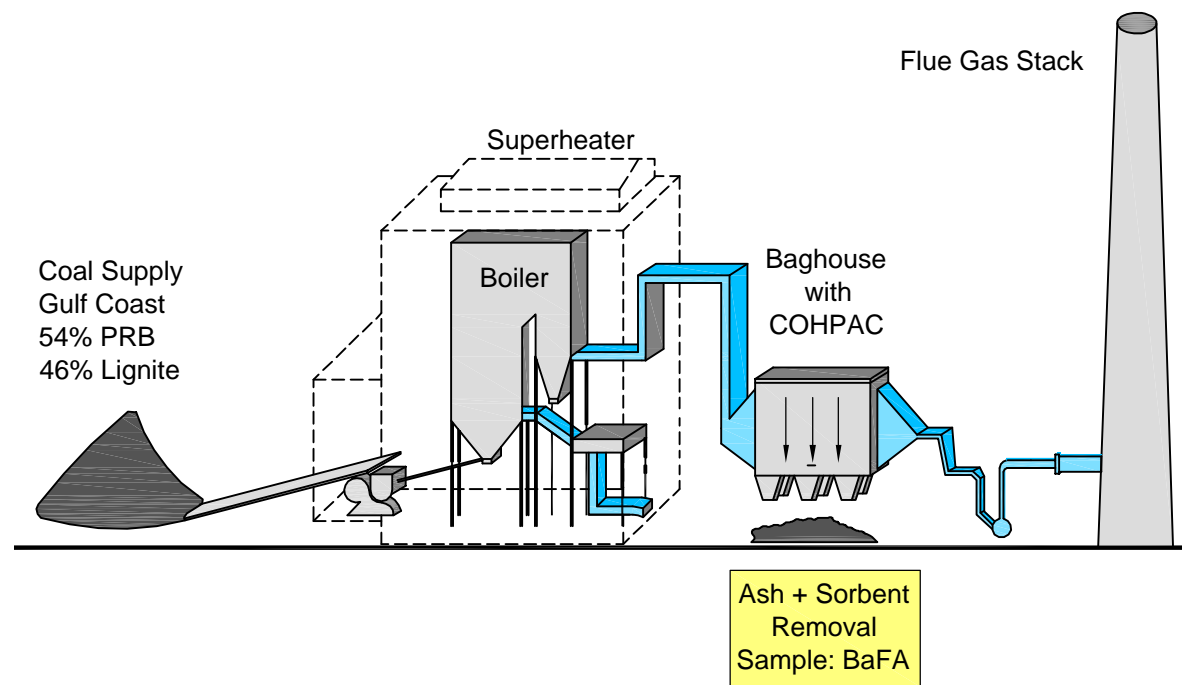
SCR - Selective Catalytic Reduction
CS-ESP - Cold Side-Electrostatic Precipitator
FGD - Flue Gas Desulfurization

Facility: Aa Unit 3 & 4



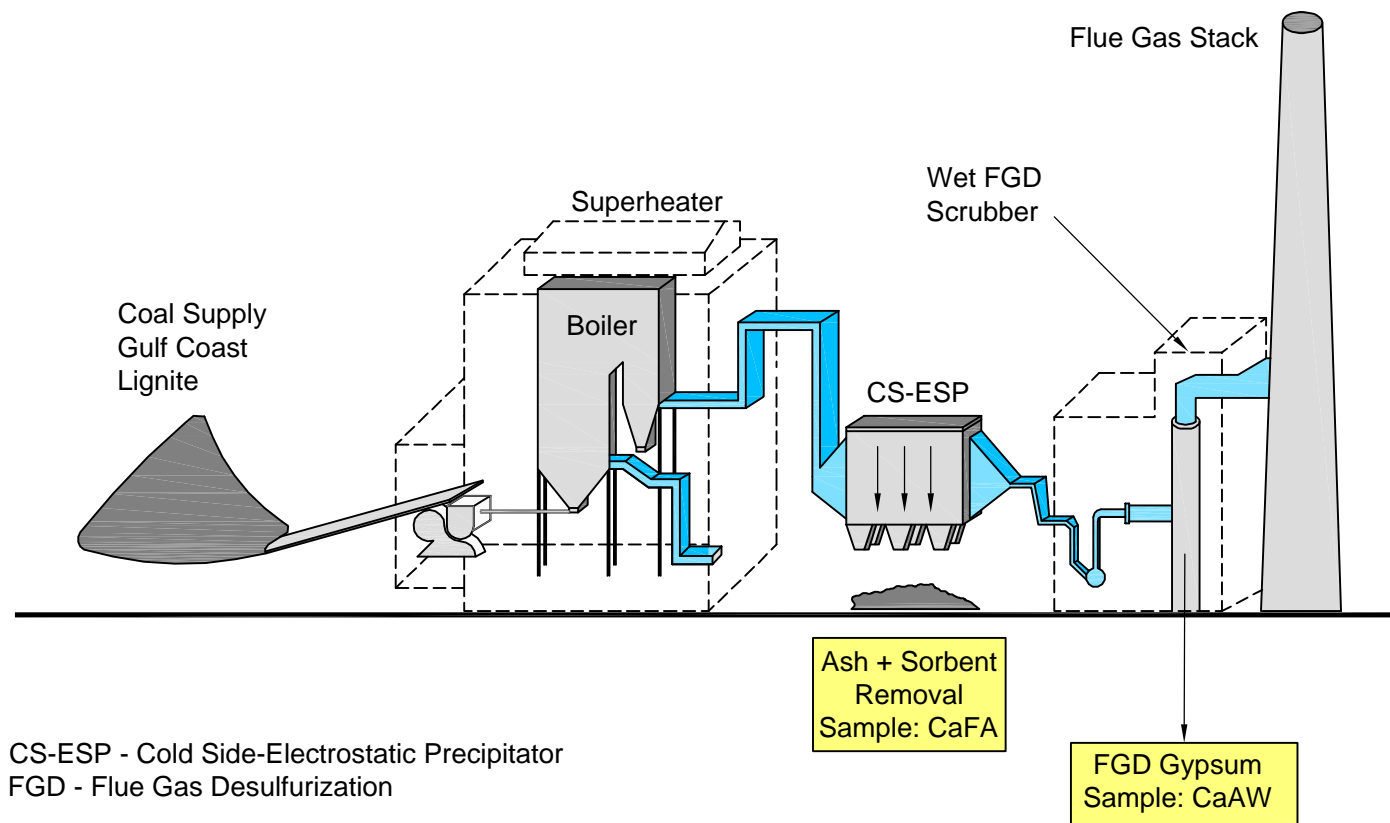
SCR - Selective Catalytic Reduction
 CS-ESP - Cold Side-Electrostatic Precipitator
 HS-ESP - Hot Side-Electrostatic Precipitator
 FGD - Flue Gas Desulfurization

Facility: Ba

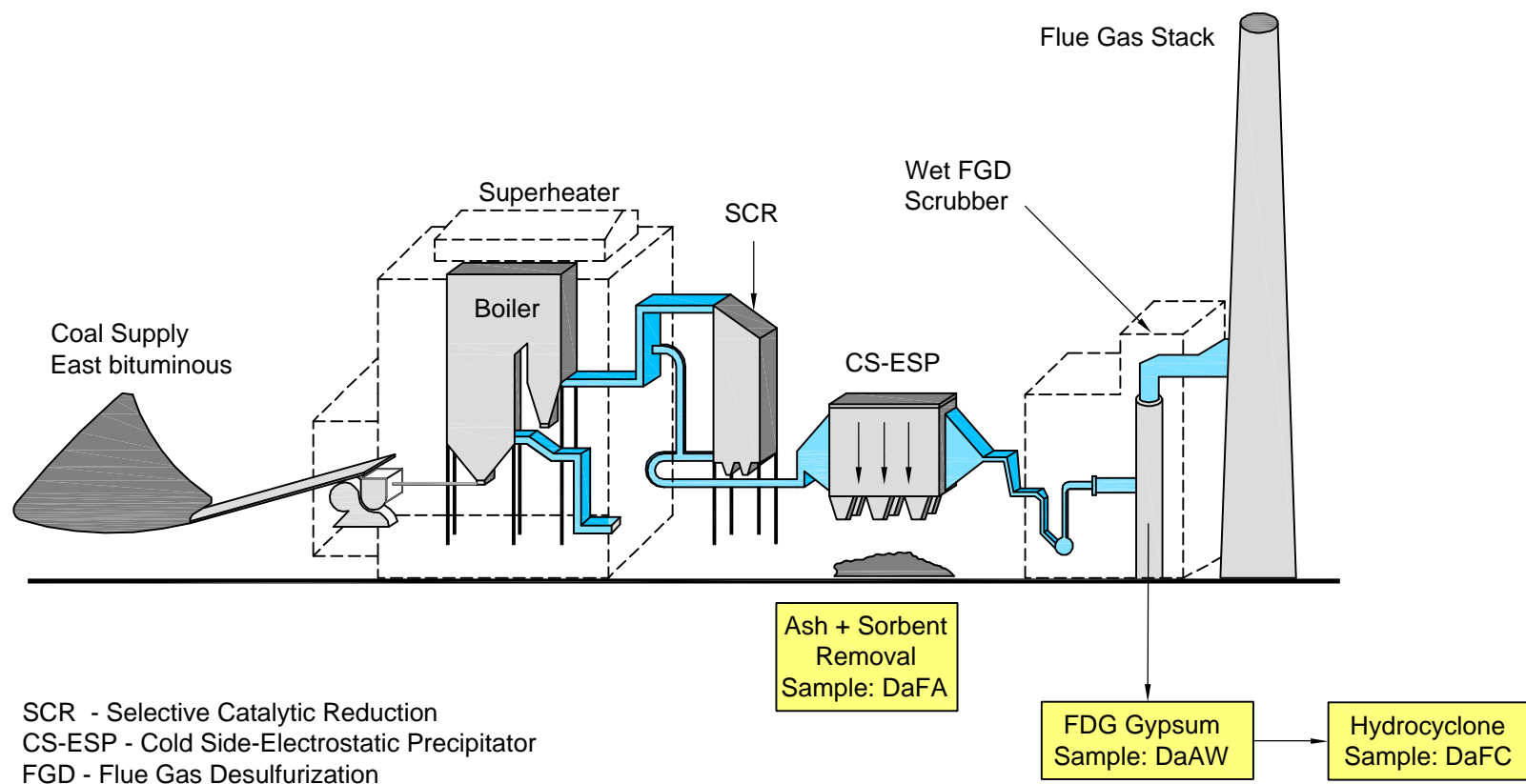


PRB - Powder River Basin
COHPAC - Compact Hybrid Particulate Collector

Facility: Ca



Facility: Da



Appendix B

Quality Assurance Project Plan for the Characterization of Coal Combustion Residues

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12/2/2009
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12/2/09
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

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RN990270.0007

Date:

December 2009

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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.

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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.

Phone: (919) 541-2709

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.

Phone: (919) 544-4535

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

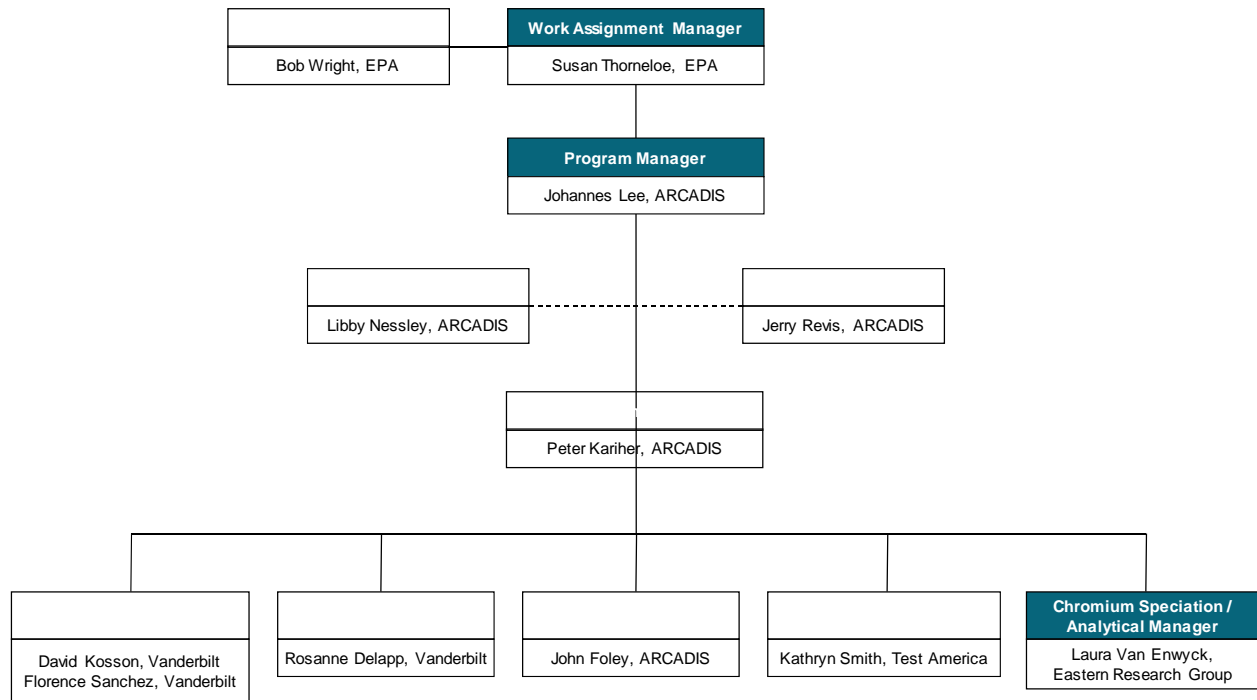


Figure 2-1. Project Organizational Chart

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 Version¹ 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

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 if 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 $0.45 \mu\text{m}$ 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 HNO₃ 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 (NH₂OH 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 HNO₃ 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 N₂ gas from the analysis manifold known volume. Report forms are automatically generated after each completed analysis. The instrument uses successive dosings of N₂ 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 $\pm 1\%$ and have a precision of $\pm 1\%$. 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 to 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 μ L 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. 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 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 derivatization 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 be 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 $\pm 10\%$ 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 VERSION² 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.

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 ($2 \leq \text{pH} \leq 13$) 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:

$$\% \text{ Passing} = \frac{M_{\text{sieved}}}{M_{\text{total}}} \times 100\%$$

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:

$$SC = \frac{M_{\text{dry}}}{M_{\text{test}}}$$

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:

$$MC_{\text{wet}} = \frac{M_{\text{test}} - M_{\text{dry}}}{M_{\text{test}}}$$

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:

$$M_{\text{test}} = \frac{M_{\text{dry}}}{SC}$$

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:

$$M_{\text{test}} = \frac{M_{\text{dry}}}{\text{SC}}$$

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 ($\pm 5\%$ 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 ($\pm 1\%$ 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 $0.45\text{-}\mu\text{m}$ 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 ($\text{g}_{\text{H}_2\text{O}}/\text{g}$)
- 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.

NOTE: 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., $[\text{Pb}(\text{OH}_3)]^-$).

Oxyanionic Species (e.g., $[\text{AsO}_4]^-$, $[\text{SeO}_4]^-$, $[\text{MnO}_4]^-$) — 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. Hjelm 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

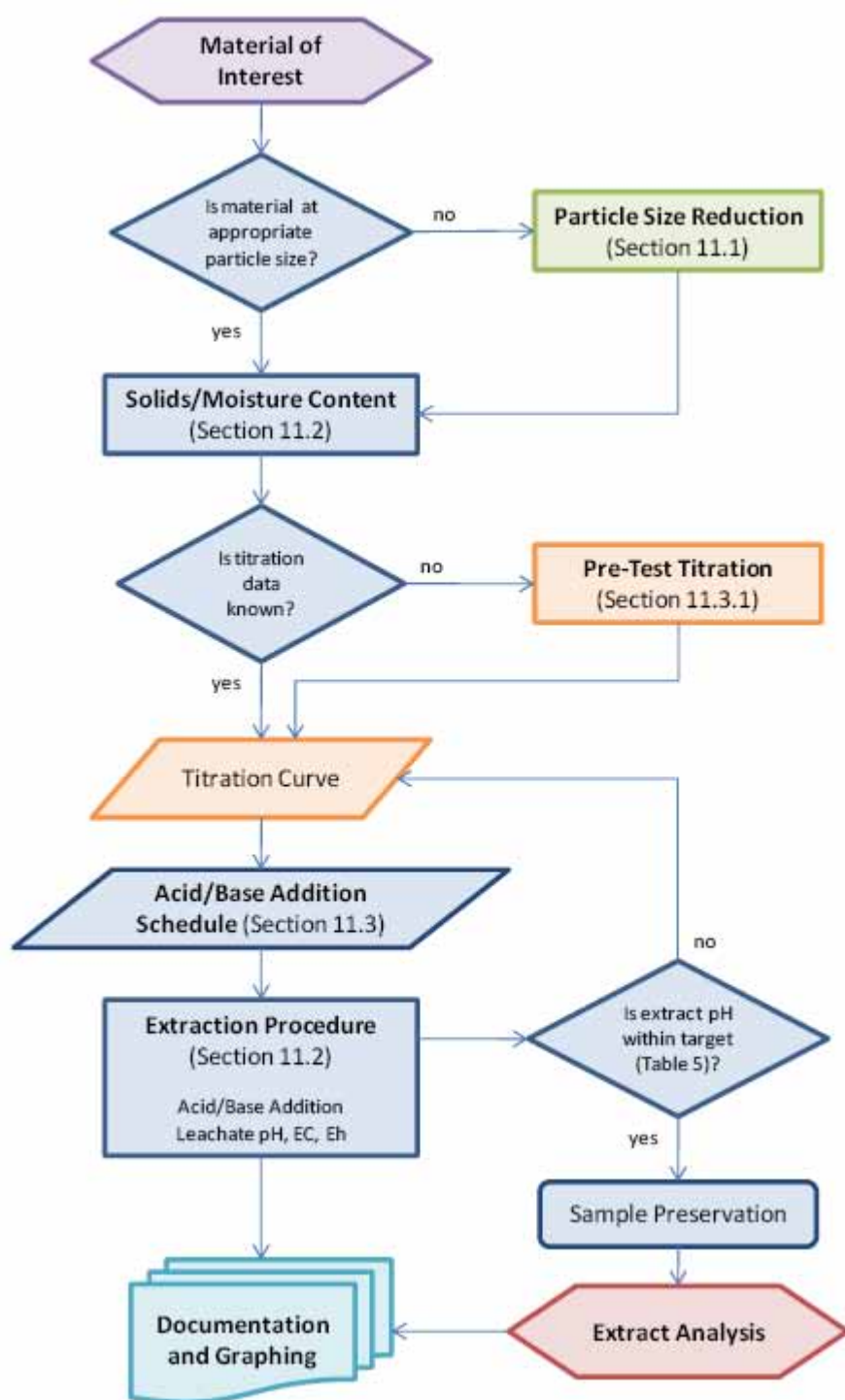
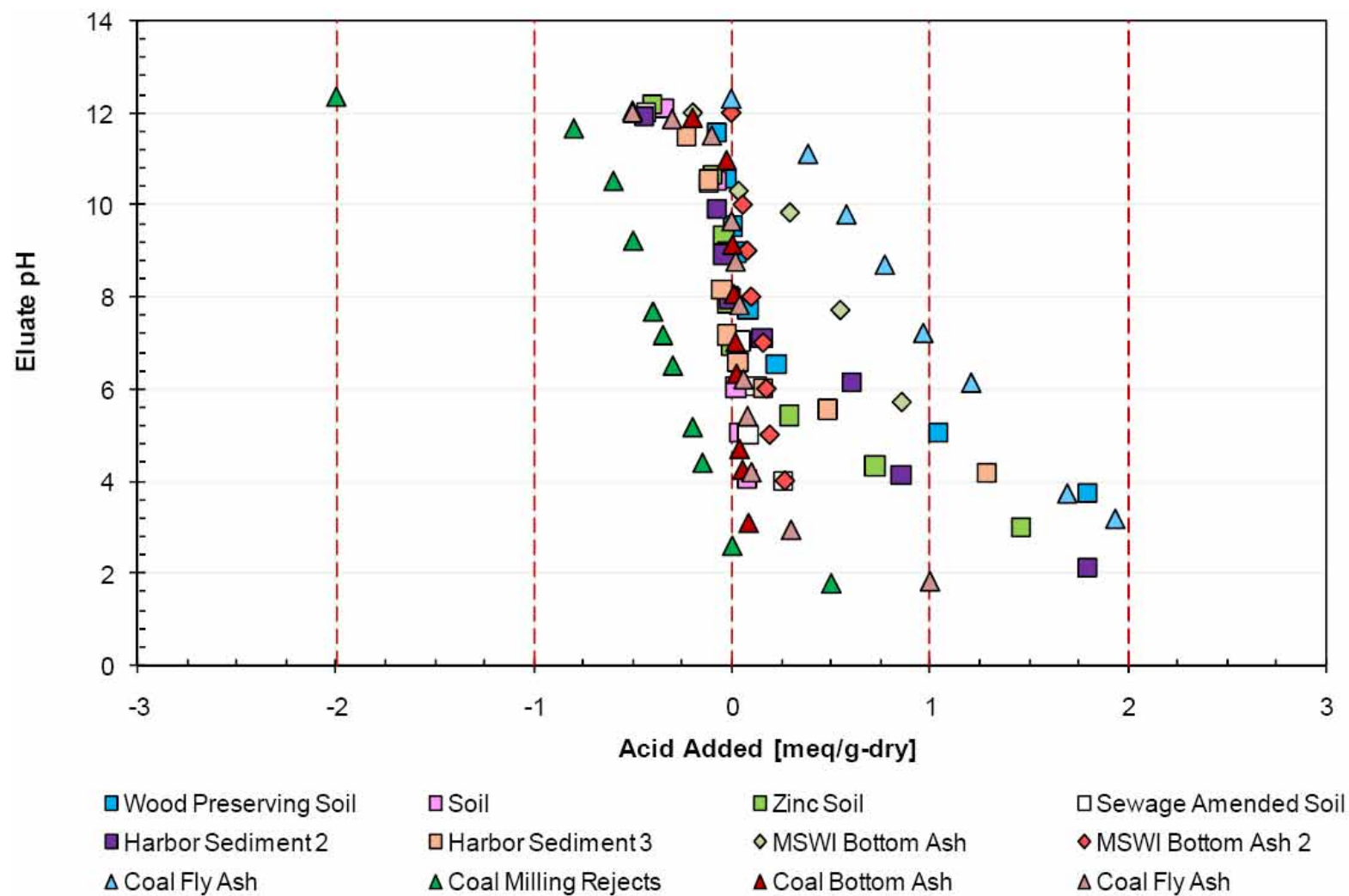


FIGURE 2

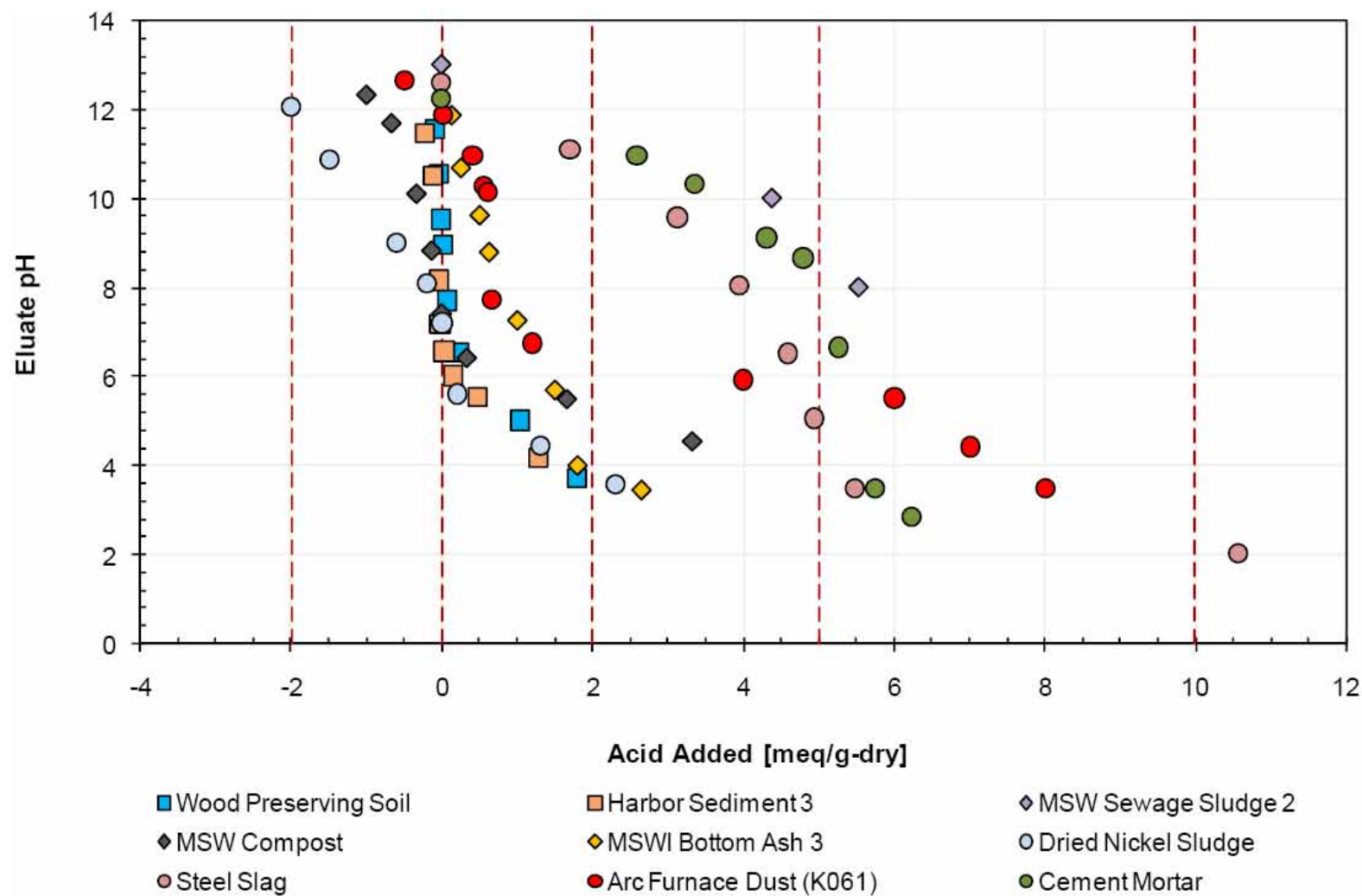
EXAMPLE TITRATION CURVES FOR SELECTED "LOW ALKALINITY" WASTES



Some data taken LeachXS database (Ref. 1).

FIGURE 3

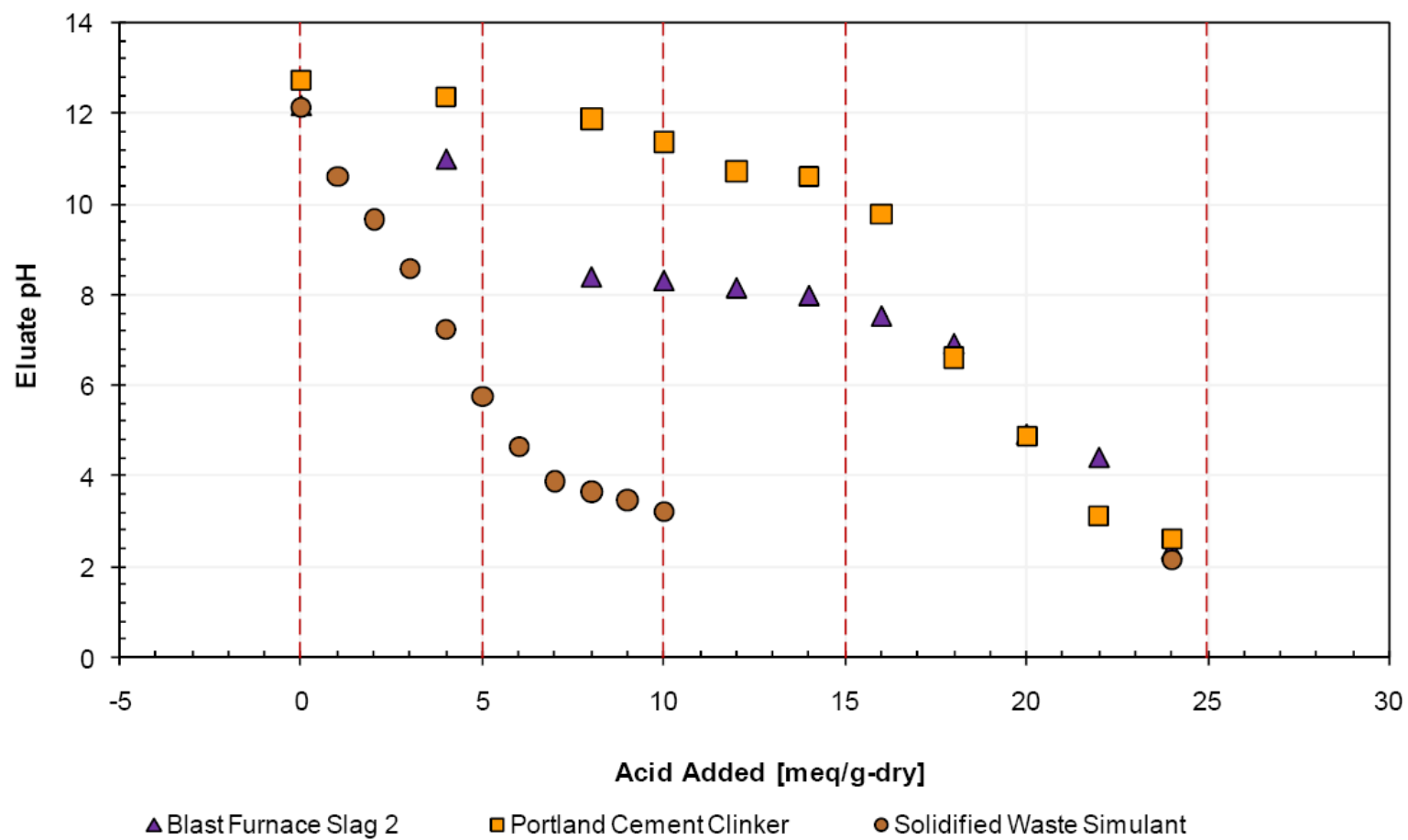
EXAMPLE TITRATION CURVES FOR SELECTED "MODERATE ALKALINITY" WASTES



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

ABC Laboratories

123 Main Street

Anytown, USA

Contact: John Smith

(555) 111-1111

EPA METHOD 1313**Report of Analysis**

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 _{H₂O} /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 _{H₂O} /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)

Fly Ash without Hg Sorbent Injection	C-1
Fly Ash without and with Hg Sorbent Injection Pairs	C-3
Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	C-4
Gypsum, Unwashed and Washed	C-5
Scrubber Sludge	C-9
Mixed Fly Ash and Scrubber Sludge (as managed)	C-11
Mixed Fly Ash and Gypsum (as managed)	C-13
Filter Cake	C-13

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
						(%)	(%)	(%)	(%)	(%)	m ² /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 m ² /g
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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
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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
						(%)	(%)	(%)	(%)	(%)	m ² /g

Fly Ash without and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

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)

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 Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	0.31	0.27	0.57	1.3	BML	0.6
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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
						(%)	(%)	(%)	(%)	(%)	m ² /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 (%)
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Gypsum, unwashed and washed

Bituminous, Low S

Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	2.27	0.42	2.69	3.7
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Bituminous, Med S

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 m ² /g
----------	-----------	--------------	------------	-------------	-------------------	-----------------------	-------------------------	--------------	--------------------------------

Gypsum, unwashed and washed

Bituminous, Low S

Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	25.8	4.4
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Bituminous, Med S

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 (%)
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Gypsum, unwashed and washed

Bituminous, High S

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 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 Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1.64	BML	1.64	4.8
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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 m ² /g
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Gypsum, unwashed and washed

Bituminous, High S

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 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 Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	38.2	5.3
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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 (%)
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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
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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
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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
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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 (%)
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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	0.17	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 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 m ² /g
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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	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 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 (%)
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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
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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
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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
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Mixed Fly Ash and Gypsum (as managed)

Bituminous, Low S

Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	11.8	7.0
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Filter Cake

Bituminous, Med S

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 X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	55.2	35.7
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BML - below method limit (not detected)

Appendix D

Total Content by Digestion

Fly Ash without Hg Sorbent Injection	D-1
Fly Ash without and with Hg Sorbent Injection Pairs	D-5
Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	D-5
Gypsum, Unwashed and Washed	D-7
Scrubber Sludge	D-9
Mixed Fly Ash and Scrubber Sludge (as managed)	D-9
Mixed Fly Ash and Gypsum (as managed)	D-11
Filter Cake	D-11

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. - 110200	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	TI	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. - 11/02/11	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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO ₃ Control	Hg		
						TI	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
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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
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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		SO ₃ Control	TI	Hg (7470)	Hg (7473)
				Sorbent Injection				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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	PM Capture	NOx Control	Hg		SO ₃ Control	TI	Hg (7470)	Hg (7473)
				Sorbent Injection				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	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	FGD	SO ₃ Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl										
					Scrubber	Scrubber																						
					type	additive																						
																			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
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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	FGD	SO ₃ Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl				
					Scrubber type	Scrubber additive																
												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	2.1	7.1	4.0	2.4	2.4	2.0	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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Hg (7470)	Hg (7473)
					Scrubber	Scrubber			
					type	additive			
								mg/kg	mg/kg

Gypsum, unwashed and washed

Bituminous, Low S

Facility U	UAU	Gyp-U	CS ESP	SCR	Forced Ox.	Limestone	None	0.25	0.09
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Bituminous, Med S

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	FGD	SO ₃ Control	Hg (7470)	Hg (7473)
					Scrubber	Scrubber			
					type	additive			
								mg/kg	mg/kg

Gypsum, unwashed and washed

Bituminous, High S

Facility N	NAU	Gyp-U	CS ESP	None	Forced Ox.	Limestone	None	0.04	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 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 Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1.8	3.1
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
					Scrubber	Scrubber												
					type	additive												
								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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
					Scrubber type	Scrubber additive												
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	FGD	SO ₃ Control	Hg (7470)	Hg (7473)
					Scrubber type	Scrubber additive			
								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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Hg (7470)	Hg (7473)
					Scrubber type	Scrubber additive			
								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	FGD	SO ₃ Control	Al	As	Ba	Cd	Co	Cr	Mo	Pb	Sb	Se	Tl
					Scrubber type	Scrubber additive												
								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
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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
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BML - below method limit (not detected); NA - not analyzed.

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Hg (7470)	Hg (7473)
					Scrubber type	Scrubber additive			
								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
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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
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BML - below method limit (not detected); NA - not analyzed.

Appendix E

Total Content by XRF

Fly Ash without Hg Sorbent Injection	E-1
Fly Ash without and with Hg Sorbent Injection Pairs	E-7
Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	E-10
Gypsum, Unwashed and Washed	E-13
Scrubber Sludge	E-19
Mixed Fly Ash and Scrubber Sludge (as managed)	E-22
Mixed Fly Ash and Gypsum (as managed)	E-25
Filter Cake	E-25

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

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 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 mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
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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
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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
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BML - below method limit (not detected)

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
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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
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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 and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

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)

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 Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	105650	2973	5700	105950	310
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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
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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 and with Hg Sorbent Injection Pairs

Bituminous, Low S (Class F)

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)

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 Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	4717	239050	2533	6651
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BML - below method limit (not detected)

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
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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 mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg
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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	FGD	SO ₃ Control	Al	Ba	C	Ca	Cl
					Scrubber type	Scrubber additive		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
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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	FGD	SO ₃ Control	F	Fe	K	Mg	Na	P
					Scrubber type	Scrubber additive							

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
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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	FGD	SO ₃ Control	S	Si	Sr	Ti
					Scrubber type	Scrubber additive					
								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
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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	FGD	SO ₃ Control	Al	Ba	C	Ca	Cl
					Scrubber type	Scrubber additive						
								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	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 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 Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	3933	BML	16400	291550	1255
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	F	Fe	K	Mg	Na	P
					Scrubber type	Scrubber additive							
								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	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 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 Ca	CaAW	Gyp-U	CS ESP	None	Forced Ox.	Limestone	Duct Sorbent inj. - Troana	1365	1667	370	4134	565	50
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	S	Si	Sr	Ti
					Scrubber type	Scrubber additive					
								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
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Al	Ba	C	Ca	Cl
					Scrubber	Scrubber						
					type	additive						
								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
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	F	Fe	K	Mg	Na	P
					Scrubber	Scrubber							
					type	additive							
								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
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	S	Si	Sr	Ti
					Scrubber	Scrubber					
					type	additive					
								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
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BML - below method limit (not detected)

Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Al	Ba	C	Ca	Cl
					Scrubber type	Scrubber additive						
								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	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 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	FGD	SO ₃ Control	F	Fe	K	Mg	Na	P
					Scrubber type	Scrubber additive							
								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	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 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	FGD	SO ₃ Control	S	Si	Sr	Ti
					Scrubber type	Scrubber additive					
								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	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 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 mg/kg	Ba mg/kg	C mg/kg	Ca mg/kg	Cl mg/kg
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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
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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
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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 mg/kg	Fe mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	P mg/kg
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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
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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
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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 mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg
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Mixed Fly Ash and Gypsum (as managed)

Bituminous, Low S

Facility U	UGF	Other	CS ESP	SCR	Forced Ox.	Limestone	None	85198	27858	540	1328
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Filter Cake

Bituminous, Med S

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 X	XFC	Other	CS ESP	SCR	Forced Ox.	Limestone	None	96640	80960	156	2088
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BML - below method limit (not detected)

Appendix F

Leaching Test Results

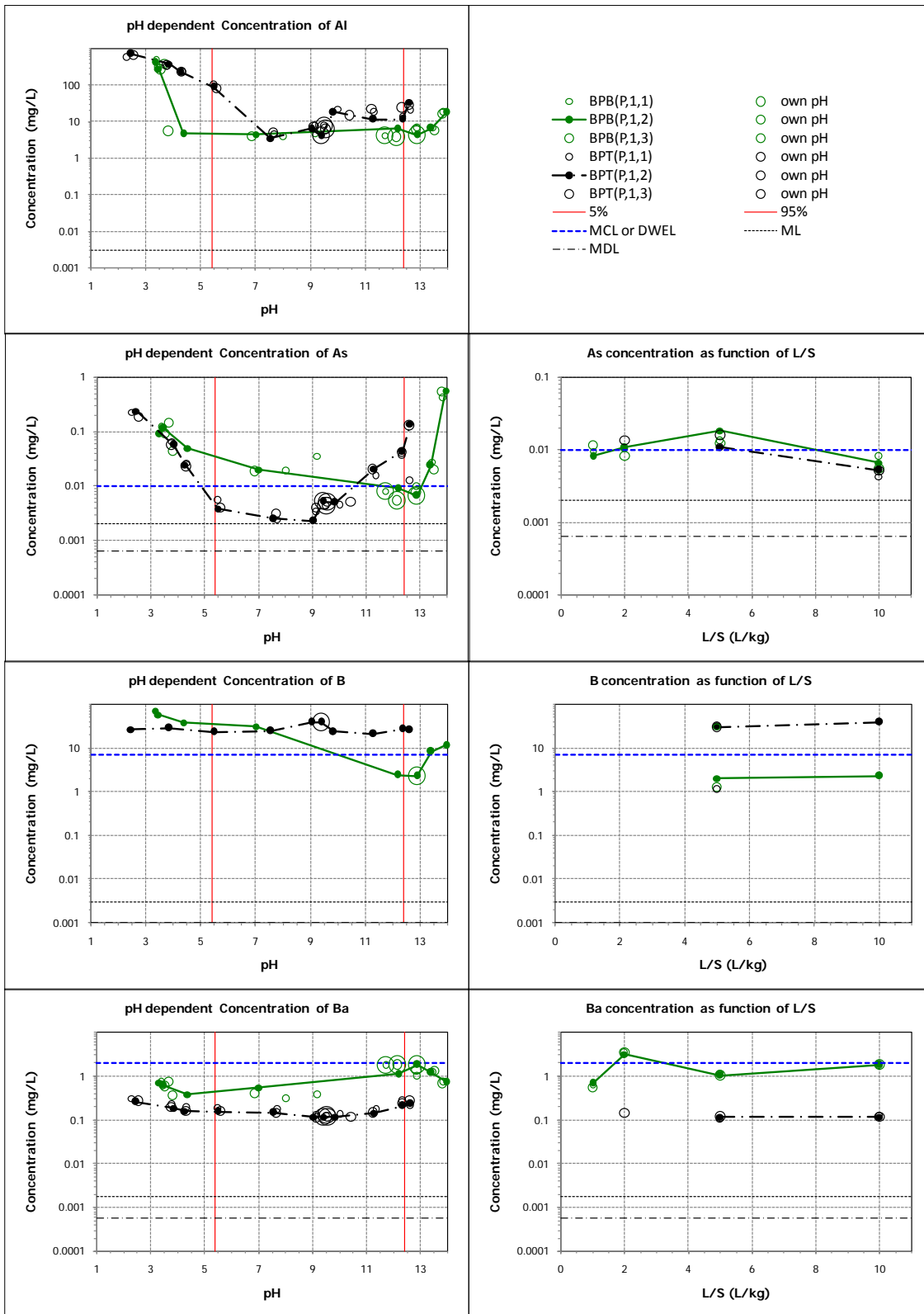
SR002 - Concentration as a Function of pH and

SR003 - Concentration as a Function of LS

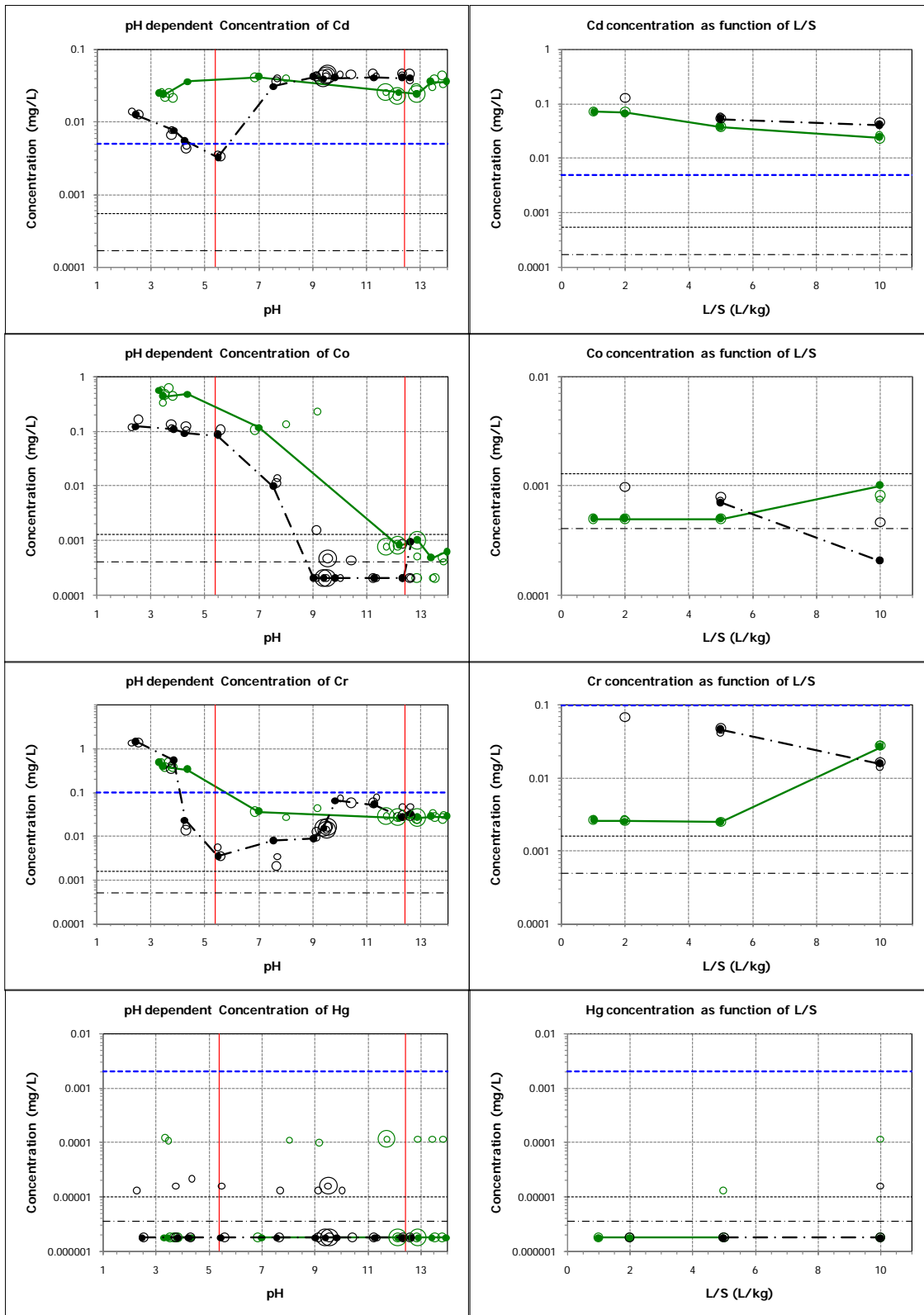
Elements Reported: Al, As, B, Ba, Cd, Co, Cr, Hg, Mo, Pb, Sb, Se, and Tl

Brayton Point - Fly ash without and with ACI (Samples BPB, BPT)	F-1
Pleasant Prairie - Fly ash without and with ACI (Samples PPB, PPT)	F-5
Salem Harbor - Fly ash without and with ACI (Samples SHB, SHT)	F-9
Facility A - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SNCR-BP (Samples CFA, CGD, CCC)	F-13
Facility A - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SNCR on (Samples AFA, AGD, ACC)	F-17
Facility B - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SCR-BP (Samples BFA, BGD, BCC)	F-21
Facility B - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SCR on (Samples DFA, DGD, DCC)	F-25
Facility C - Fly ash without and with ACI (Samples GAB, GAT)	F-29
Facility E - Fly ash, SCR on and SCR-BP (Samples EFA, EFC, EFB)	F-33
Facilities F, G, and H - Fly ash (Samples FFA, GFA, HFA)	F-37
Facility J - Fly ash without and with Br-ACI (Samples JAB, JAT)	F-41
Facility K - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge (Samples KFA, KGD, KCC)	F-45
Facility L - Fly ash without and with Br-ACI (Samples LAB, LAT)	F-49
Facility M - Mixed fly ash and scrubber sludge, SCR-BP and SCR on (Samples MAD, MAS)	F-53
Facility N - Gypsum, unwashed and washed (Samples NAU, NAW)	F-57

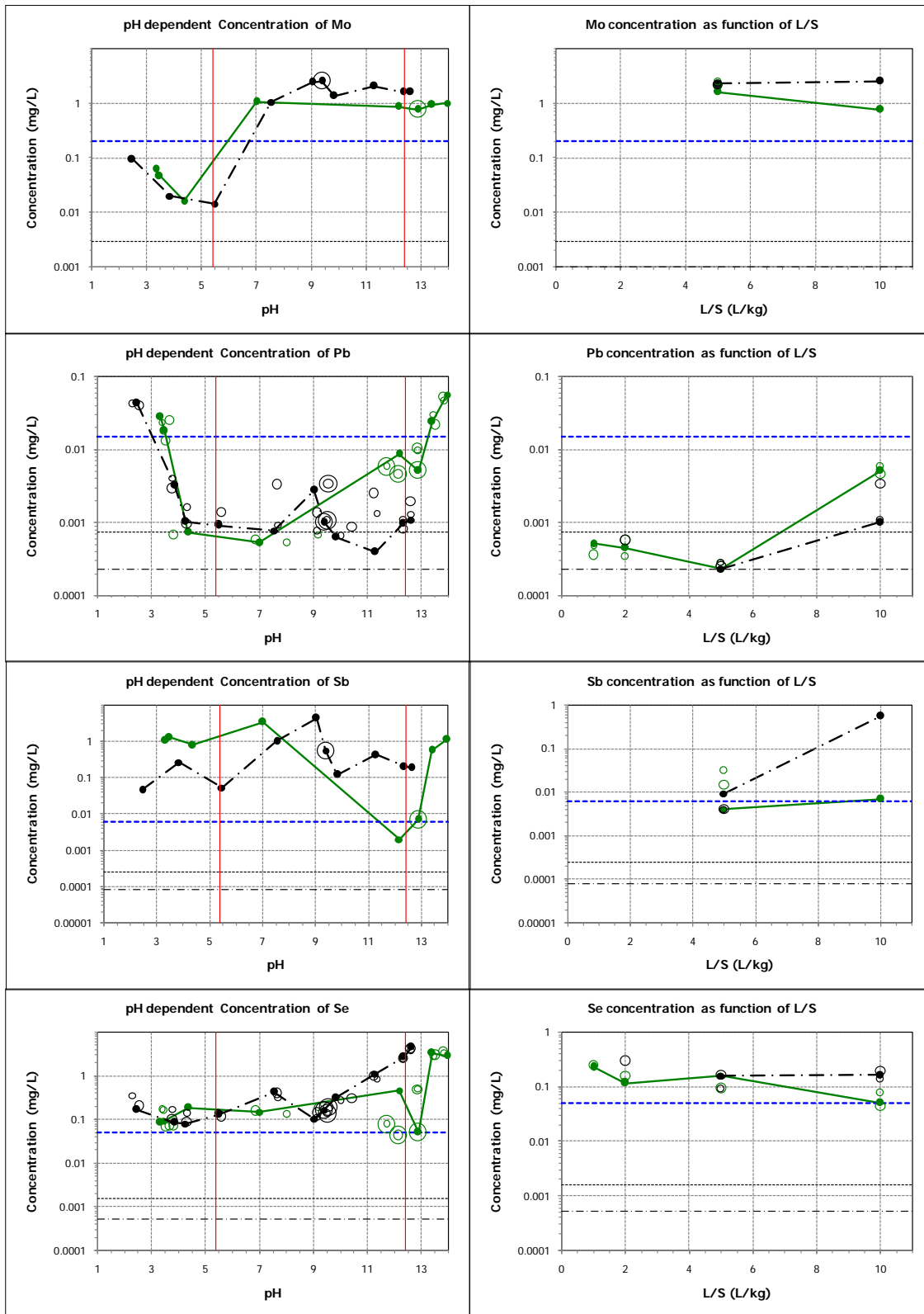
Facility O - Gypsum, unwashed and washed (Samples OAU, OAW)	F-61
Facilities P, Q, and R - Gypsum, unwashed (Samples PAD, QAU, RAU)	F-65
Facility S - Gypsum, unwashed and washed (Samples SAU, SAW)	F-69
Facility T - Fly ash; Gypsum, unwashed and washed; Filter Cake (Samples TFA, TAU, TAW, TFC)	F-73
Facility U - Fly ash; Gypsum, unwashed; Mixed fly ash and gypsum (Samples UFA, UAU, UGF)	F-77
Facility V - Spray dryer ash (Sample VSD)	F-81
Facility W - Fly ash; Gypsum, unwashed and washed; Filter Cake (Samples WFA, WAU, WAW, WFC)	F-85
Facility X - Fly ash; Gypsum, unwashed and washed; Filter Cake (Samples XFA, XAU, XAW, XFC)	F-89
Facility Y - Spray dryer ash (Sample YSD)	F-93
Facility Z - Fly ash (Sample ZFA)	F-97
Facility Aa - Fly ash; Gypsum, unwashed and washed (Samples AaFA, AaFB, AaFC, AaAU, AaAW)	F-101
Facility Ba - Fly ash (Samples BaFA)	F-105
Facility Ca - Fly ash; Gypsum, washed (Samples CaFA, CaAW)	F-109
Facility Da - Fly ash; Gypsum, washed; Filter Cake (Samples DaFA, DaAW, DaFC)	F-113



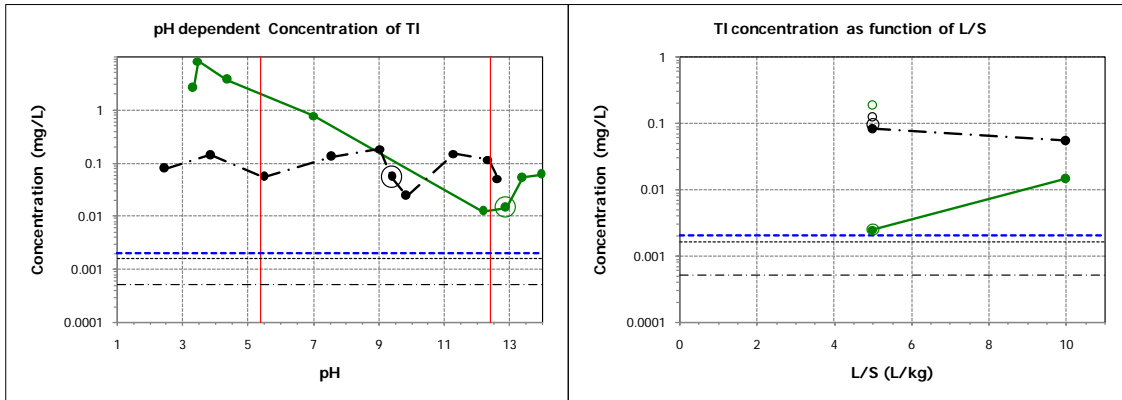
Brayton Point (East-Bit., CS-ESP). BPB - fly ash without ACI; BPT - fly ash with ACI.



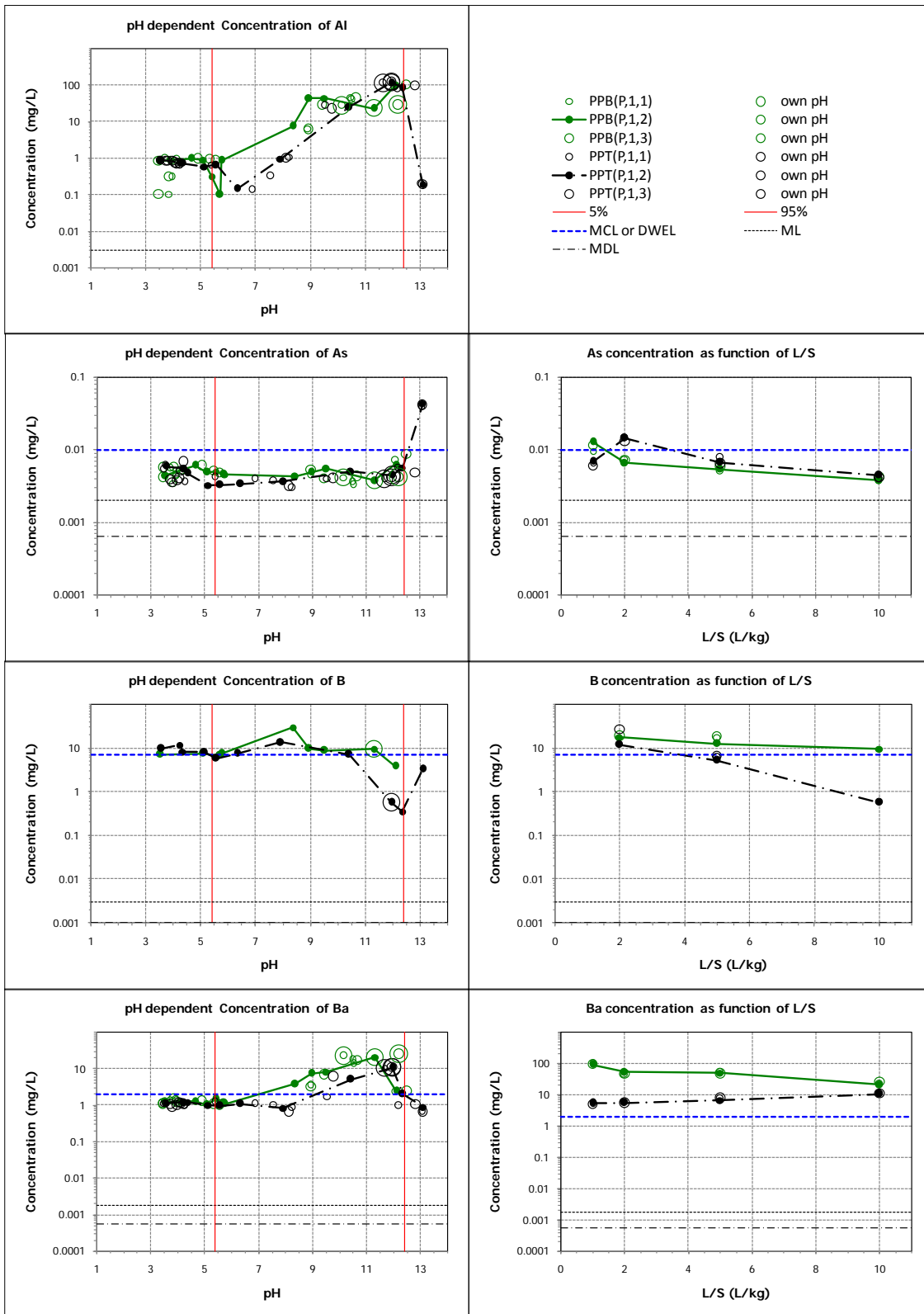
Brayton Point (East-Bit., CS-ESP). **BPB** - fly ash without ACI; **BPT** - fly ash with ACI.



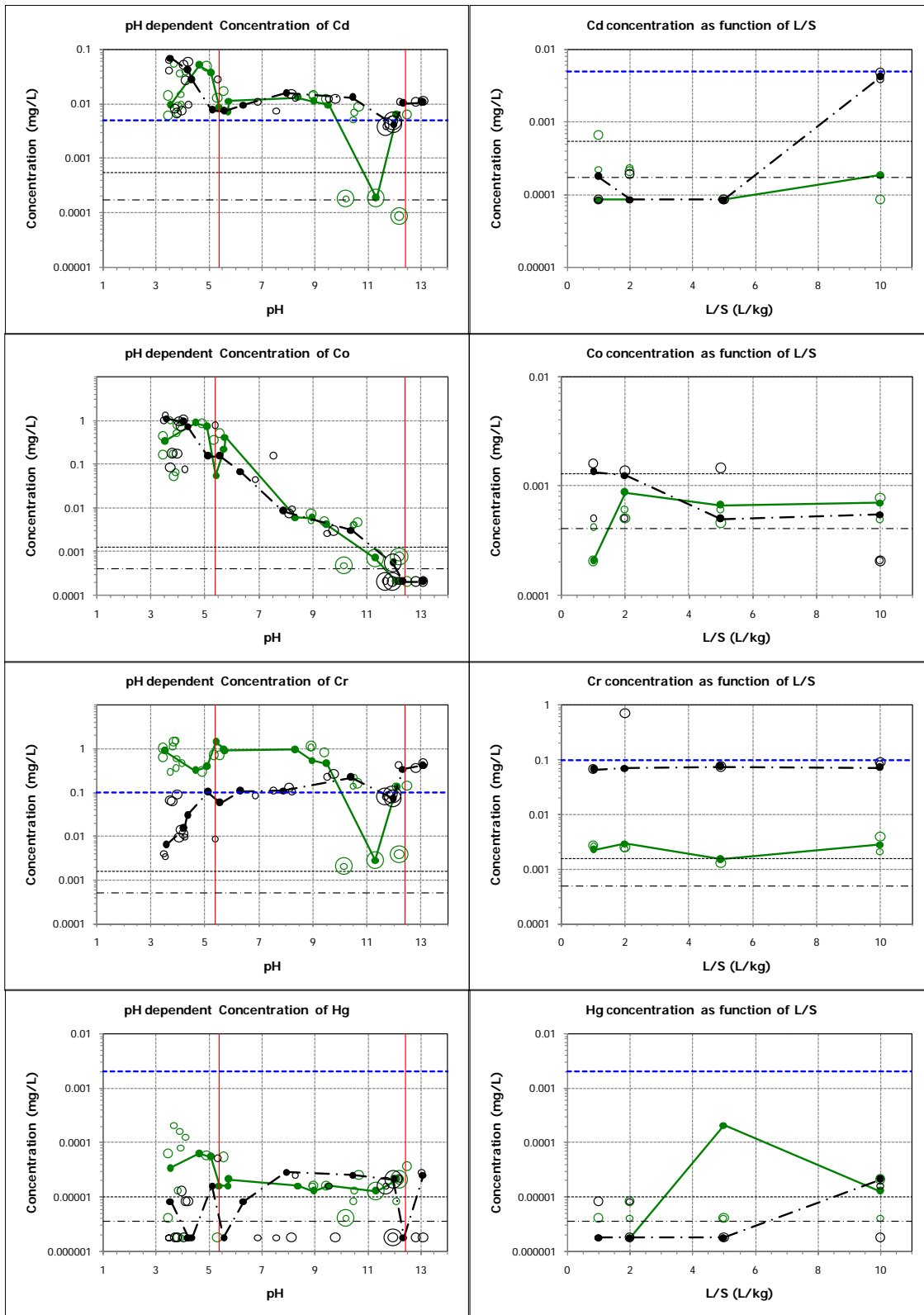
Brayton Point (East-Bit., CS-ESP). **BPB** - fly ash without ACI; **BPT** - fly ash with ACI.



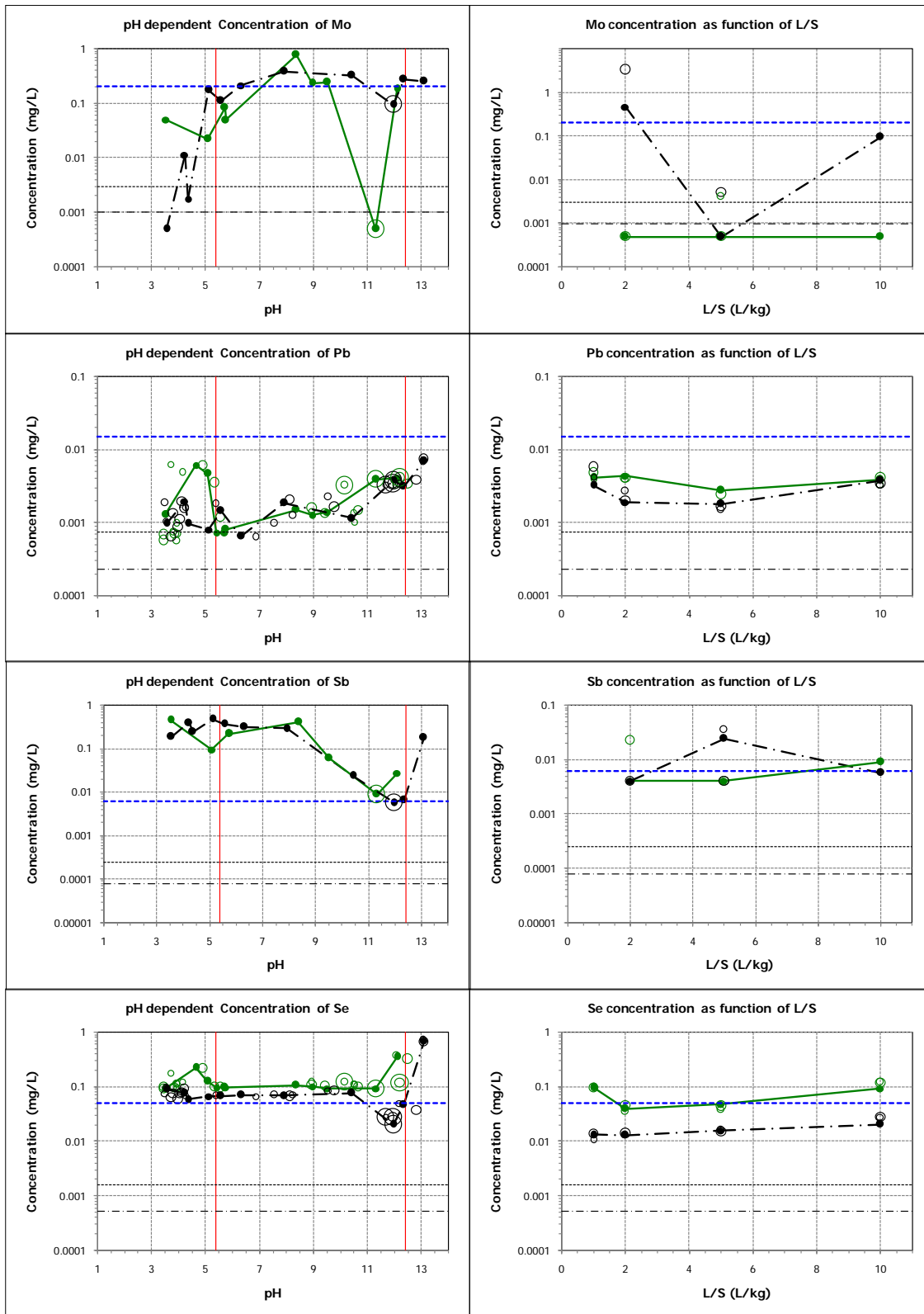
Brayton Point (East-Bit., CS-ESP). **BPB** - fly ash without ACI; **BPT** - fly ash with ACI.



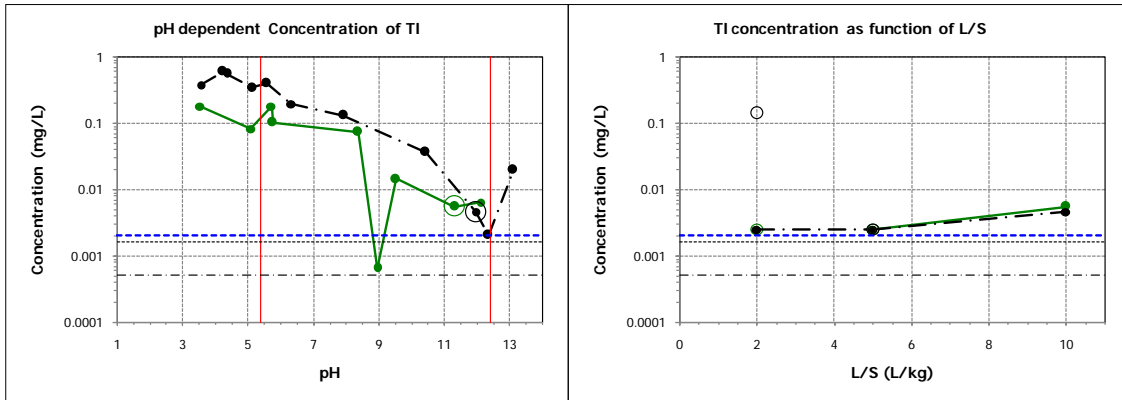
Pleasant Prairie (PRB, CS-ESP). PPB - fly ash without ACI; PPT - fly ash with ACI.



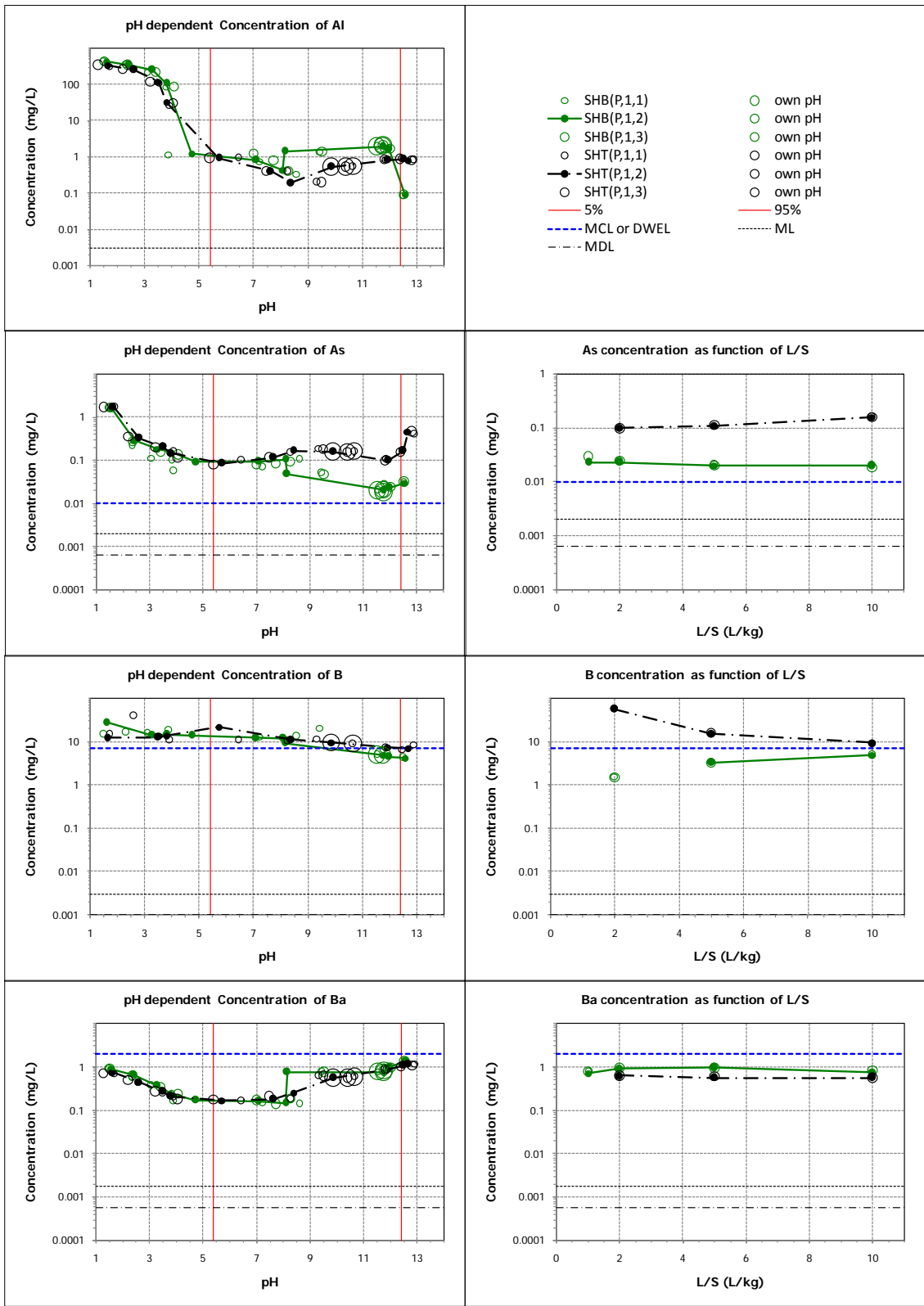
Pleasant Prairie (PRB, CS-ESP). PPB - fly ash without ACI; PPT - fly ash with ACI.



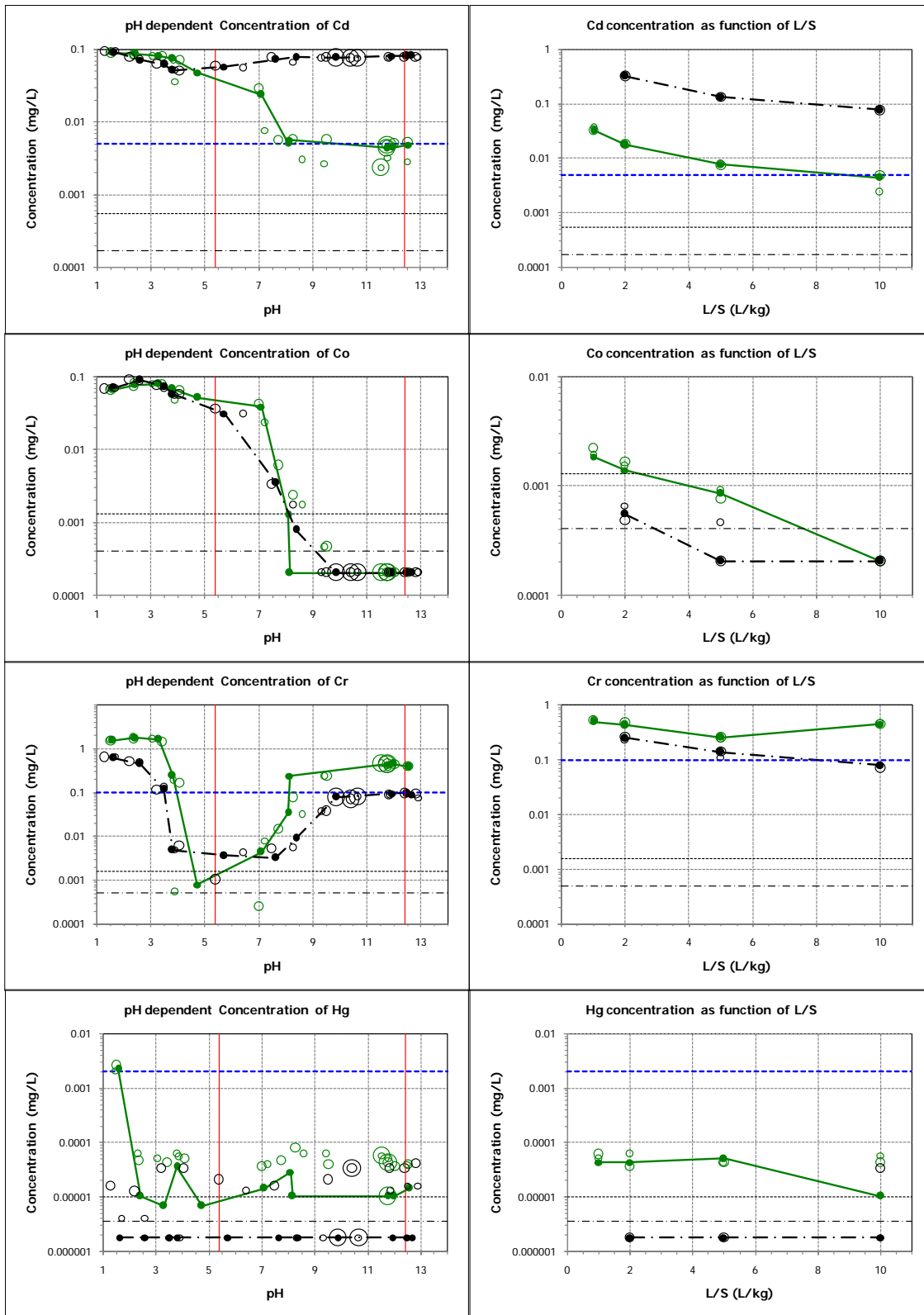
Pleasant Prairie (PRB, CS-ESP). PPB - fly ash without ACI; PPT - fly ash with ACI.



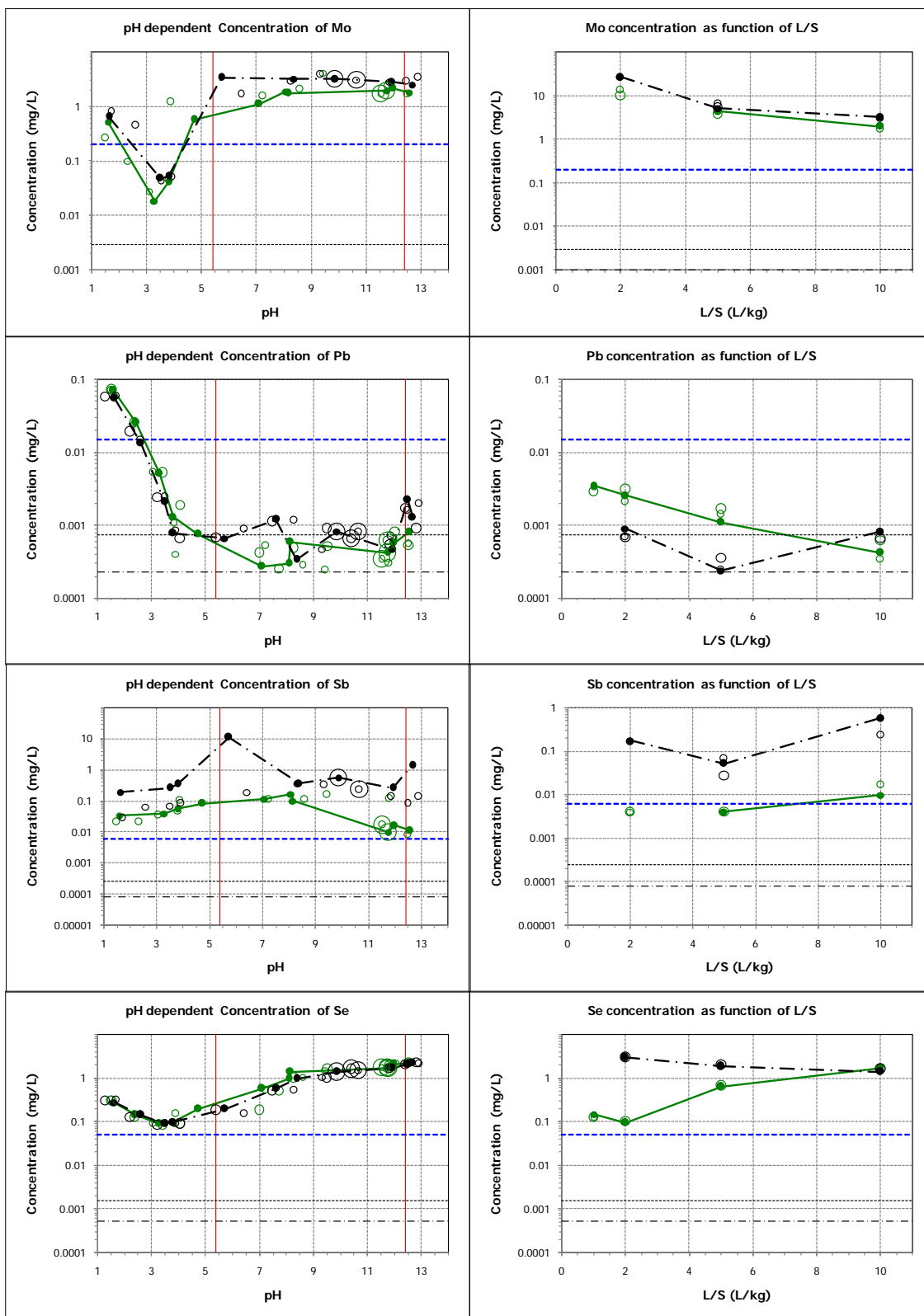
Pleasant Prairie (PRB, CS-ESP). **PPB** - fly ash without ACI; **PPT** - fly ash with ACI.



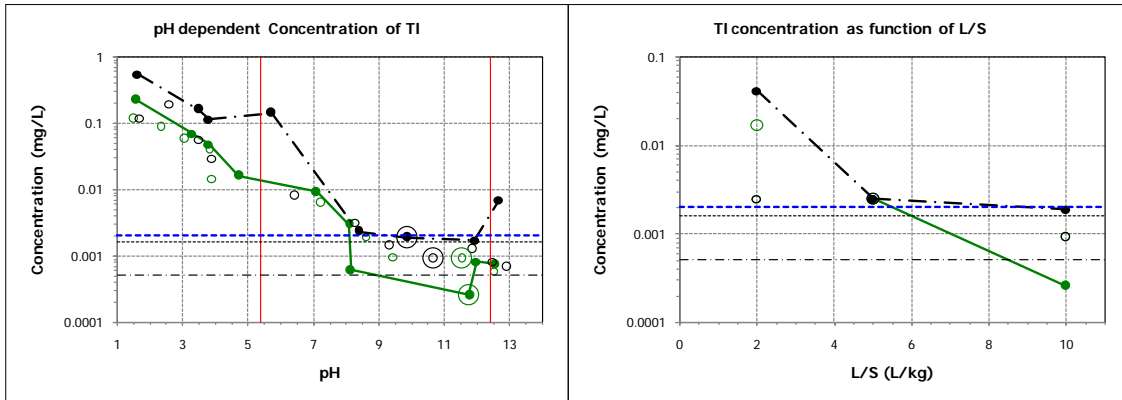
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



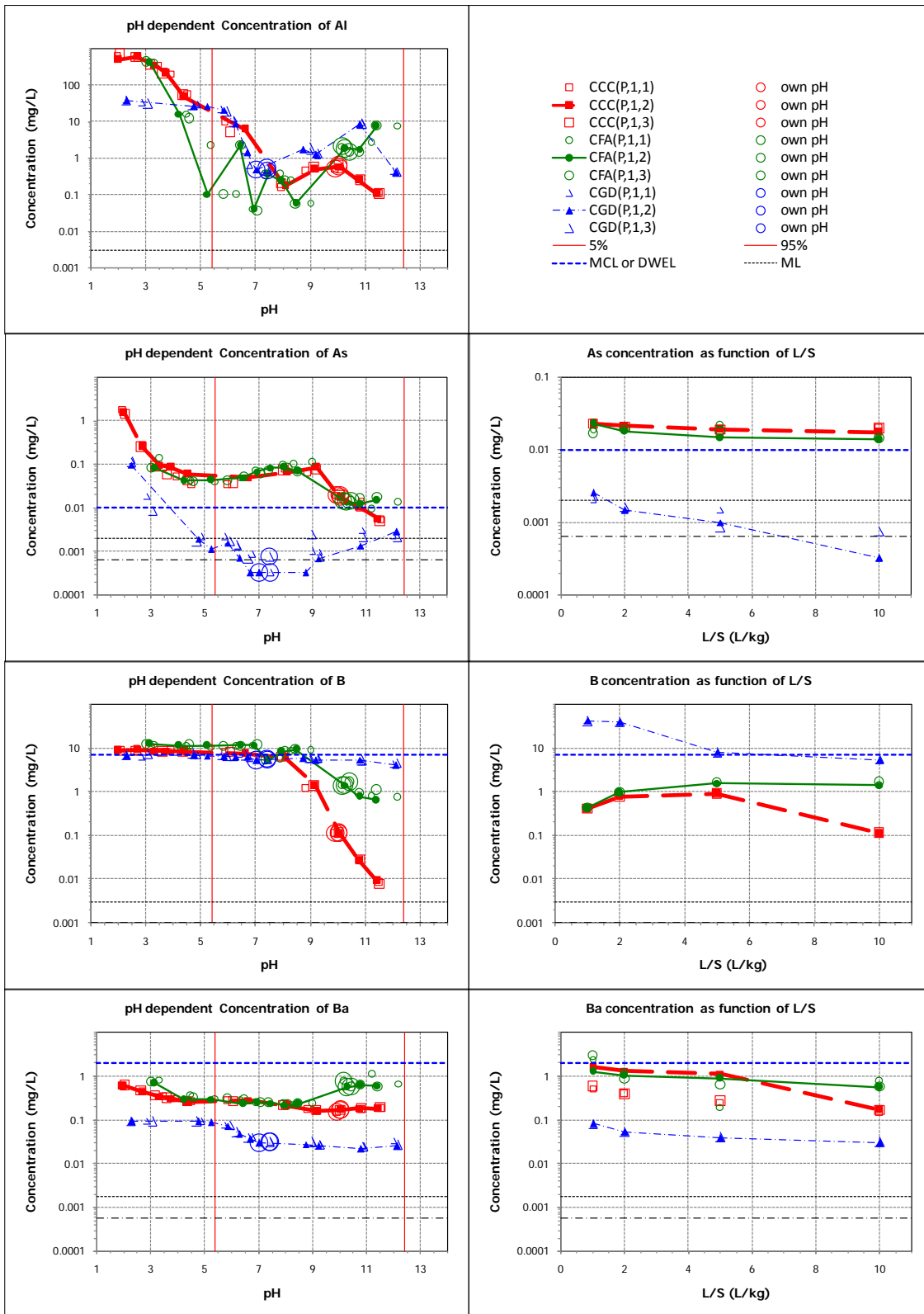
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



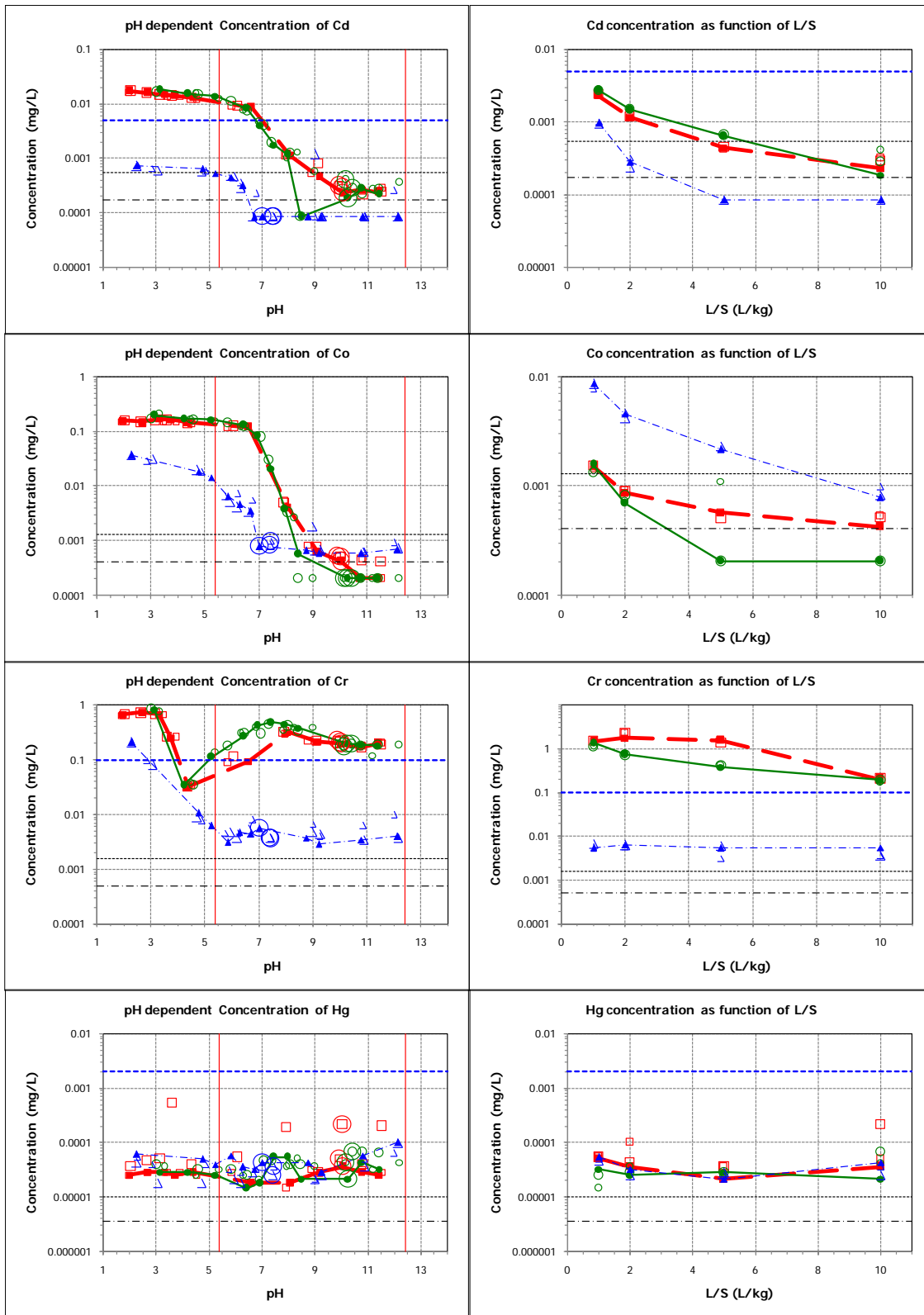
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



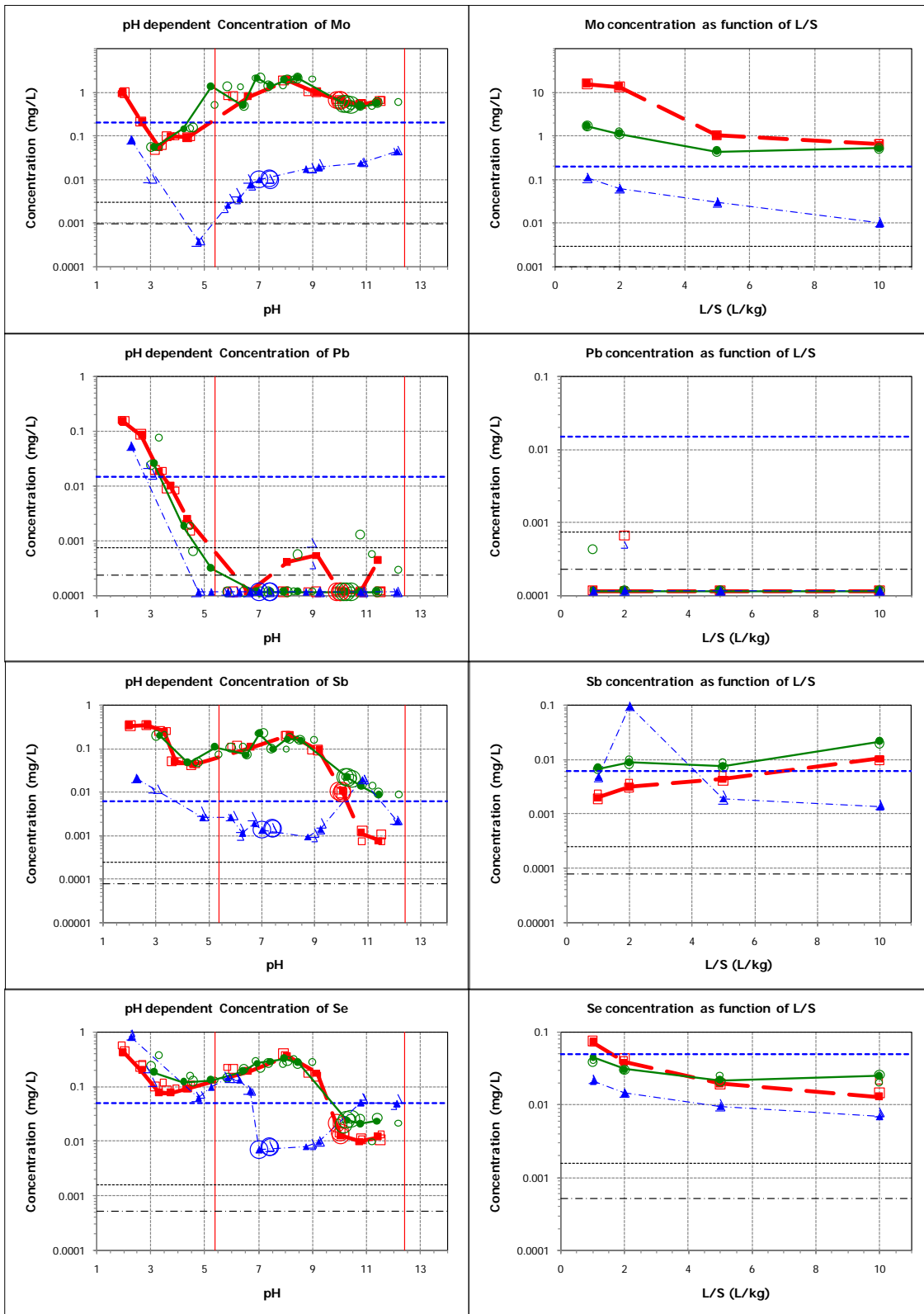
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** - fly ash without ACI; **SHT** - fly ash with ACI.



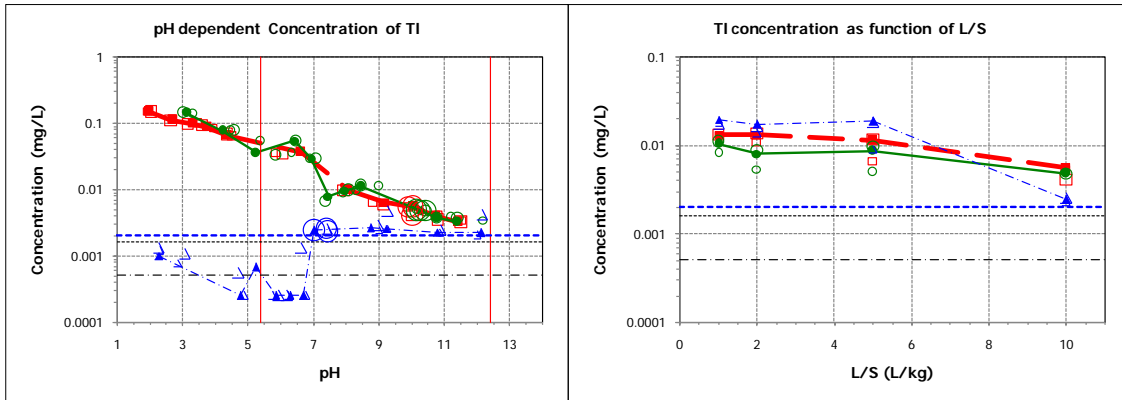
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



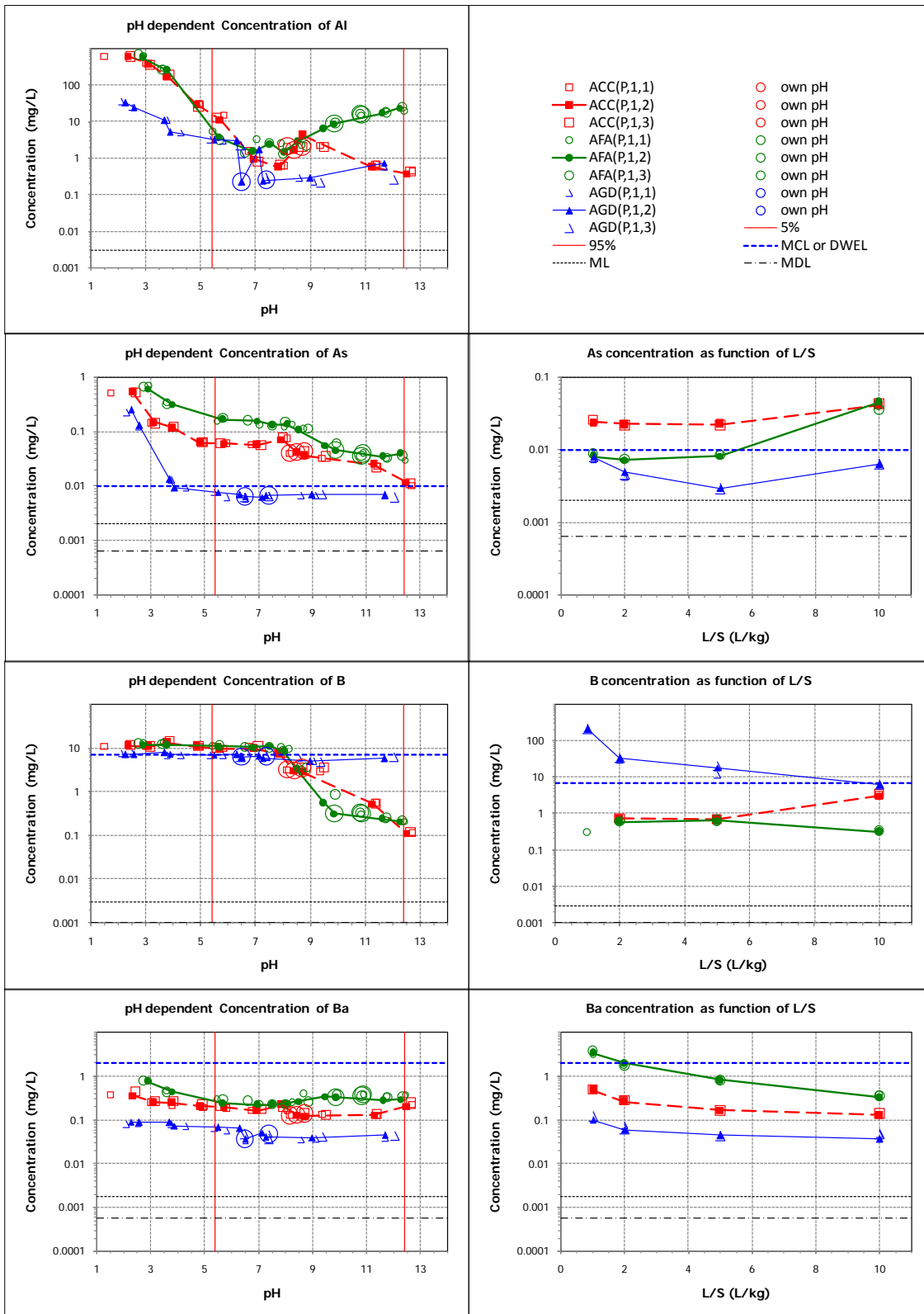
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



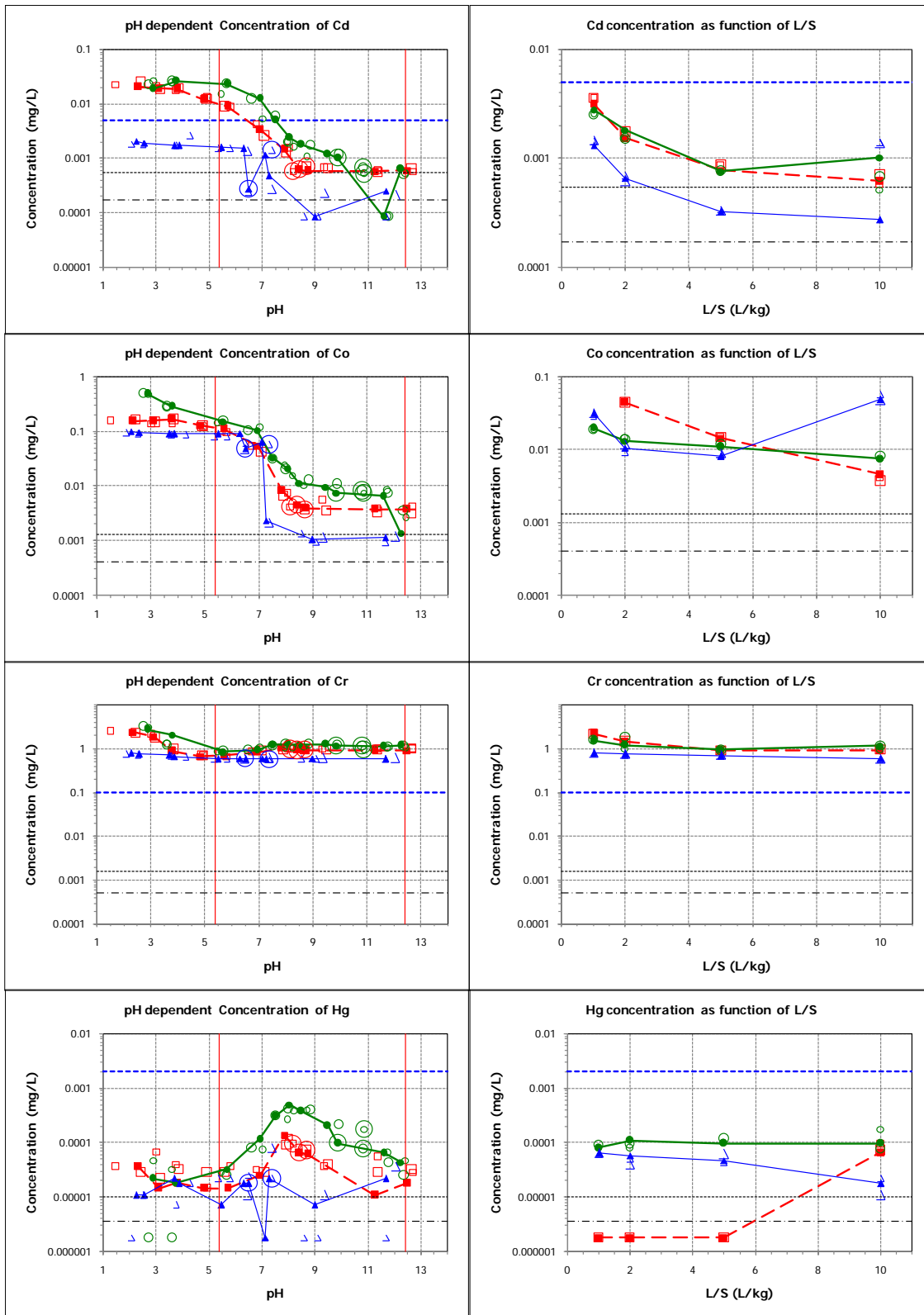
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



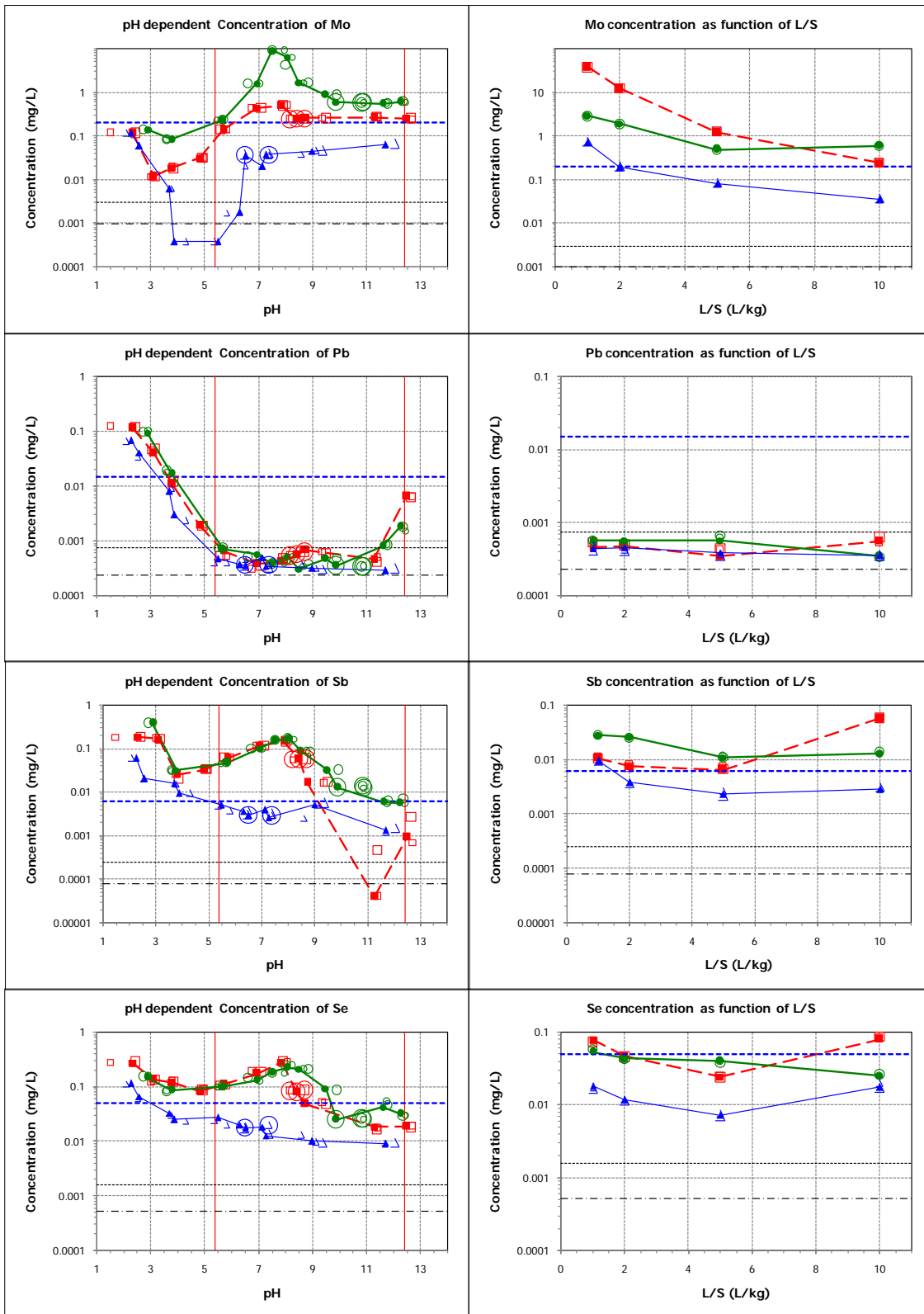
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA - fly ash; **CGD** - scrubber sludge; **CCC** - mixed fly ash and scrubber sludge (as managed).



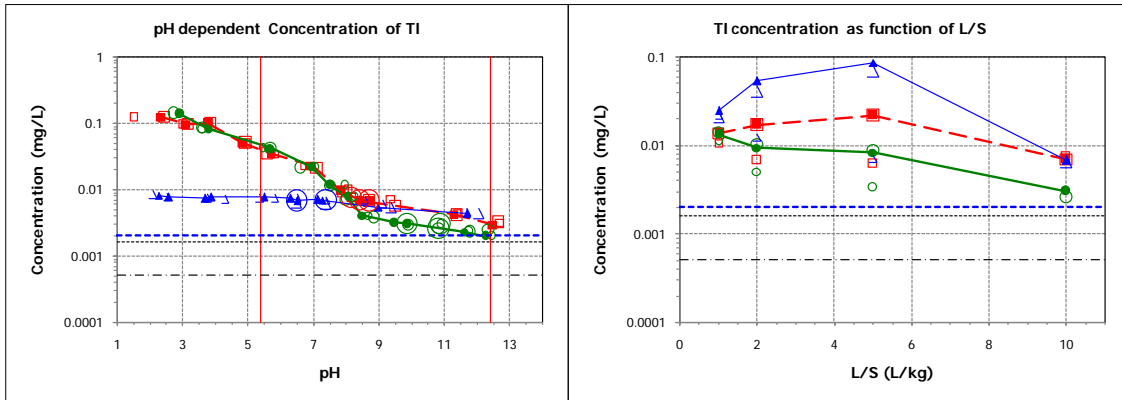
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



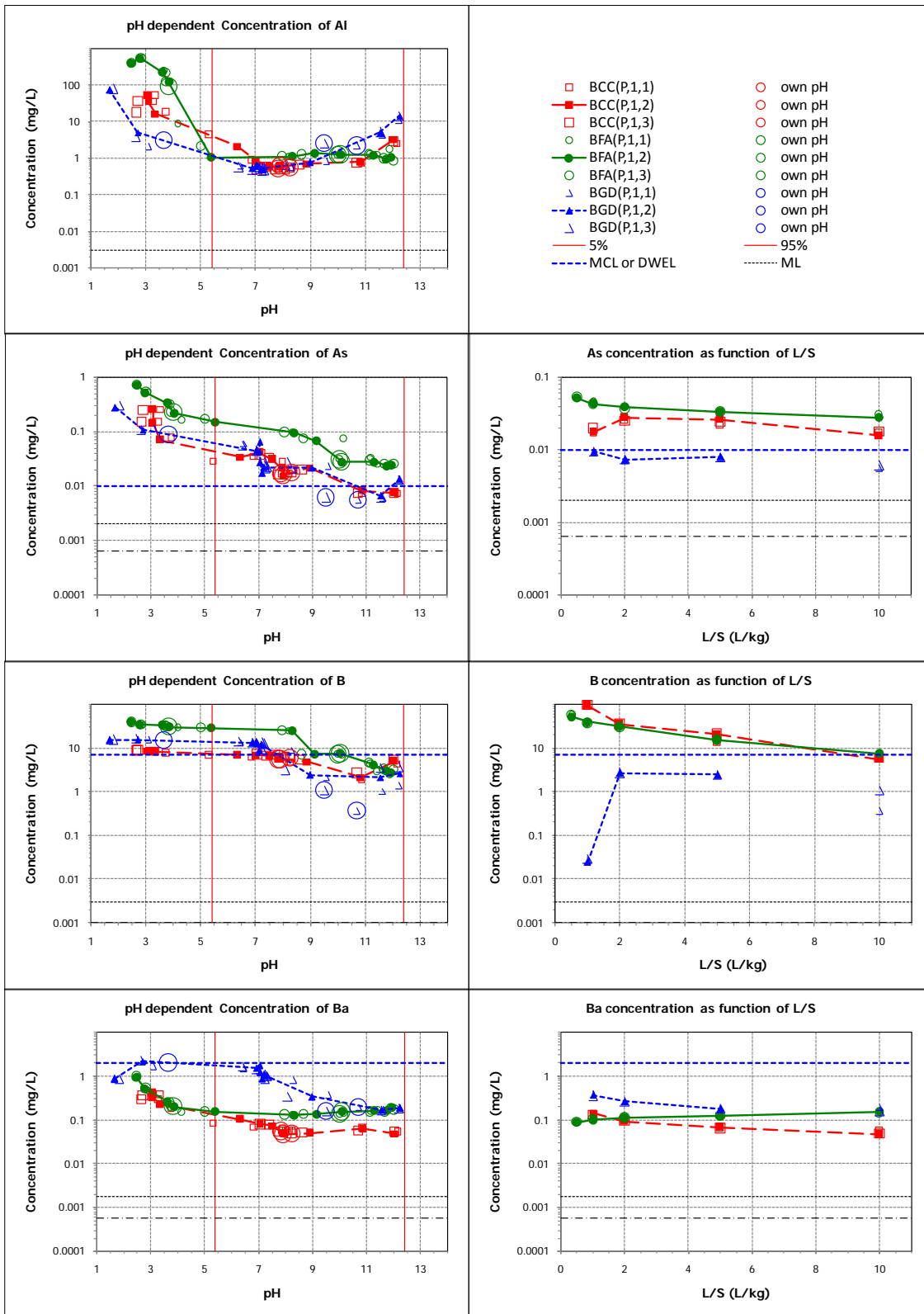
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



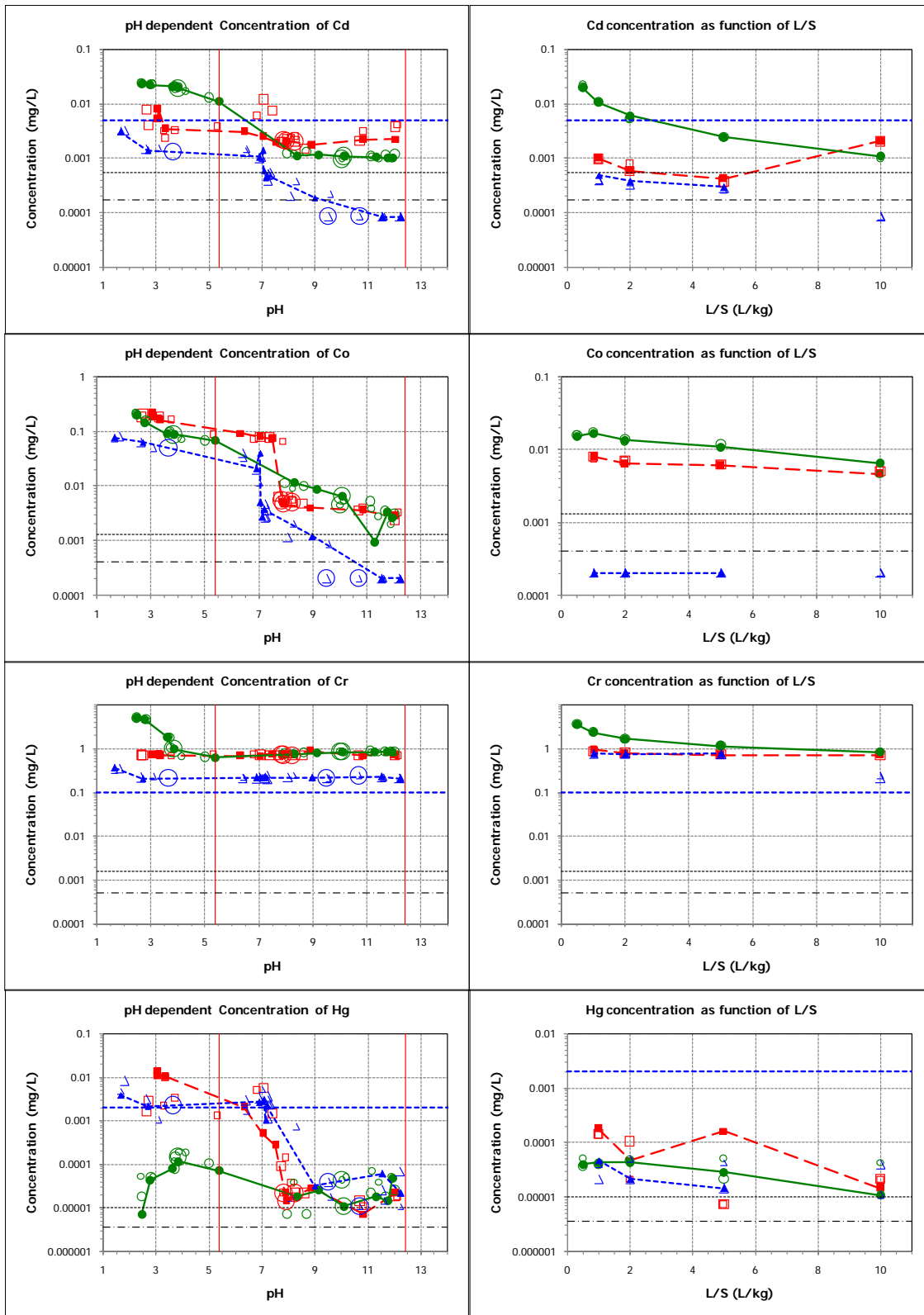
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



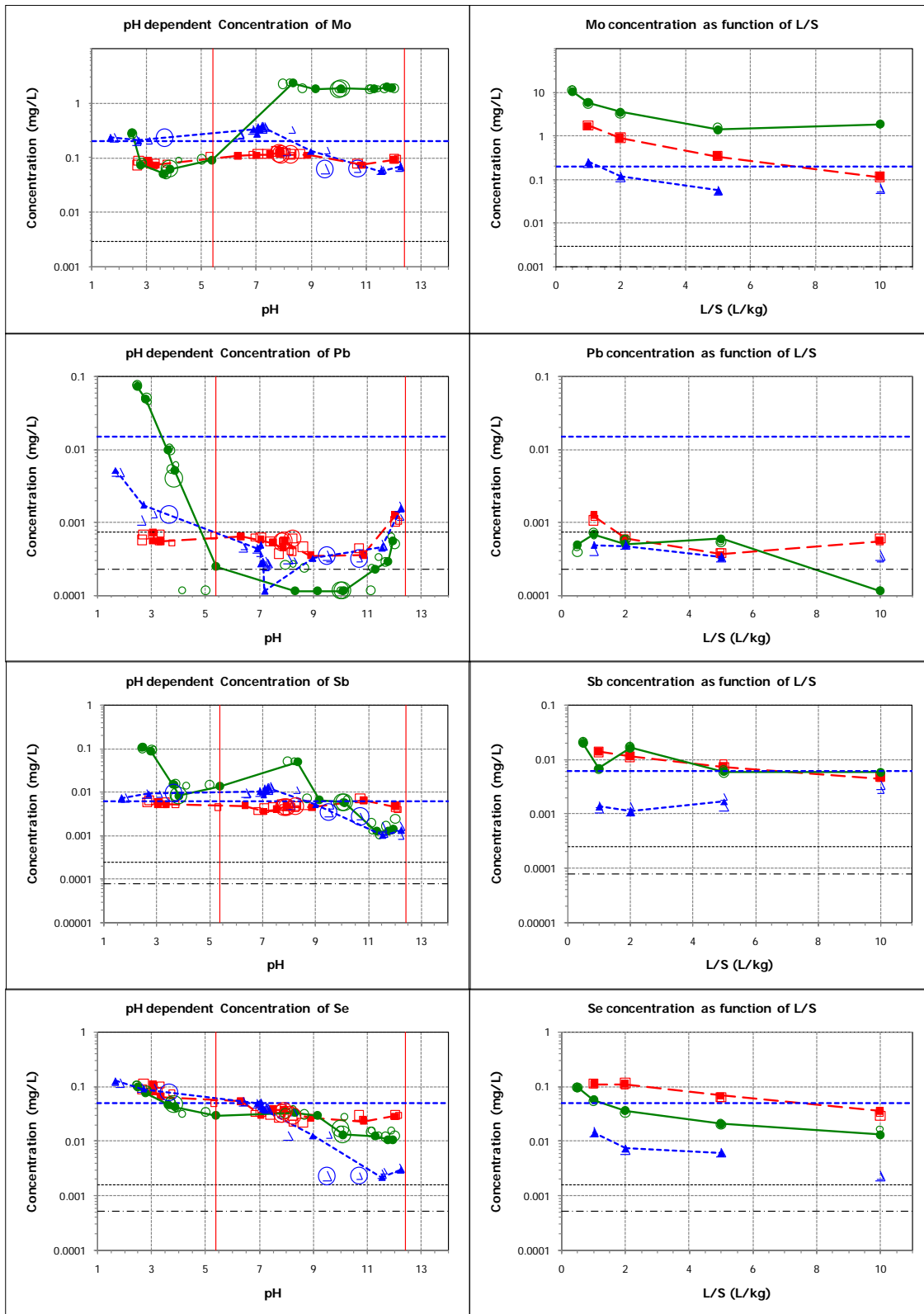
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA - fly ash; **AGD** - scrubber sludge; **ACC** - mixed fly ash and scrubber sludge (as managed).



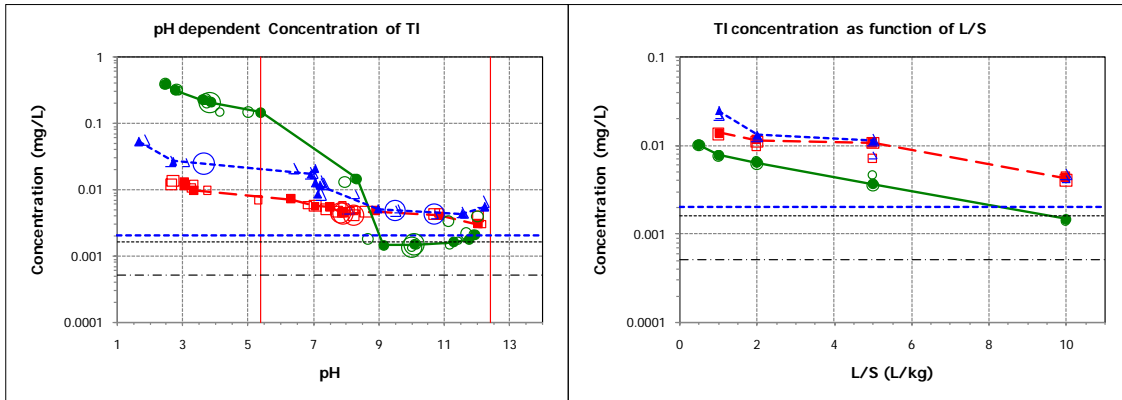
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



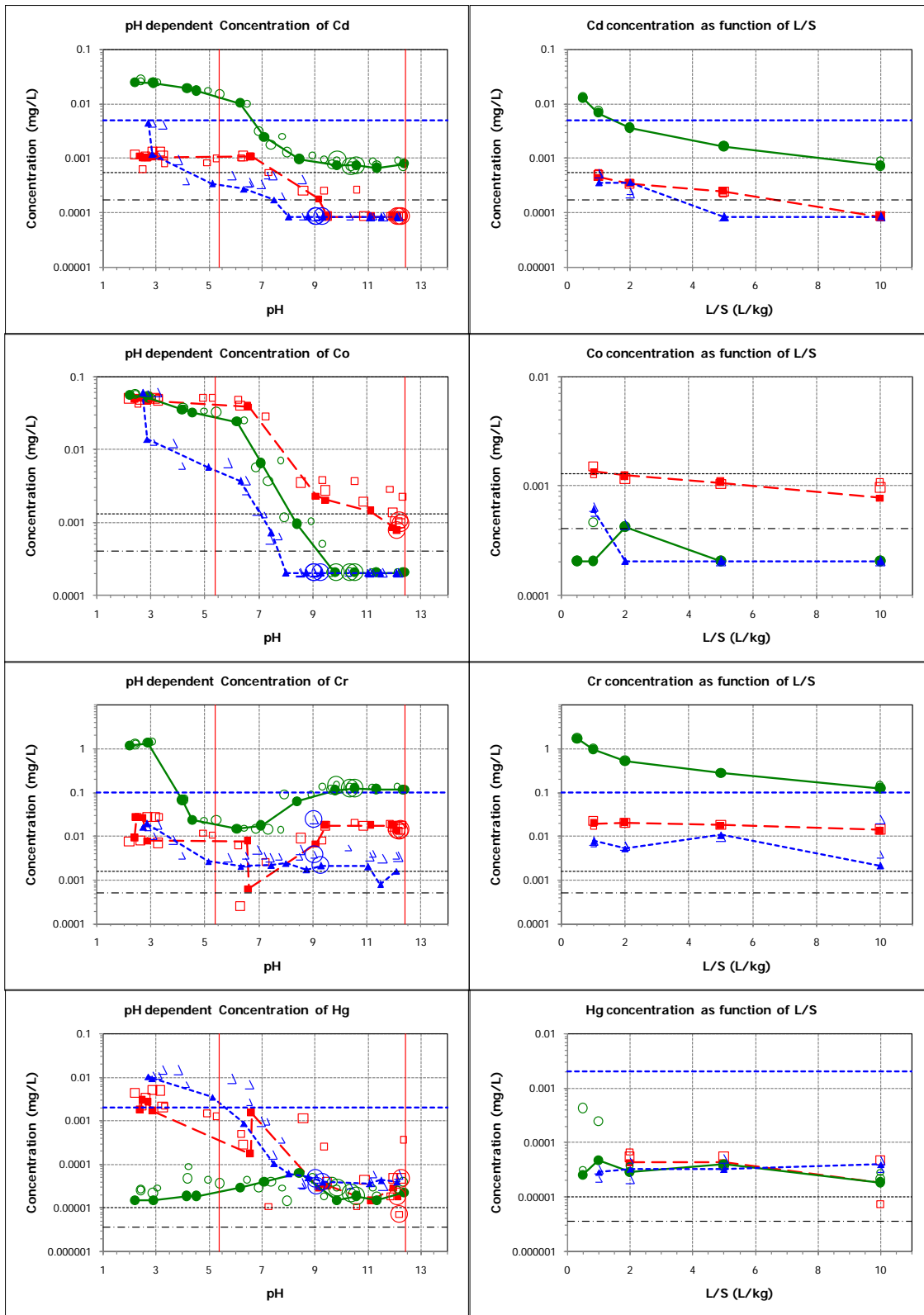
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



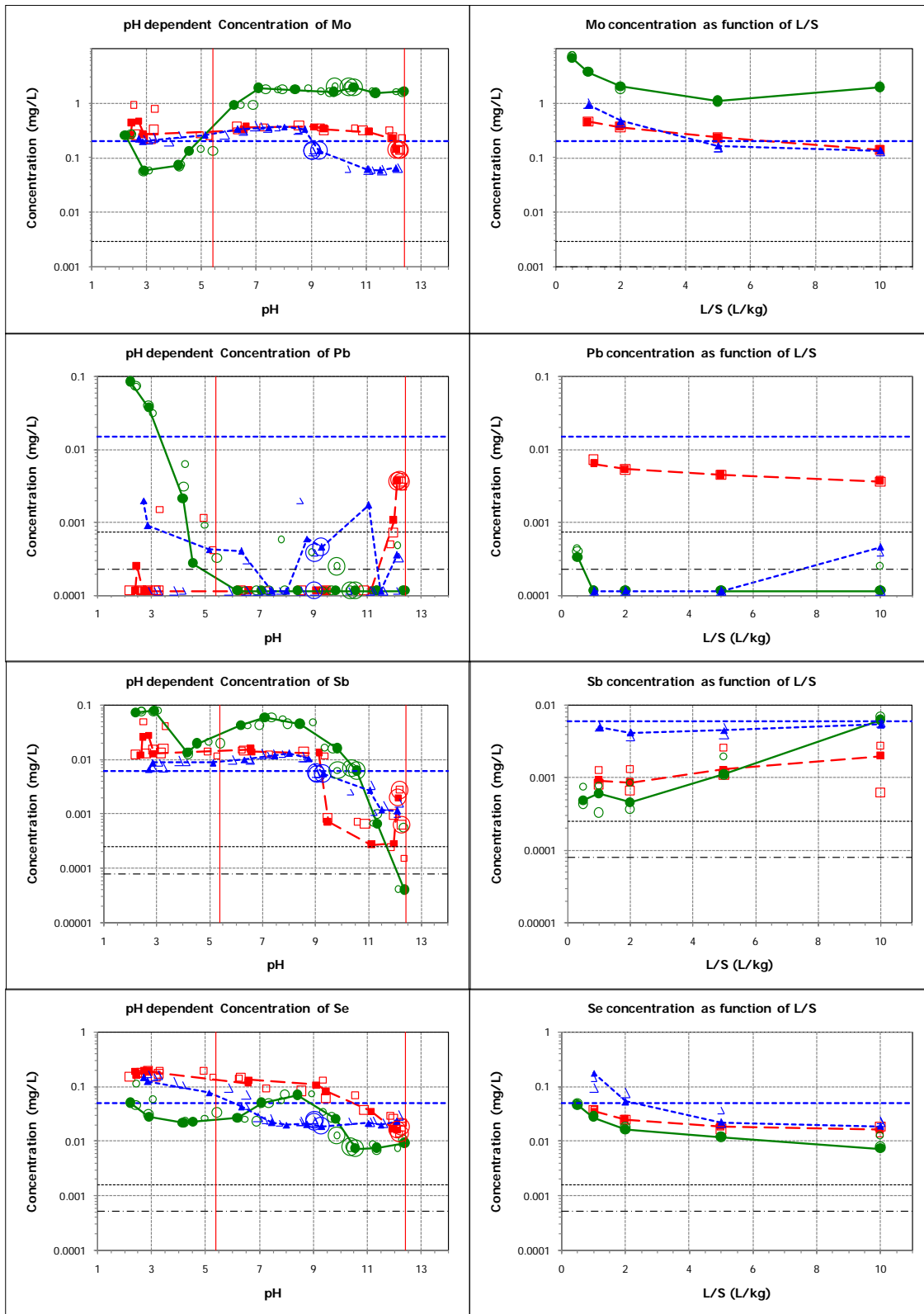
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



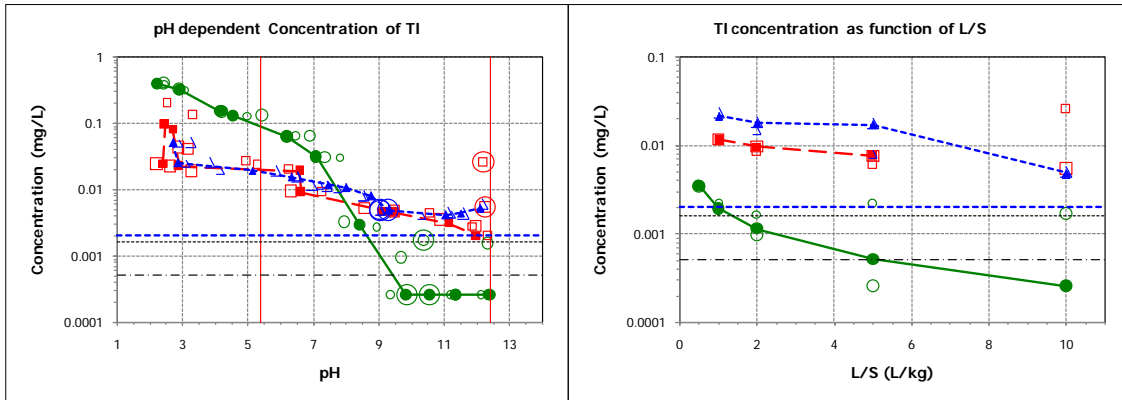
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA - fly ash; **BGD** - scrubber sludge; **BCC** - mixed fly ash and scrubber sludge (as managed).



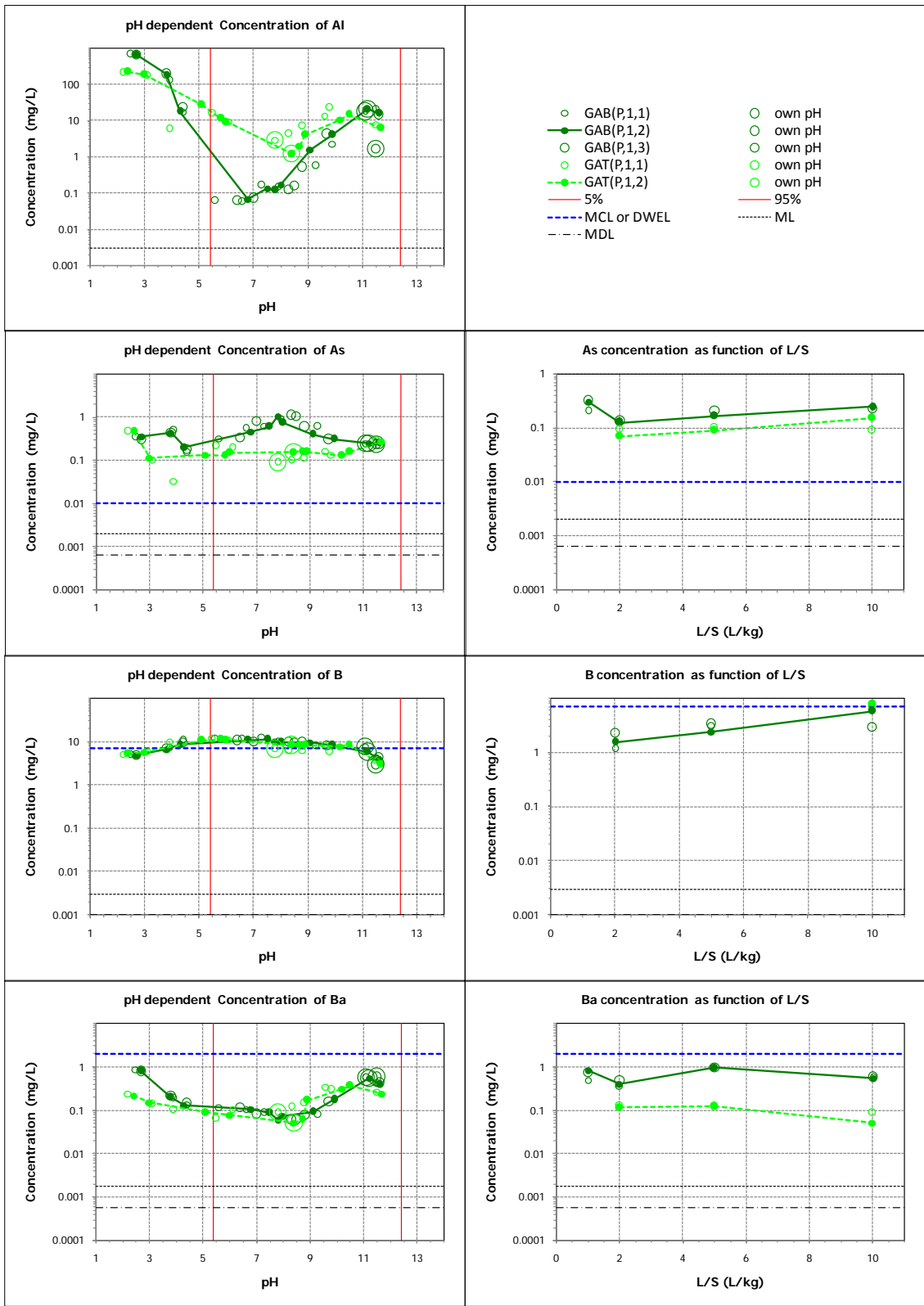
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



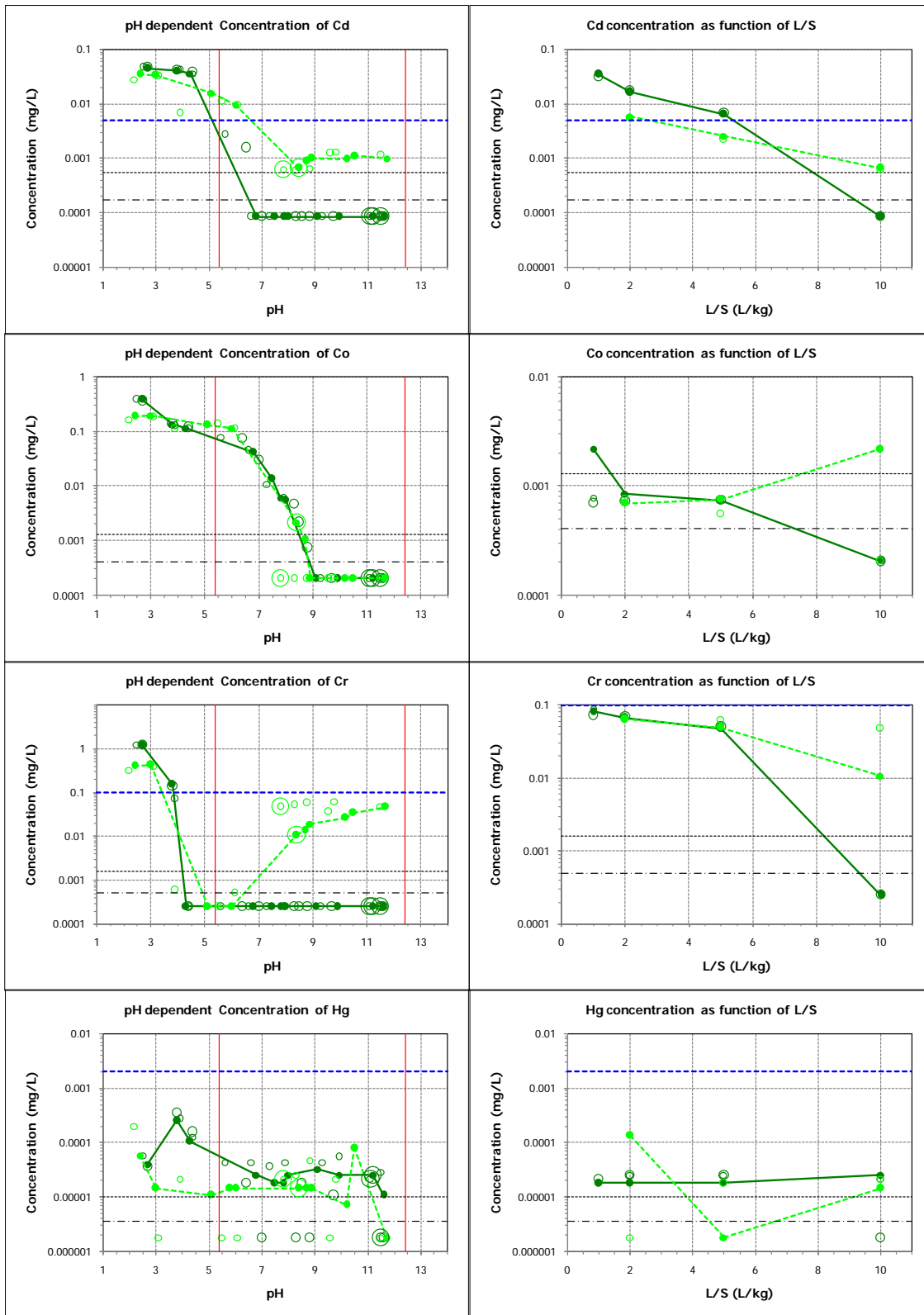
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



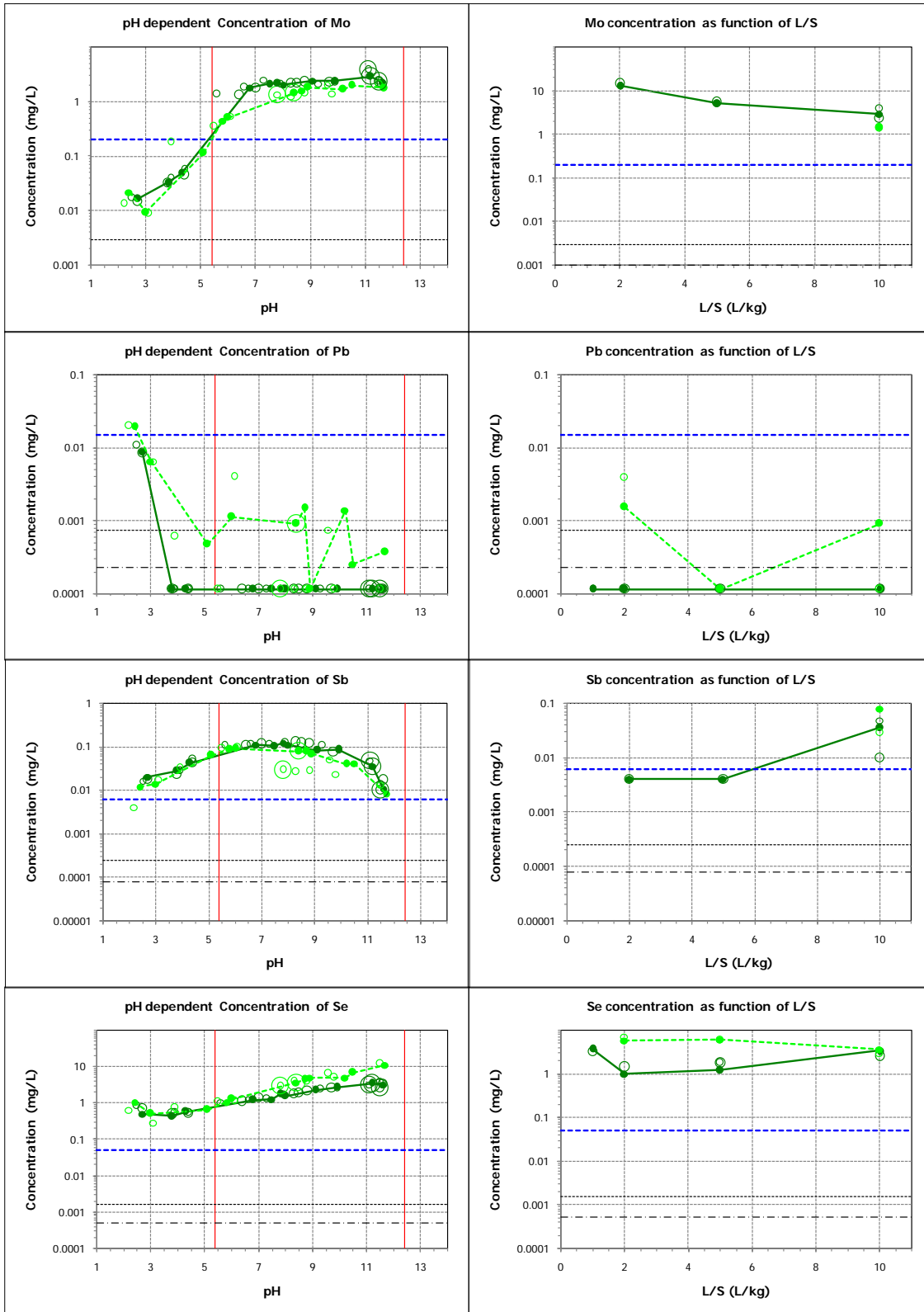
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA - fly ash; **DGD** - scrubber sludge; **DCC** - mixed fly ash and scrubber sludge (as managed).



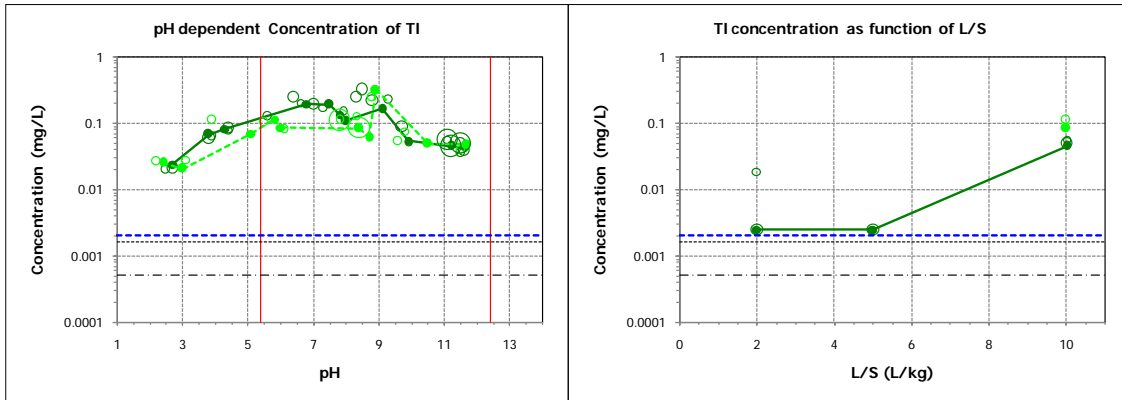
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



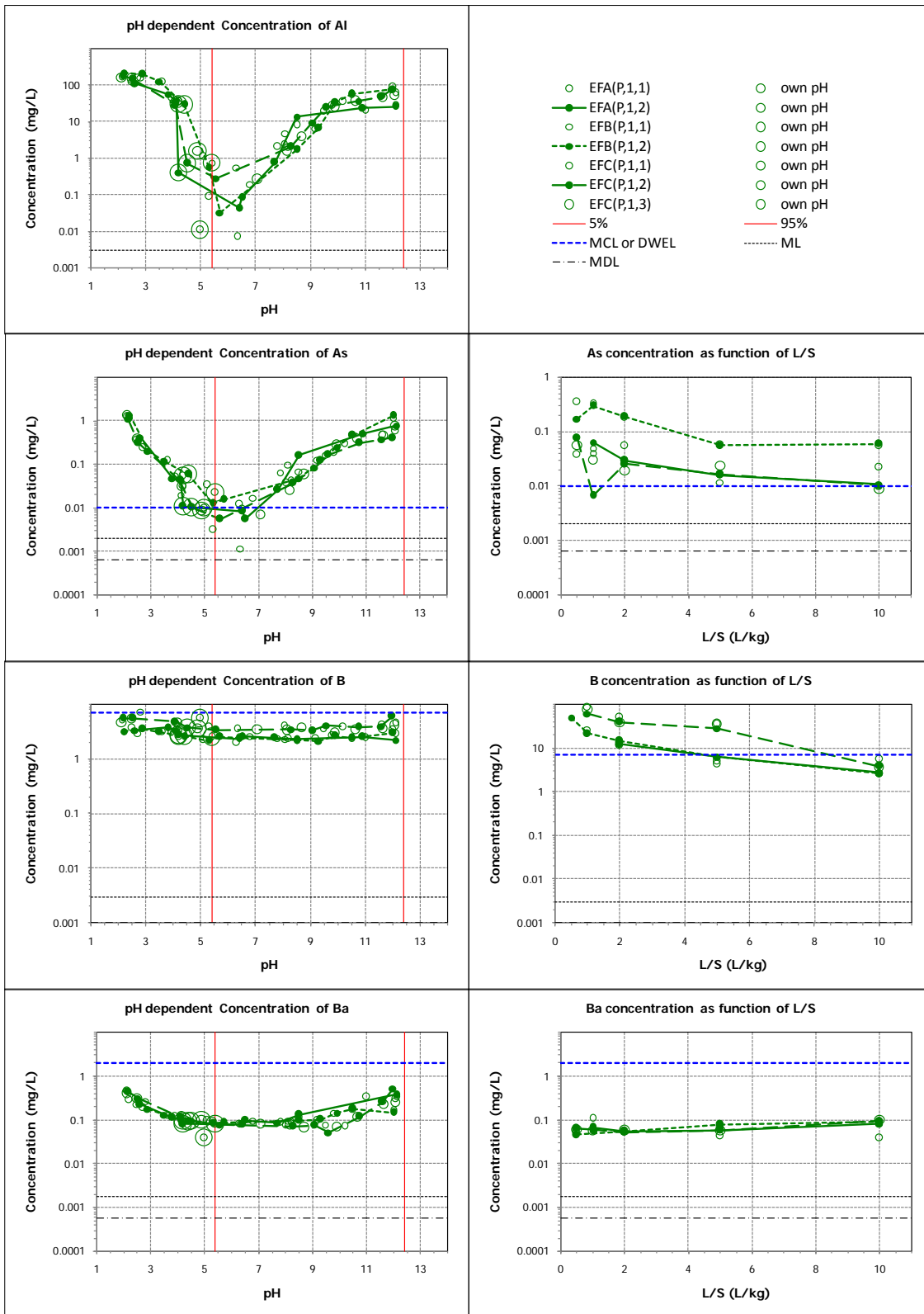
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



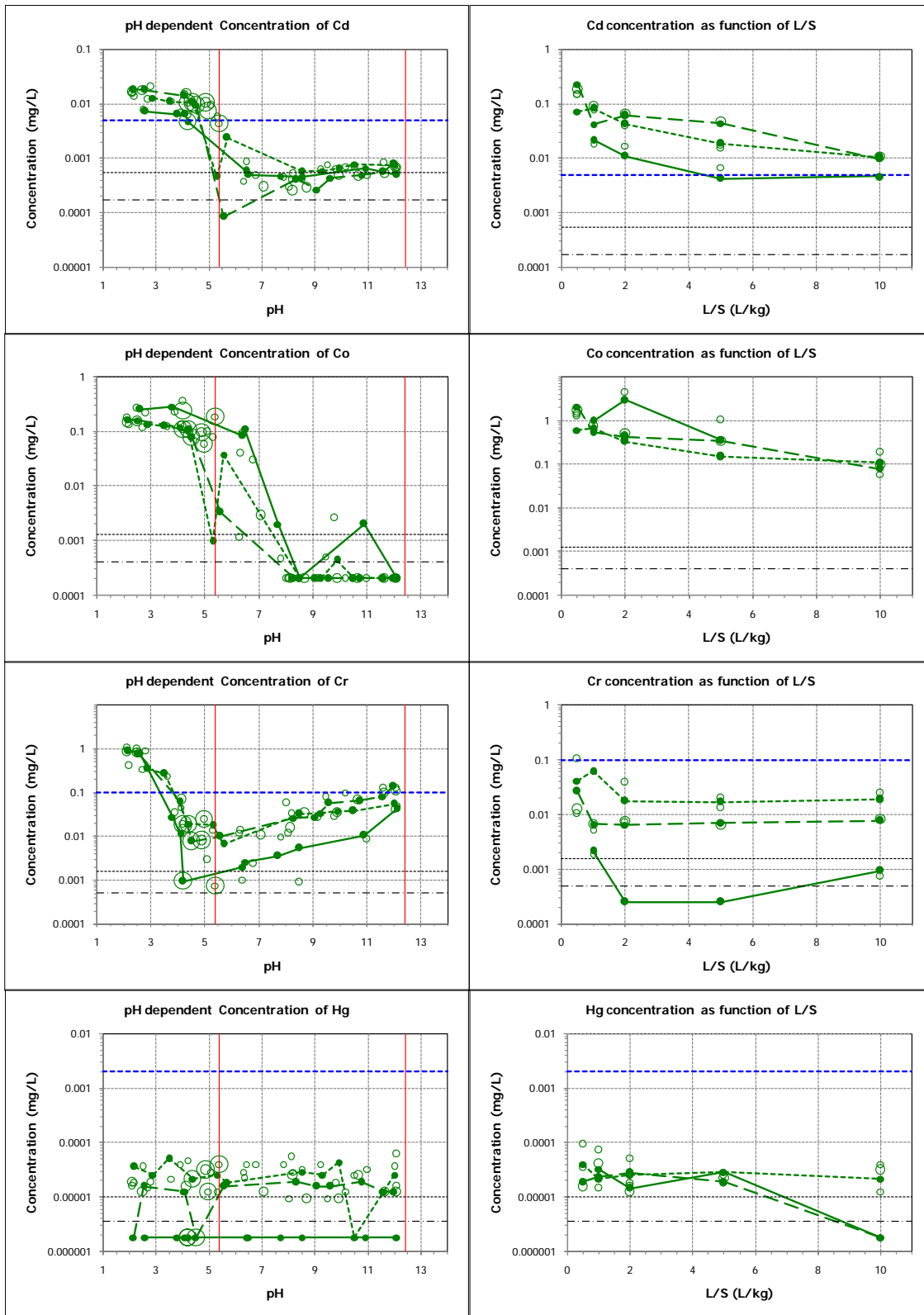
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



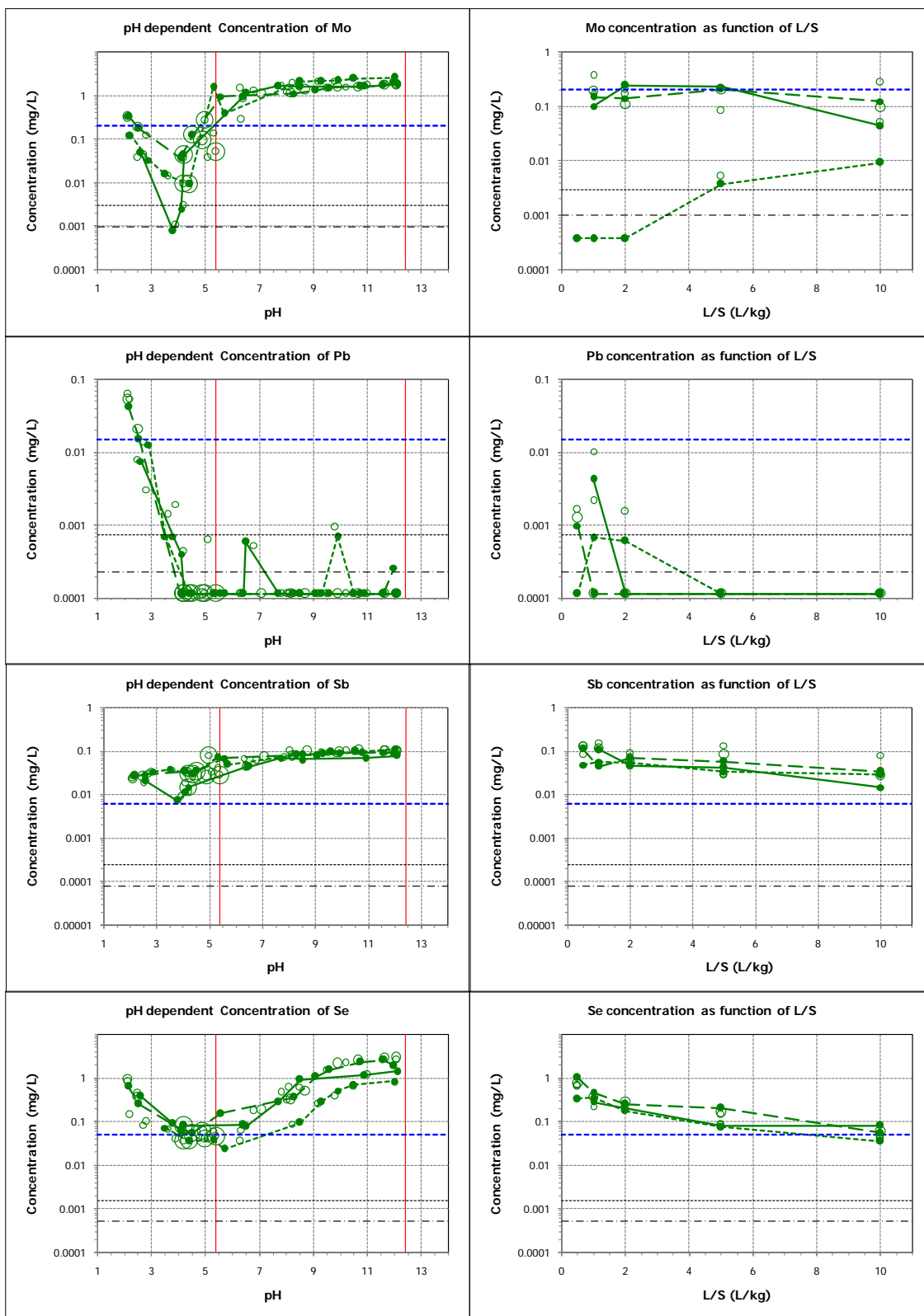
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** - fly ash without ACI; **GAT** fly ash with ACI.



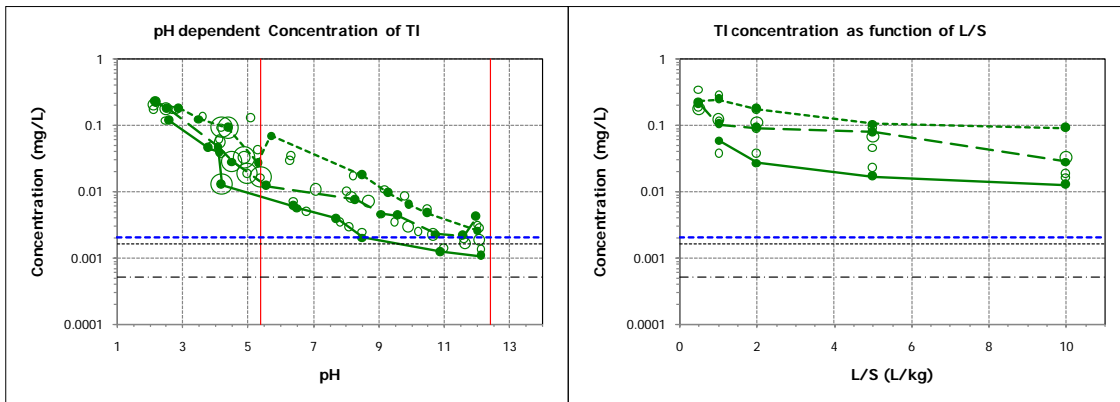
Facility E (Med. S East-Bit.). EFA, EFC - fly ash SCR on; EFB - fly ash SCR-BP.



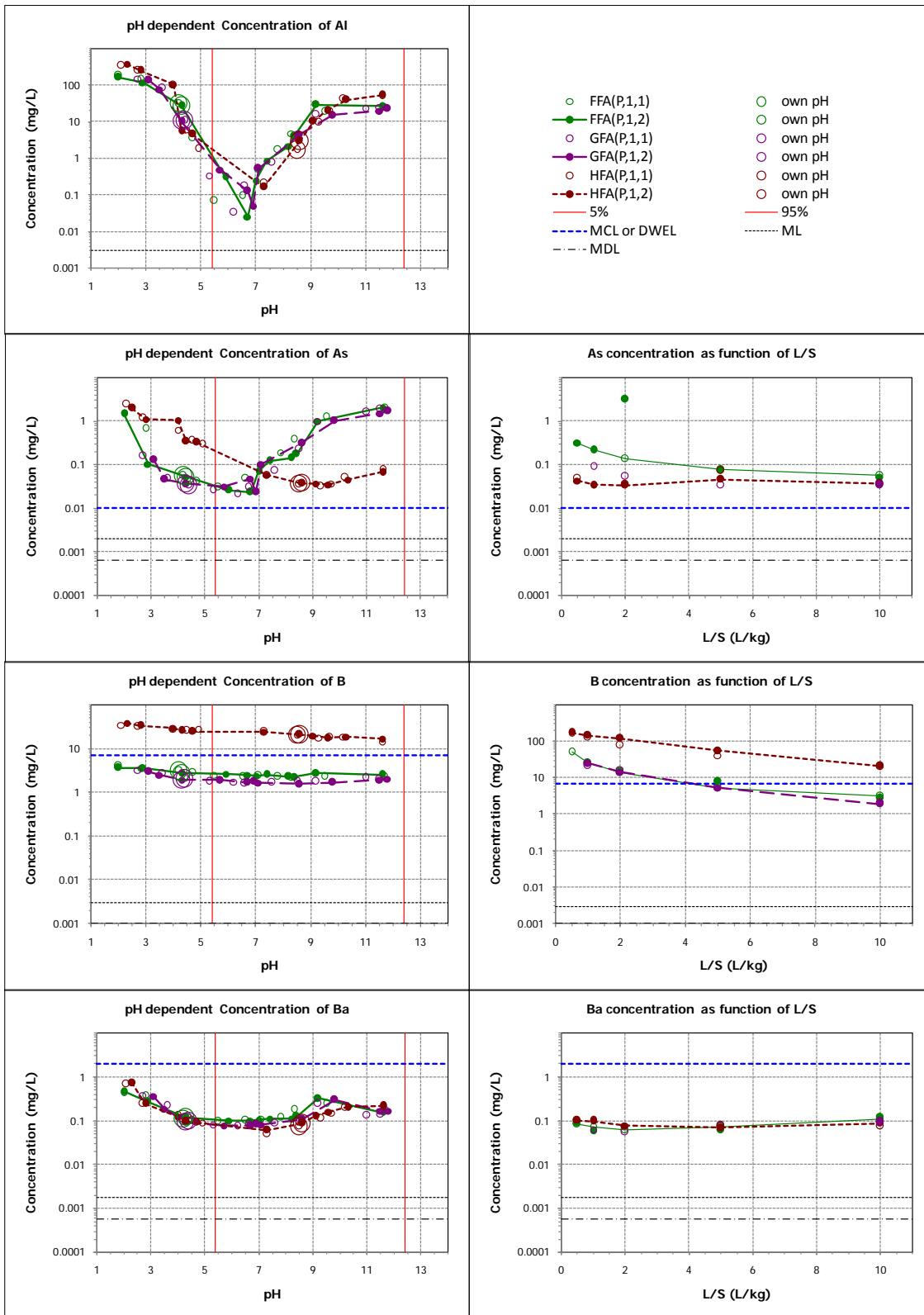
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



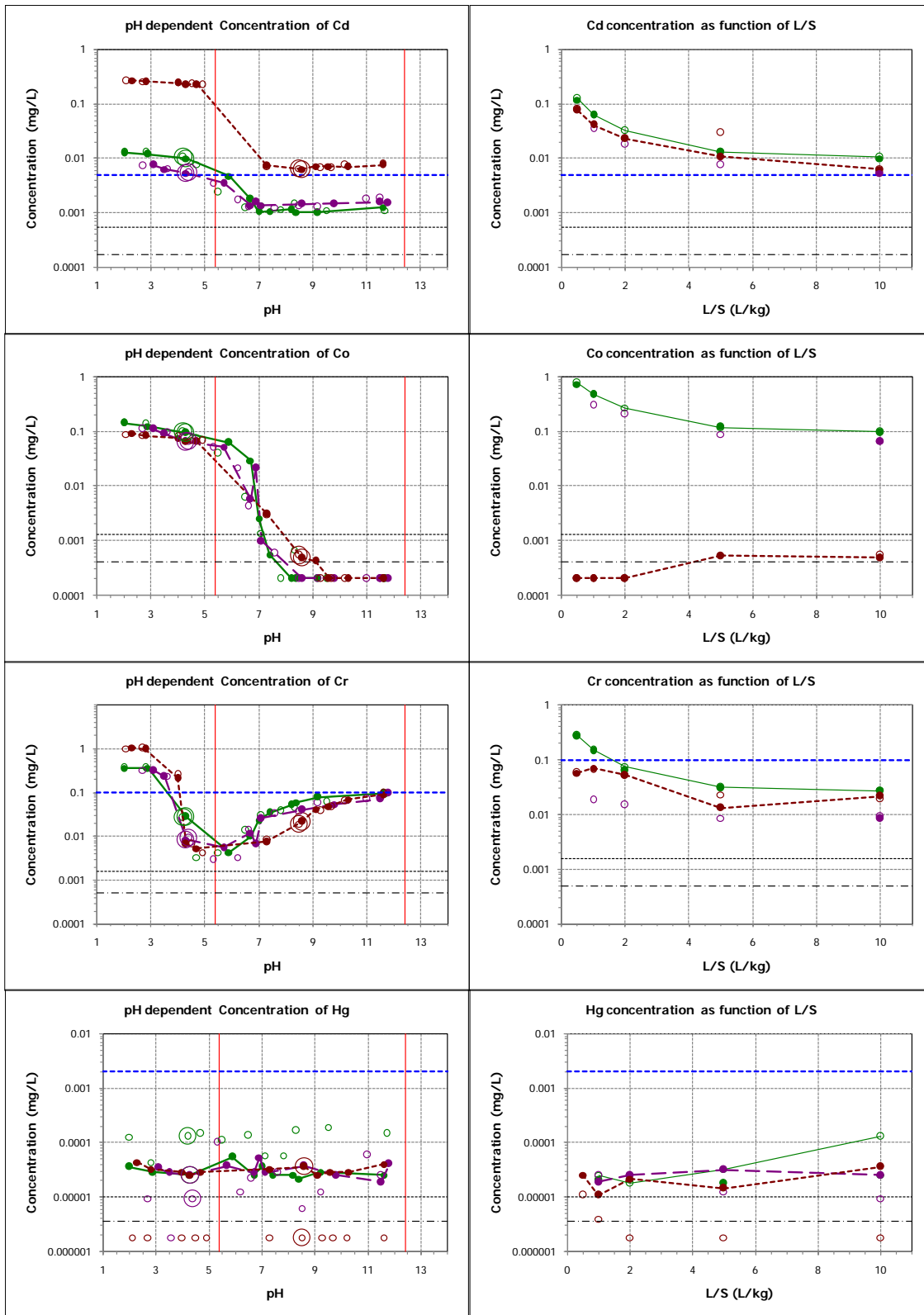
Facility E (Med. S East-Bit.). **EFA, EFC** - fly ash SCR on; **EFB** - fly ash SCR-BP.



Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.

Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.

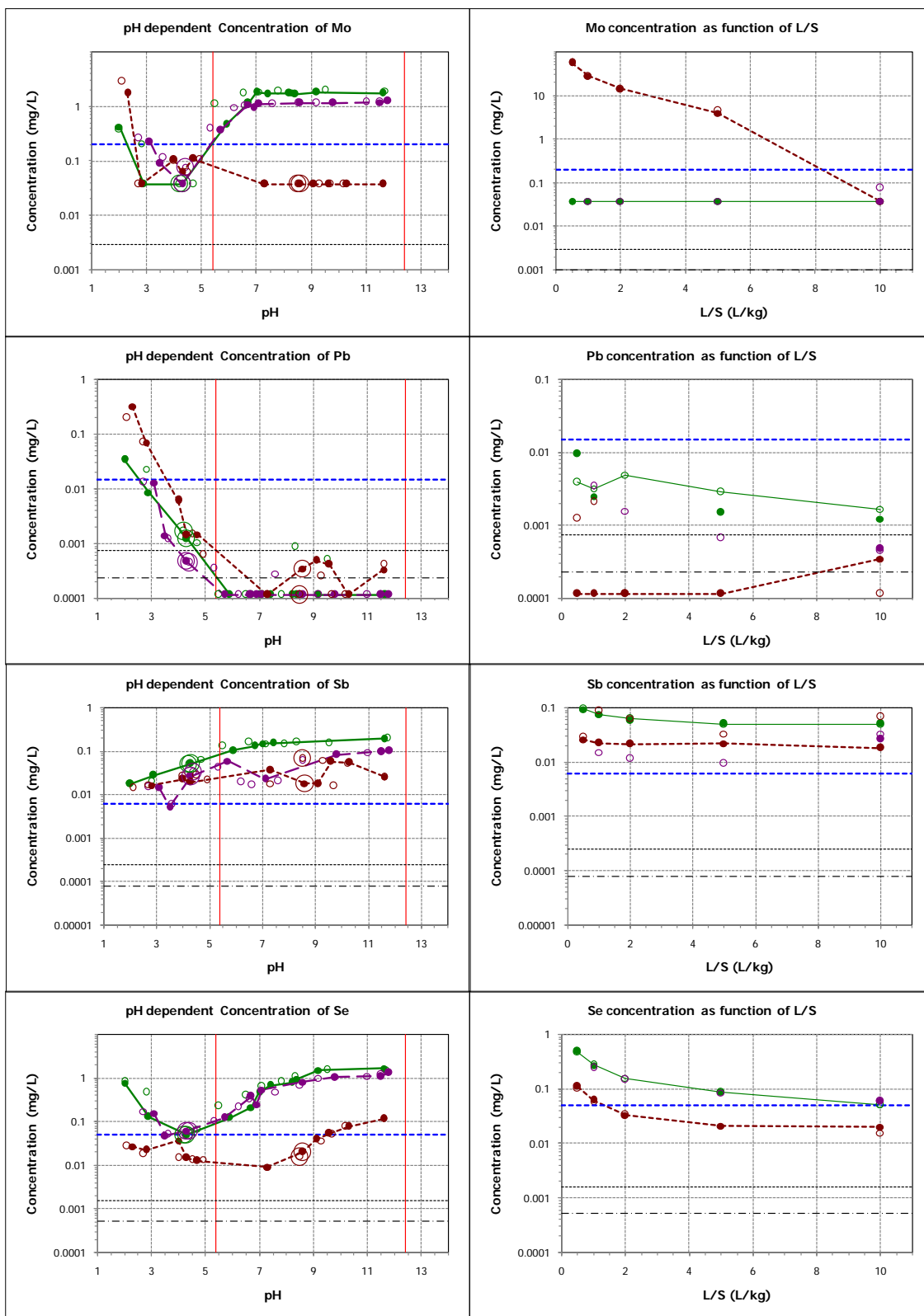
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.

Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.

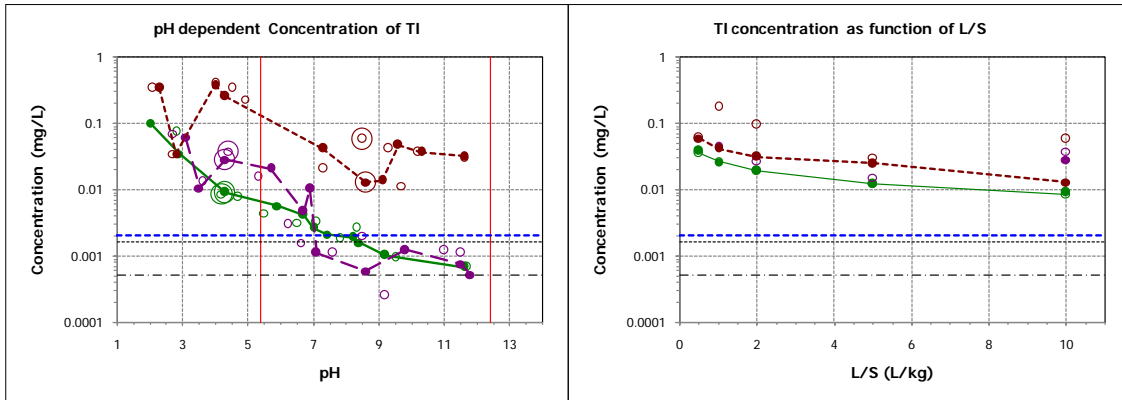
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.

Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.

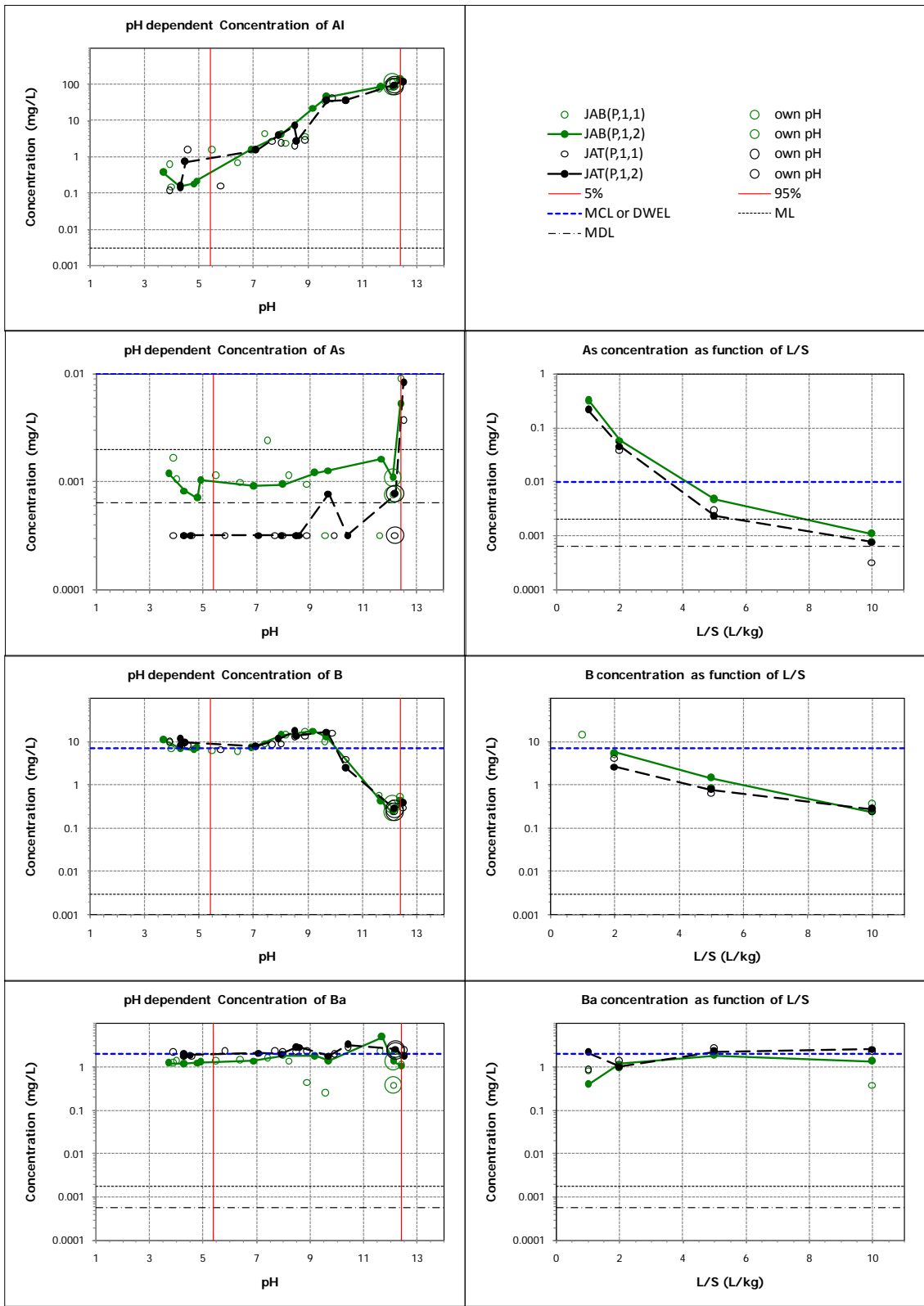
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



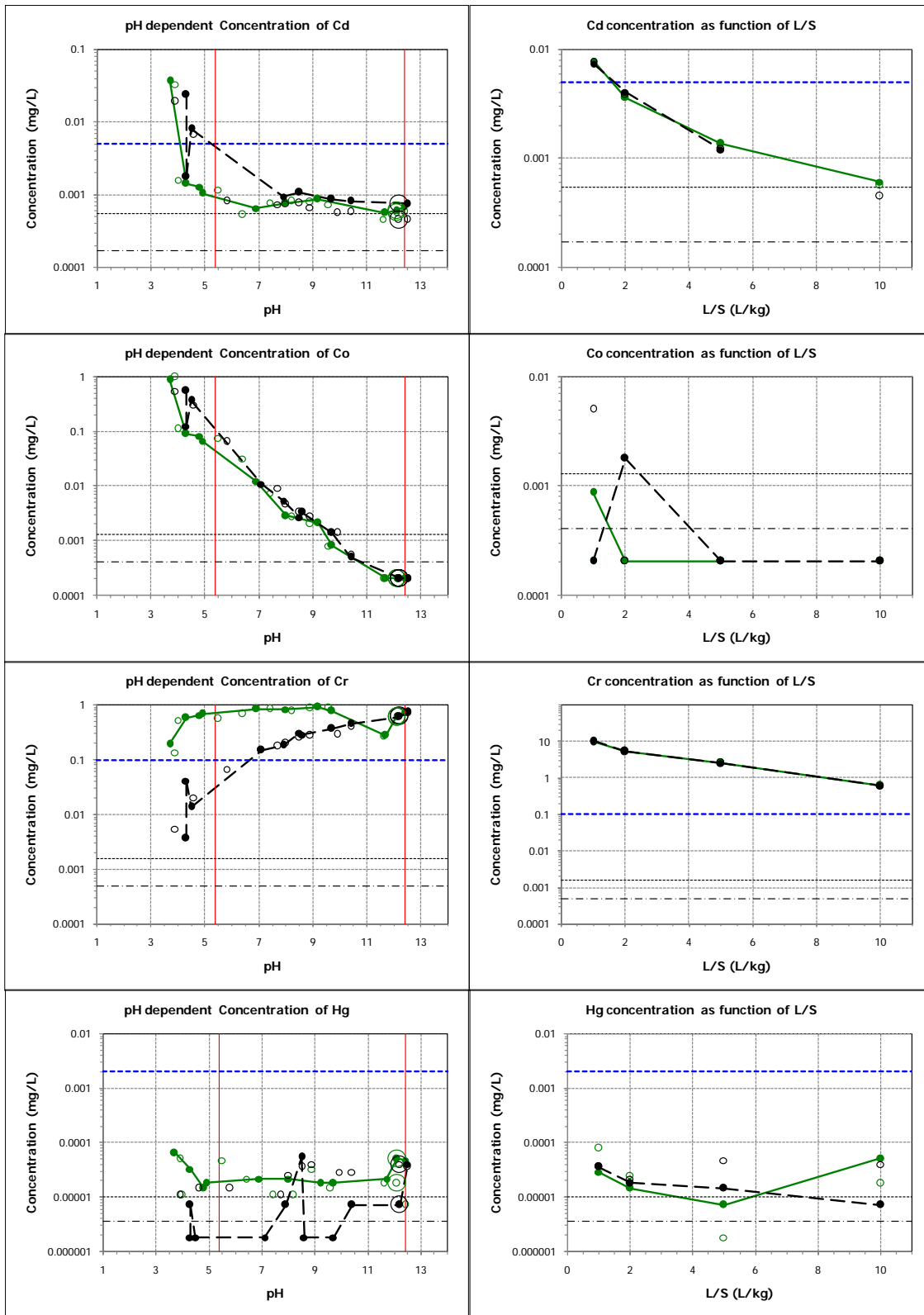
Facility F (Low S East-Bit., CS-ESP). **FFA** - fly ash.

Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** - fly ash.

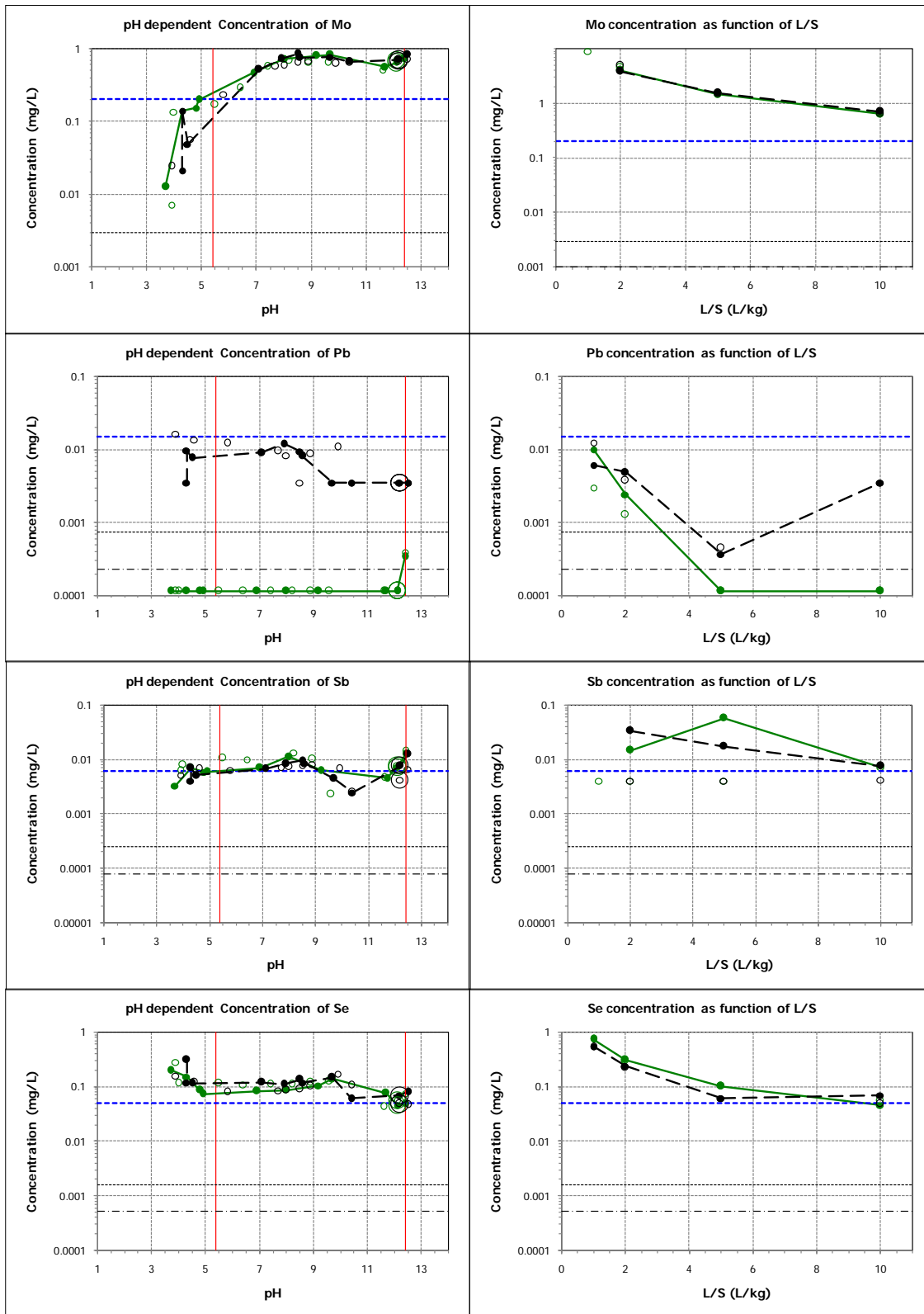
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** - fly ash.



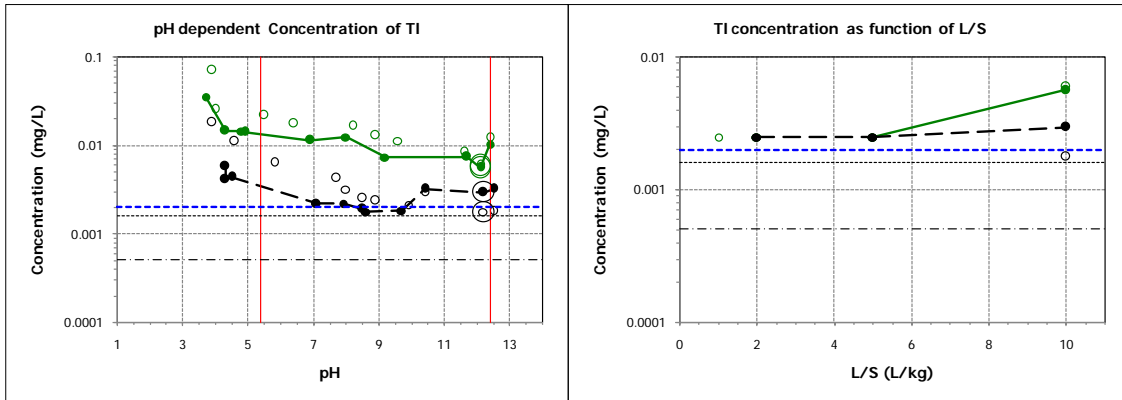
Facility J (PRB/Low S Bit mix., CS-ESP). JAB - fly ash without Br-ACI; JAT - fly ash with Br-ACI.



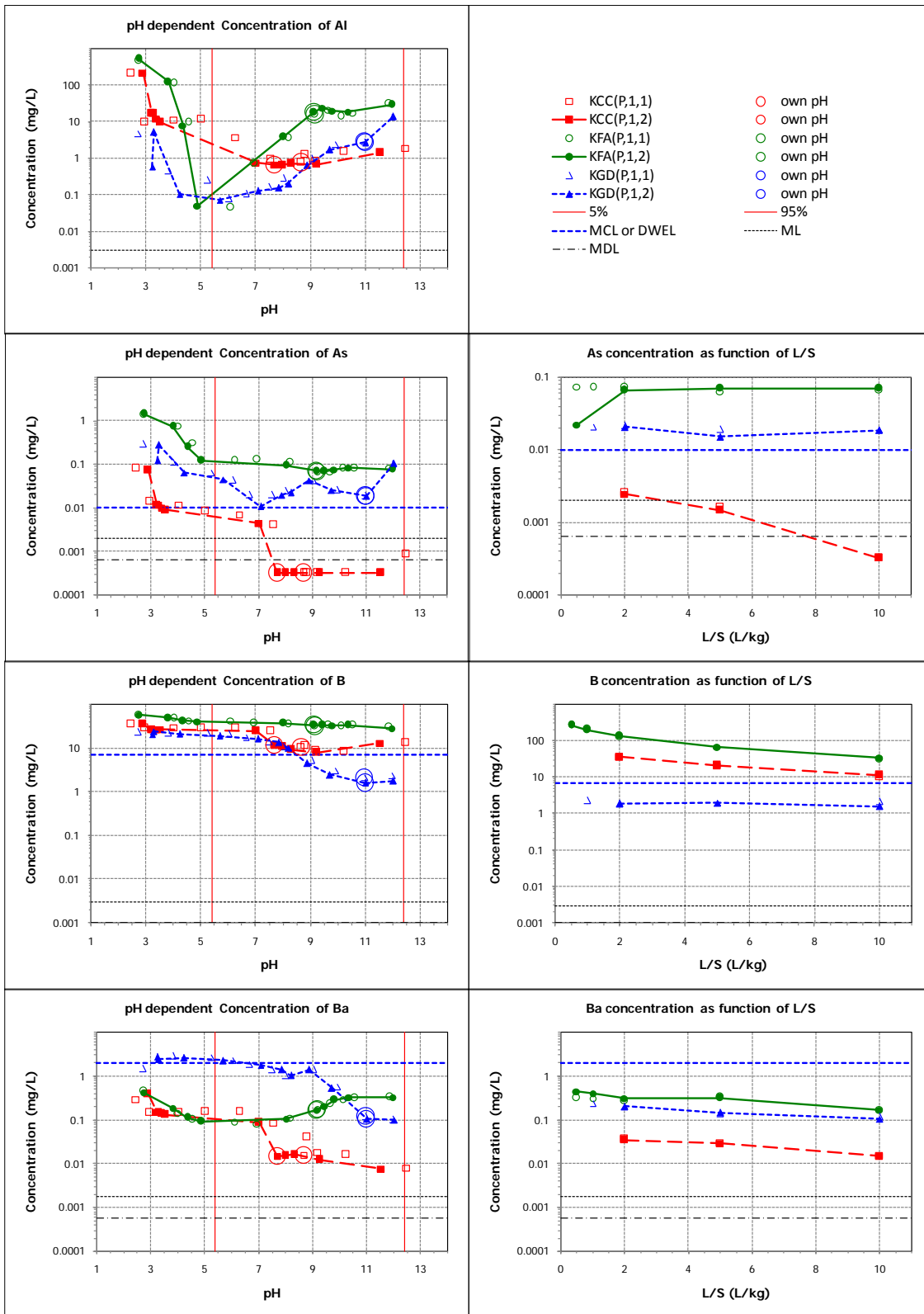
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



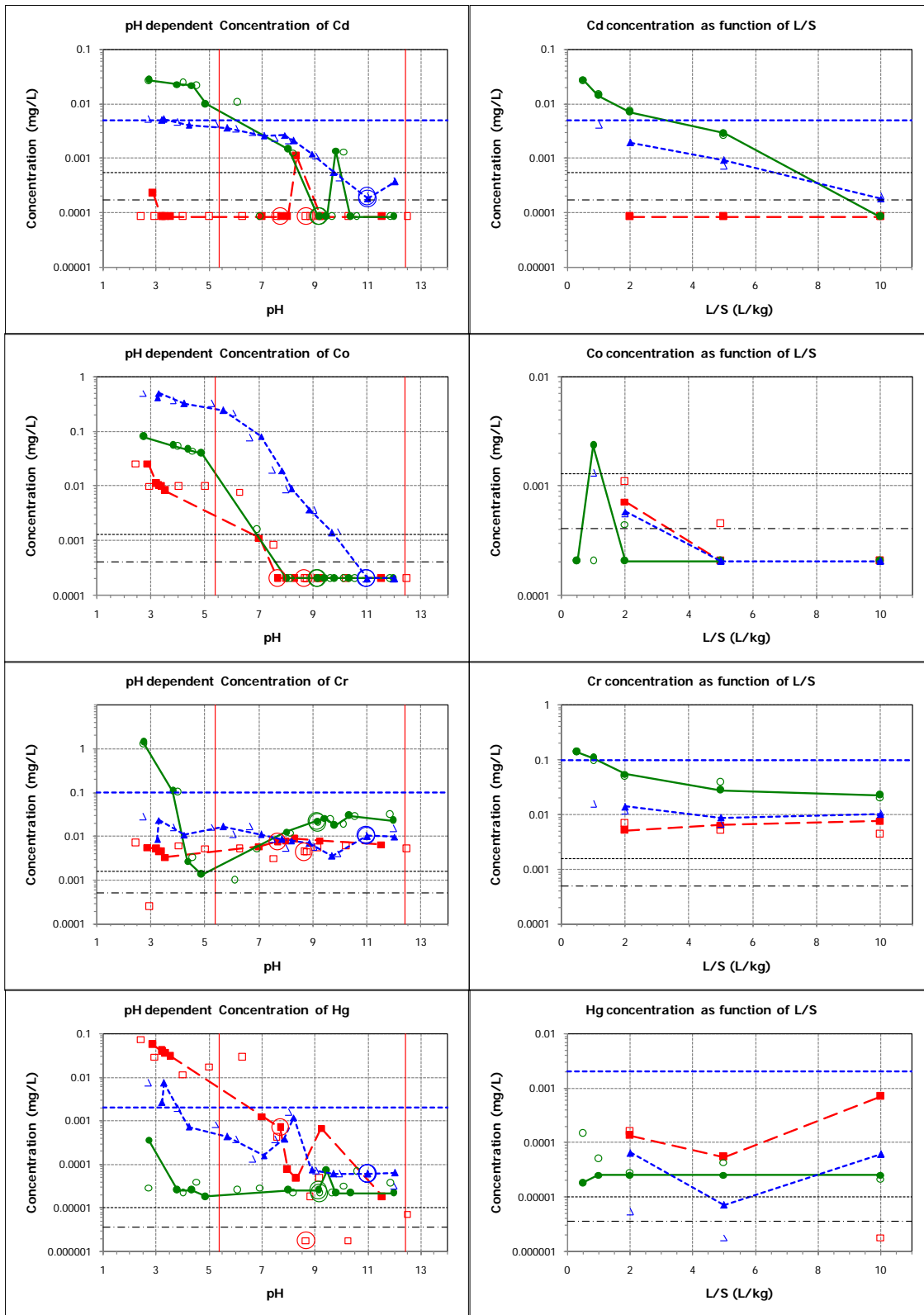
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



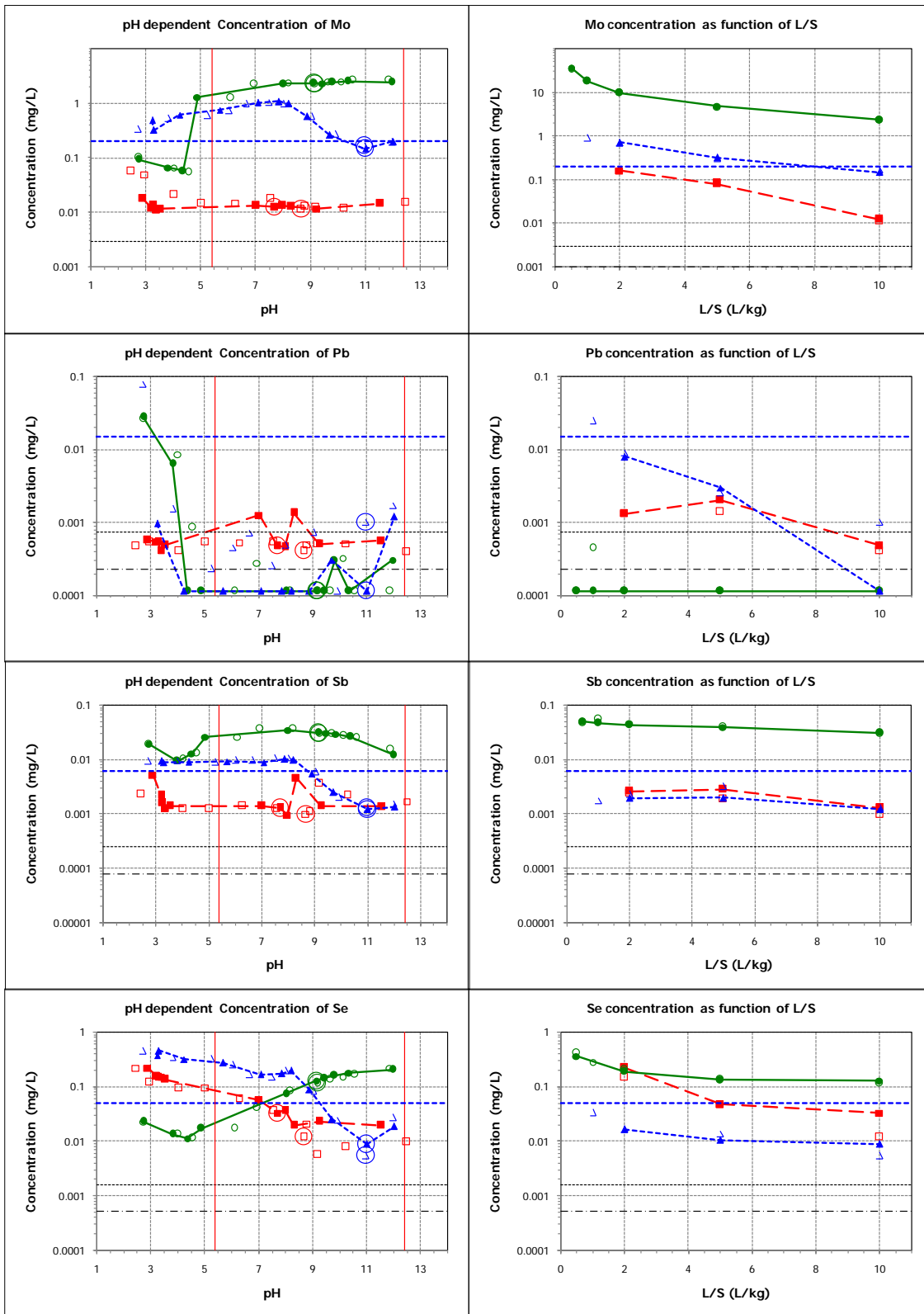
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** - fly ash without Br-ACI; **JAT** - fly ash with Br-ACI.



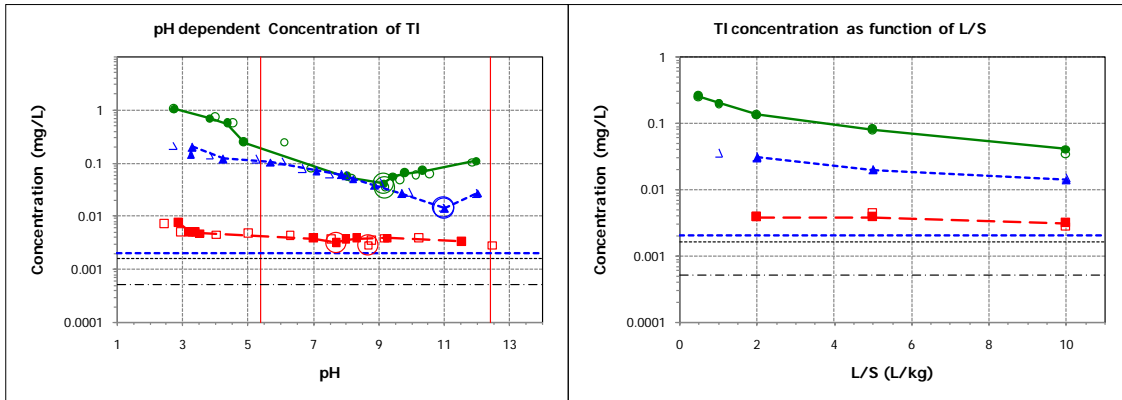
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



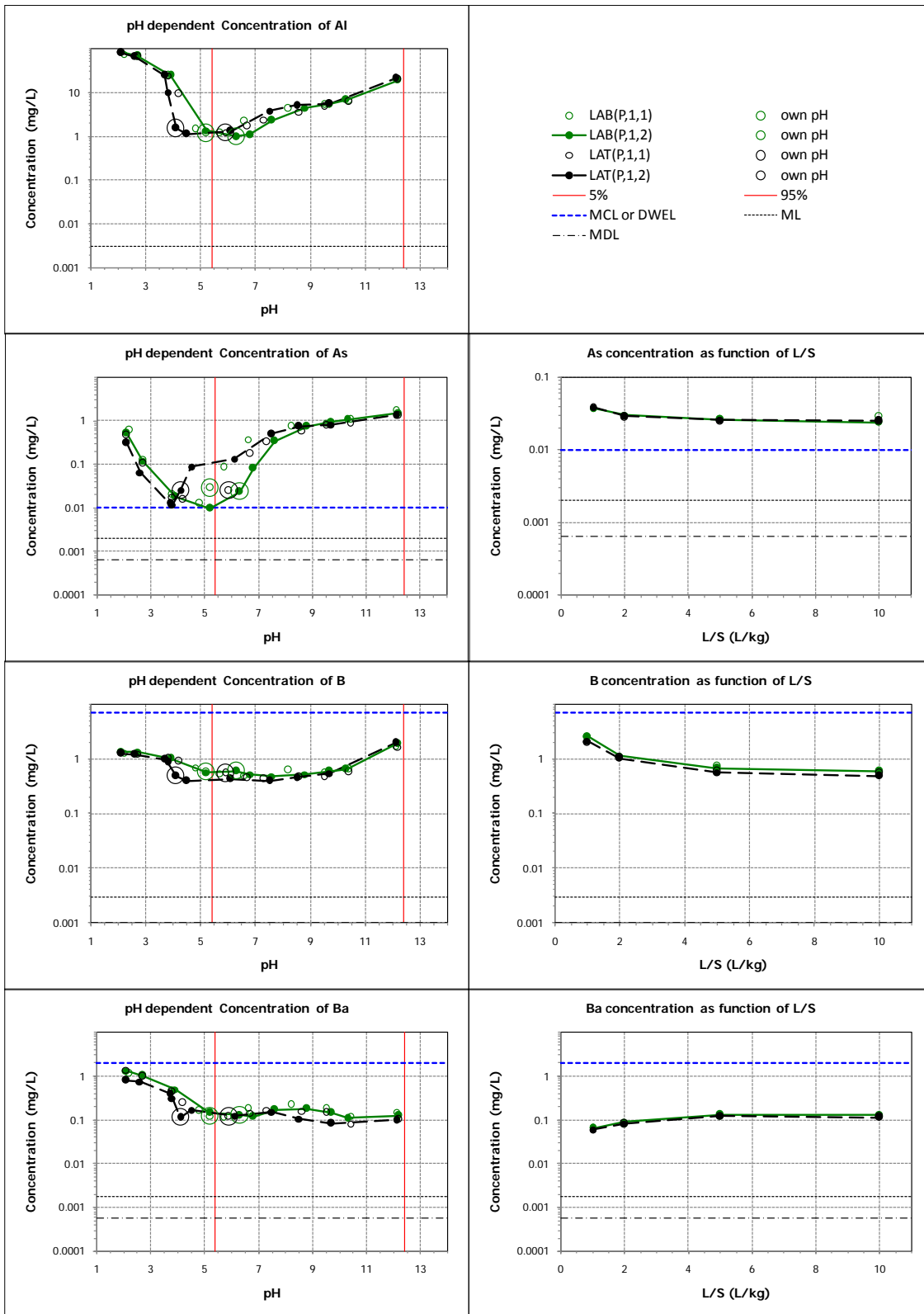
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



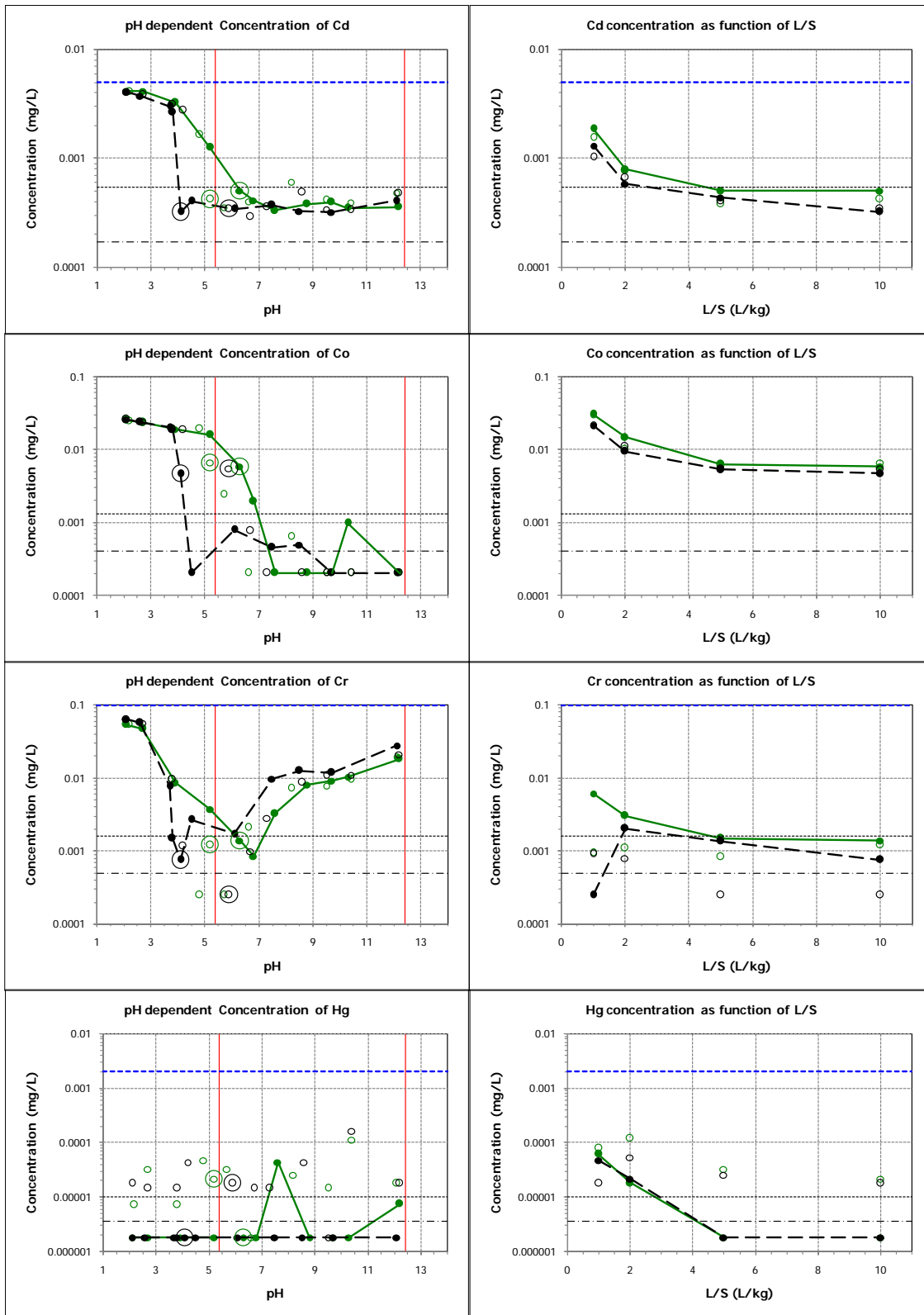
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA - fly ash; **KGD** - scrubber sludge; **KCC** - mixed fly ash and scrubber sludge (as managed).



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).

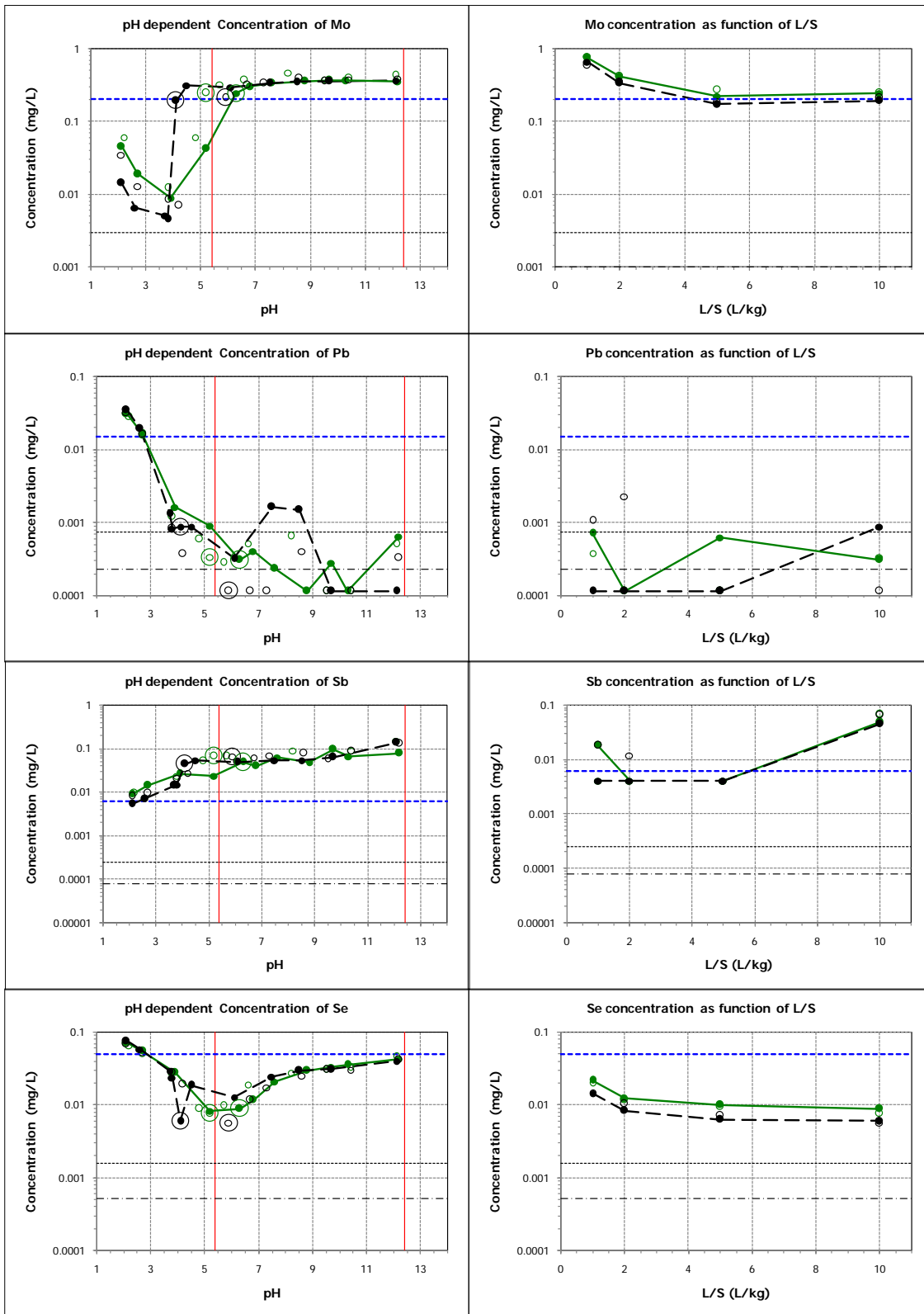


Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



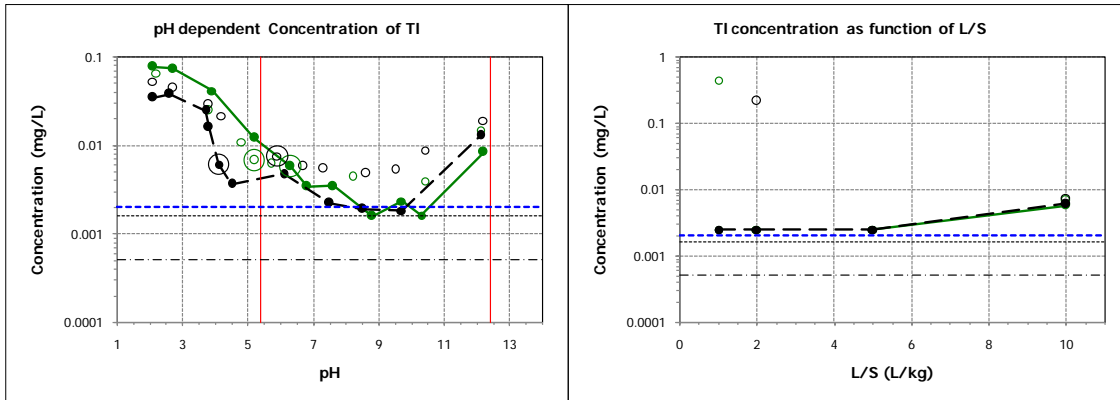
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).

LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.

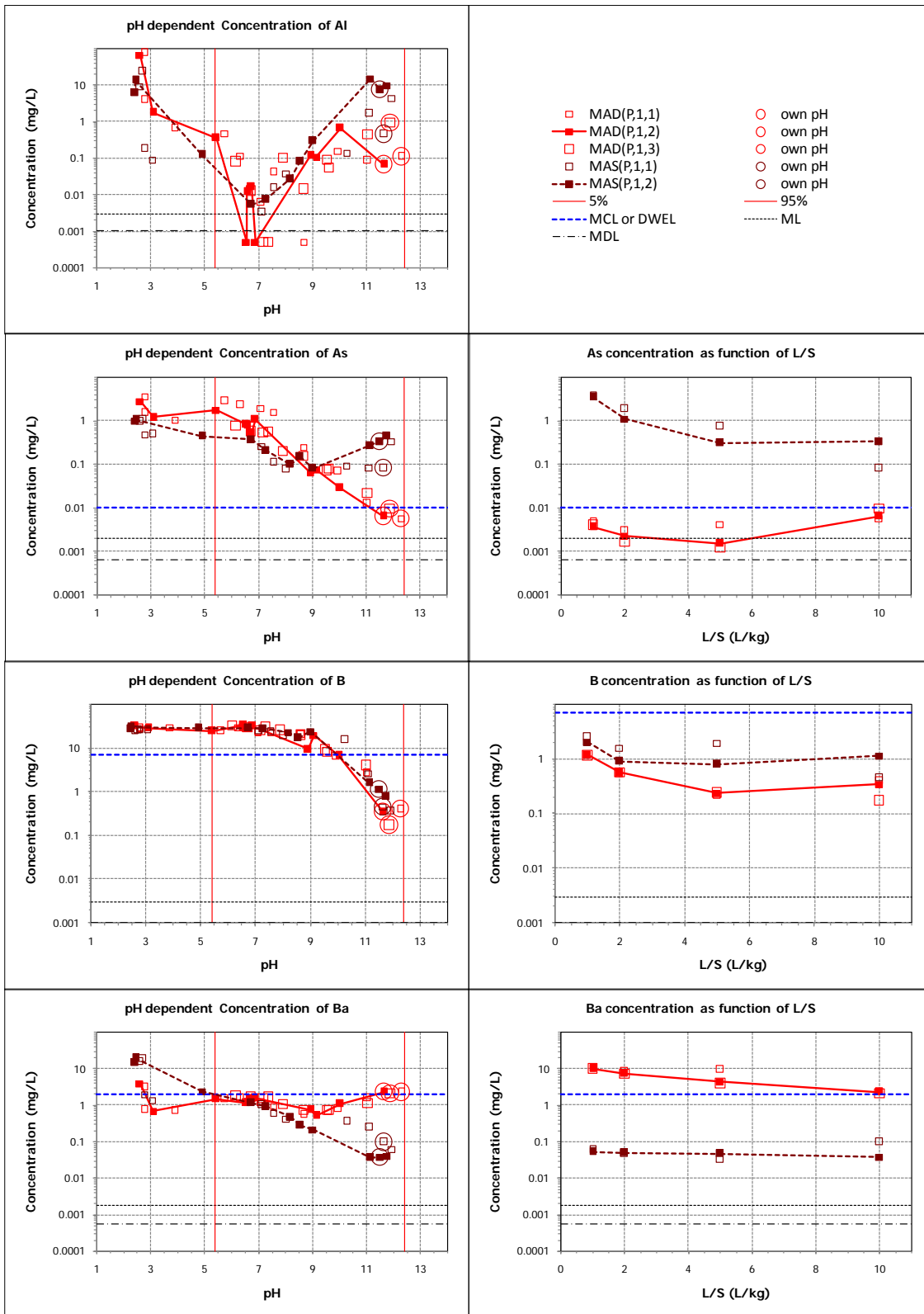


Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).

LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



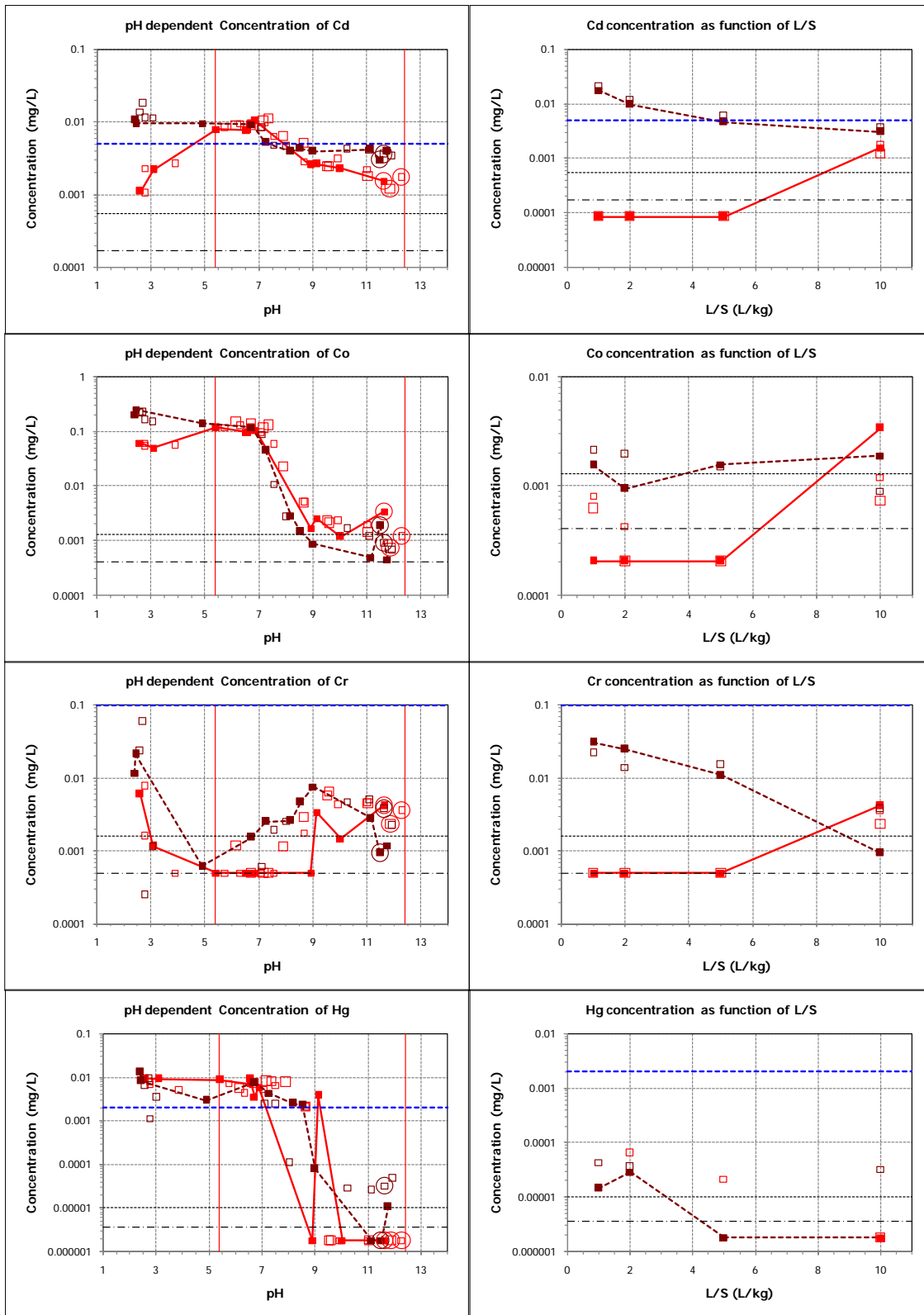
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB - fly ash without Br-ACI; **LAT** - fly ash with Br-ACI.



Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).

MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).

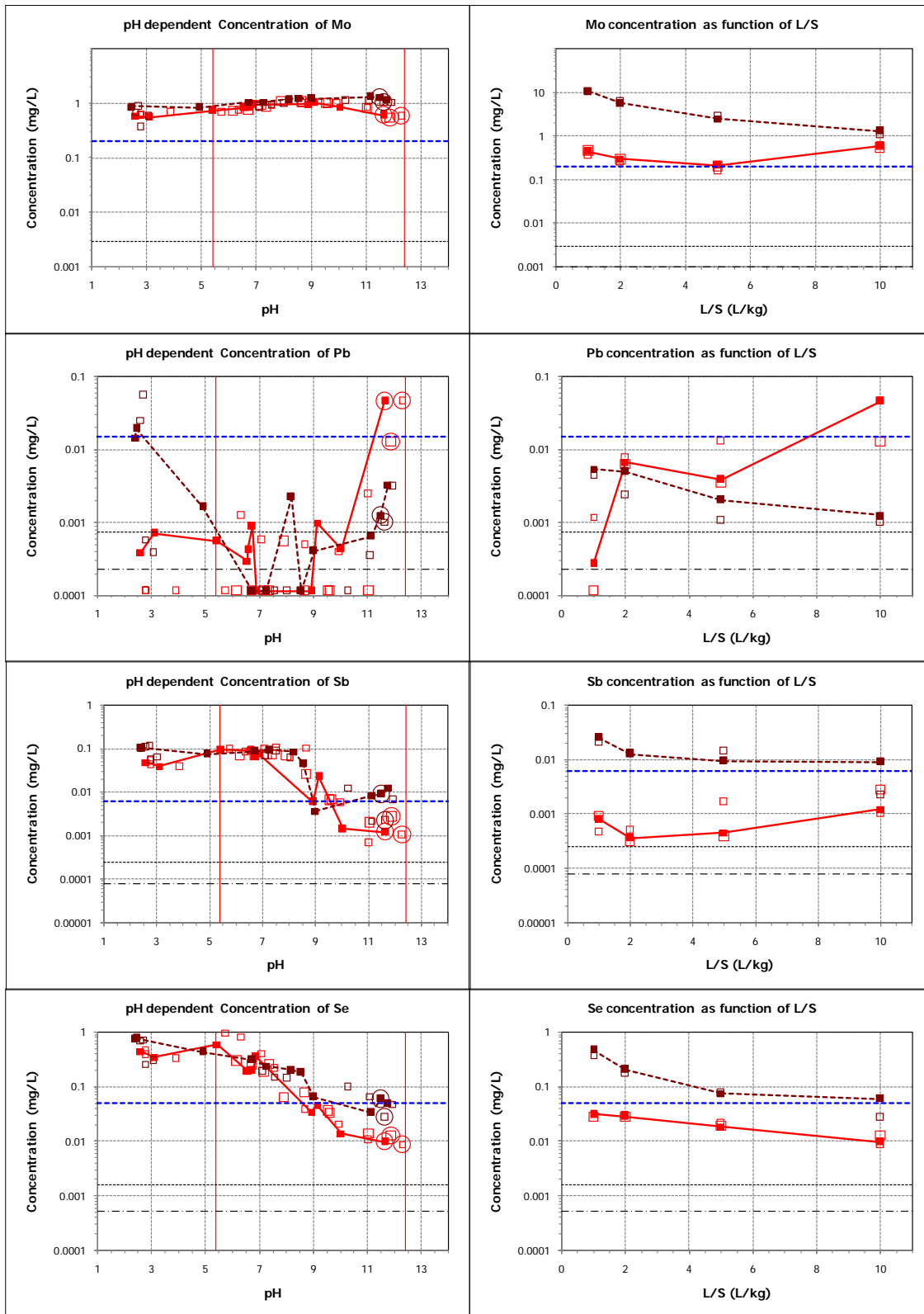
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



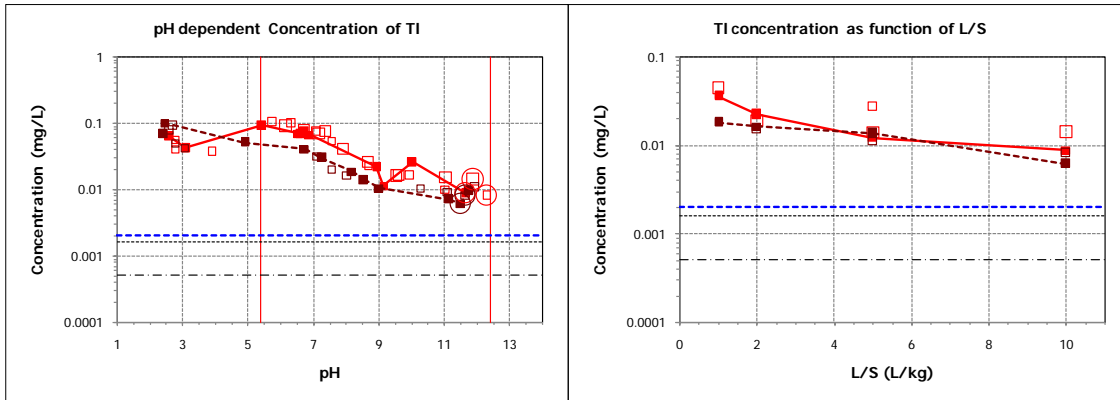
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).

MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).

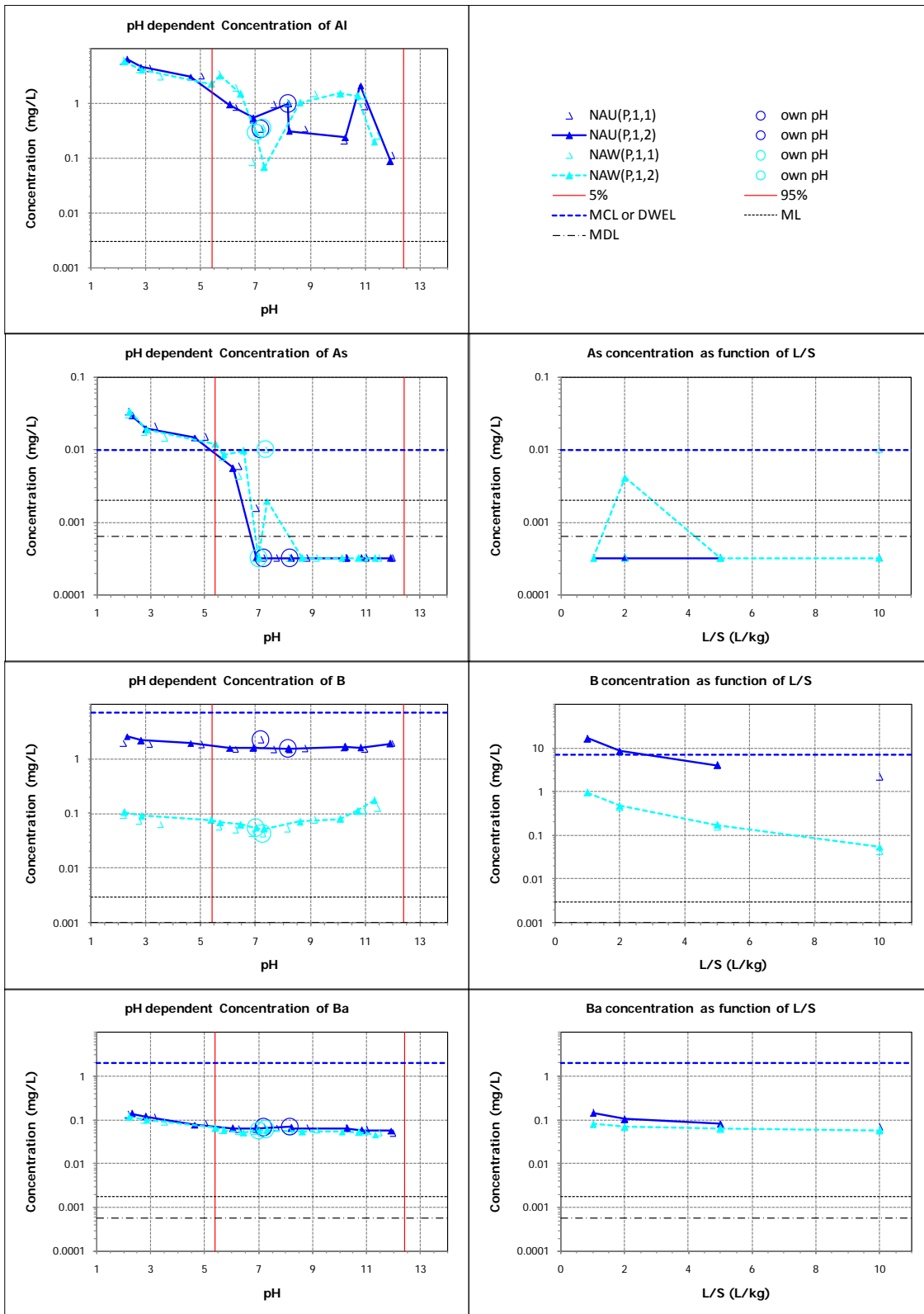
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



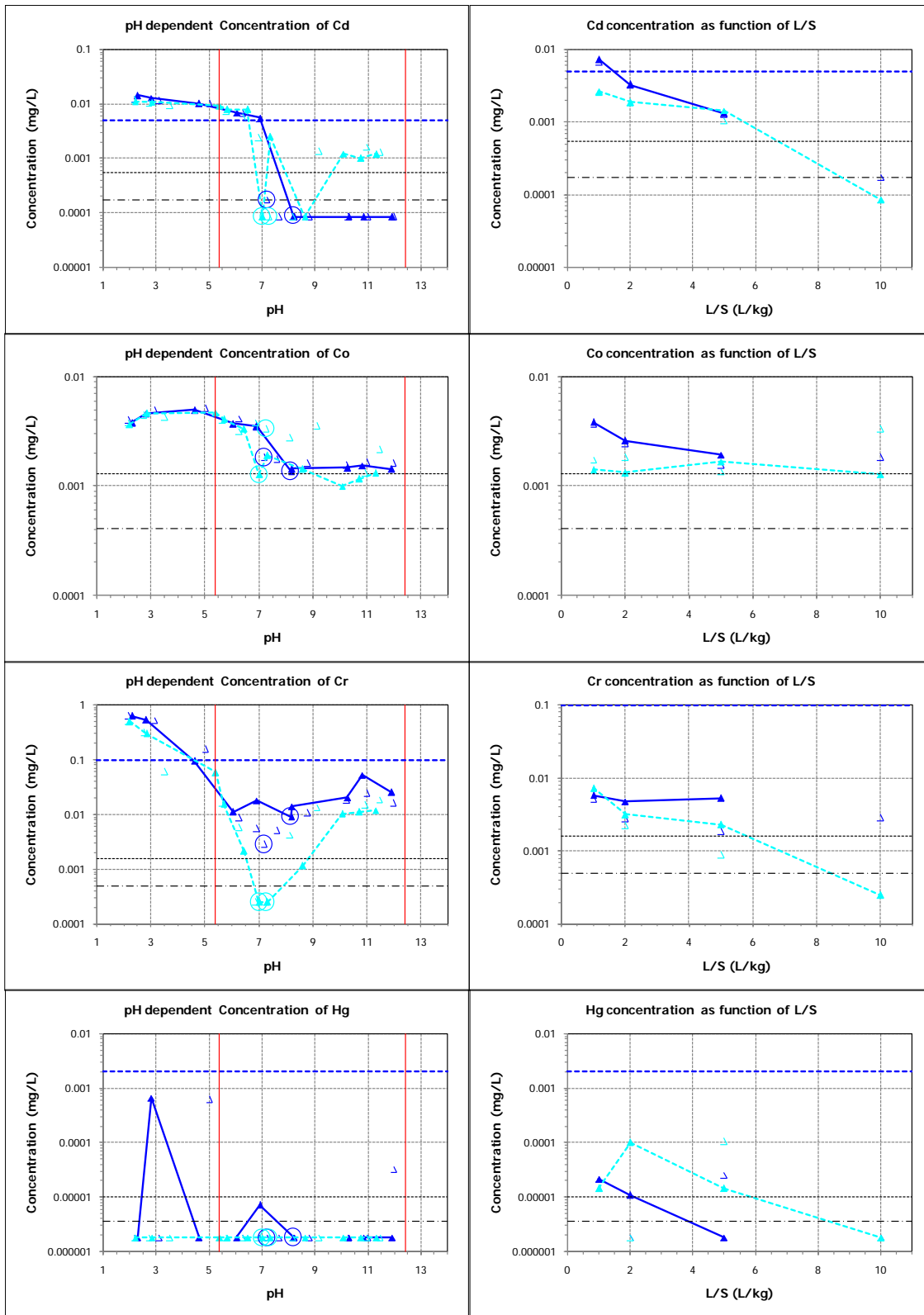
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



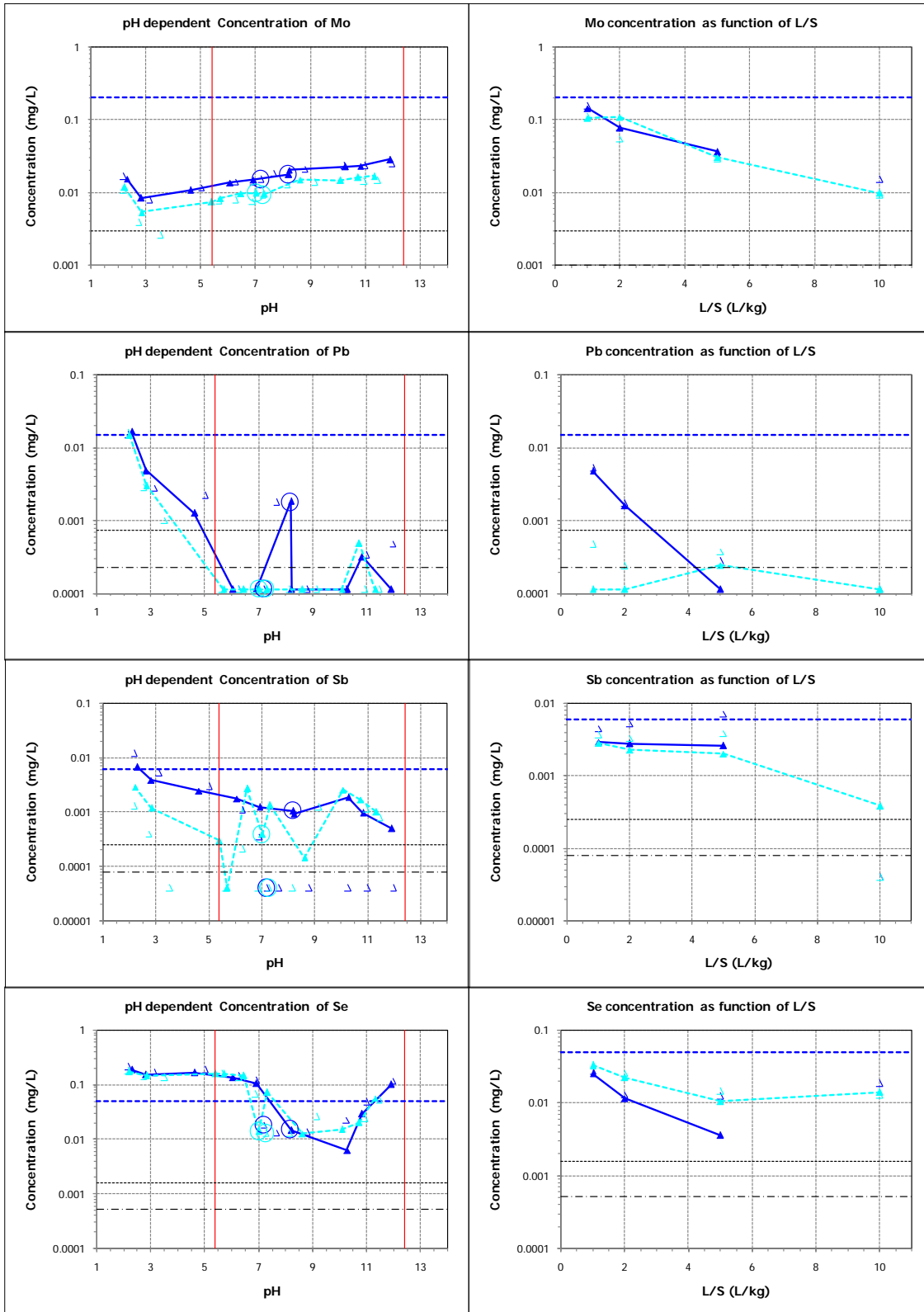
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).
MAD - SCR-BP; mixed fly ash and scrubber sludge (as managed).
MAS - SCR on; mixed fly ash and scrubber sludge (as managed).



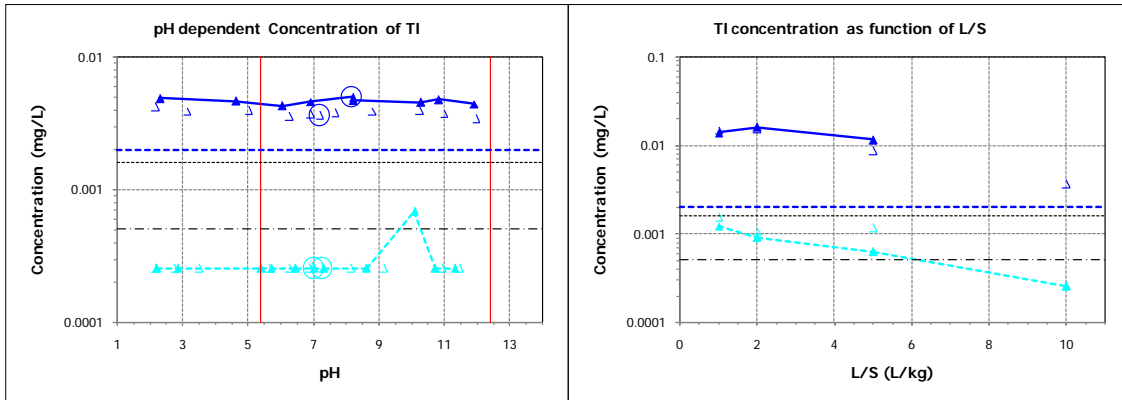
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



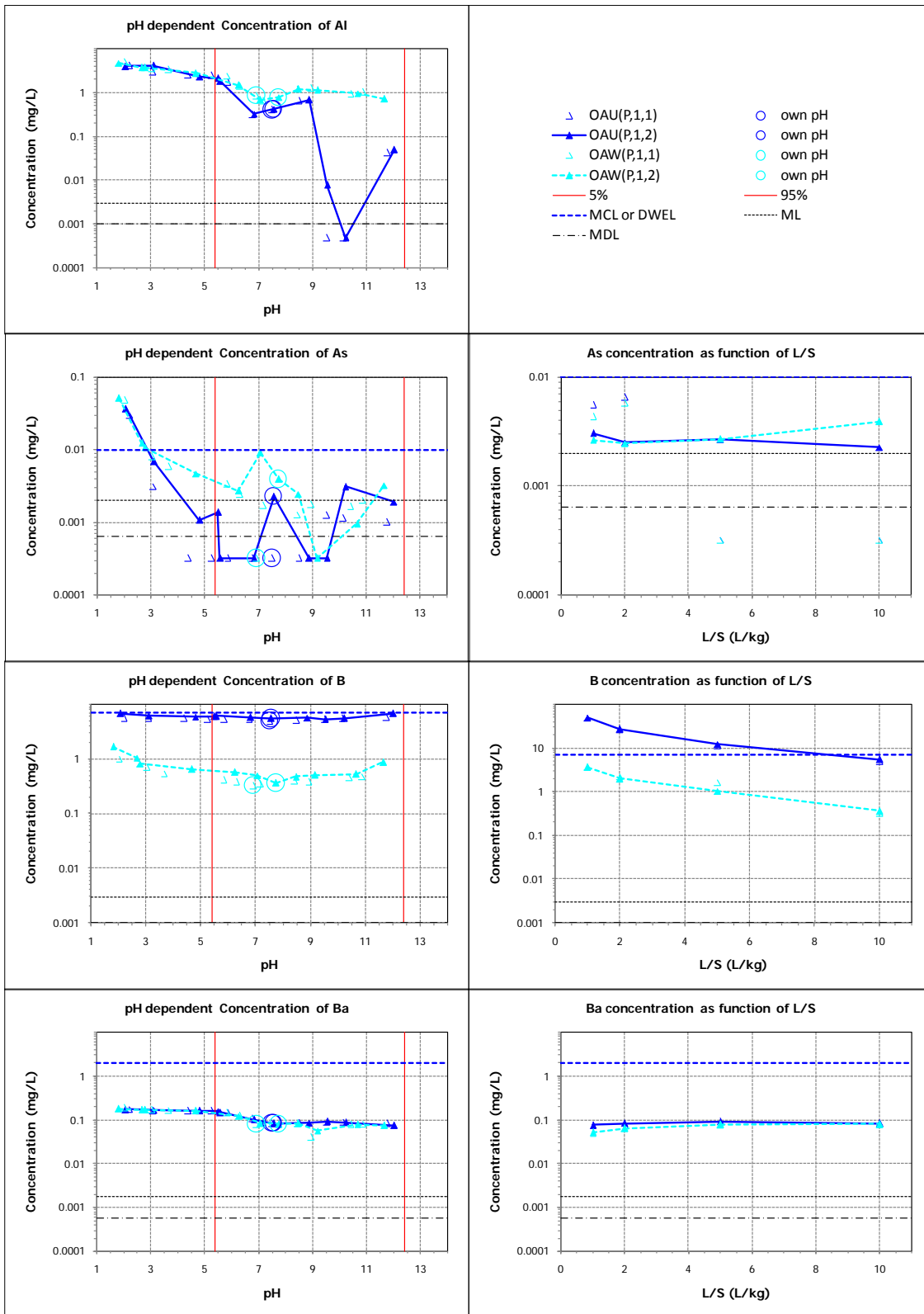
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



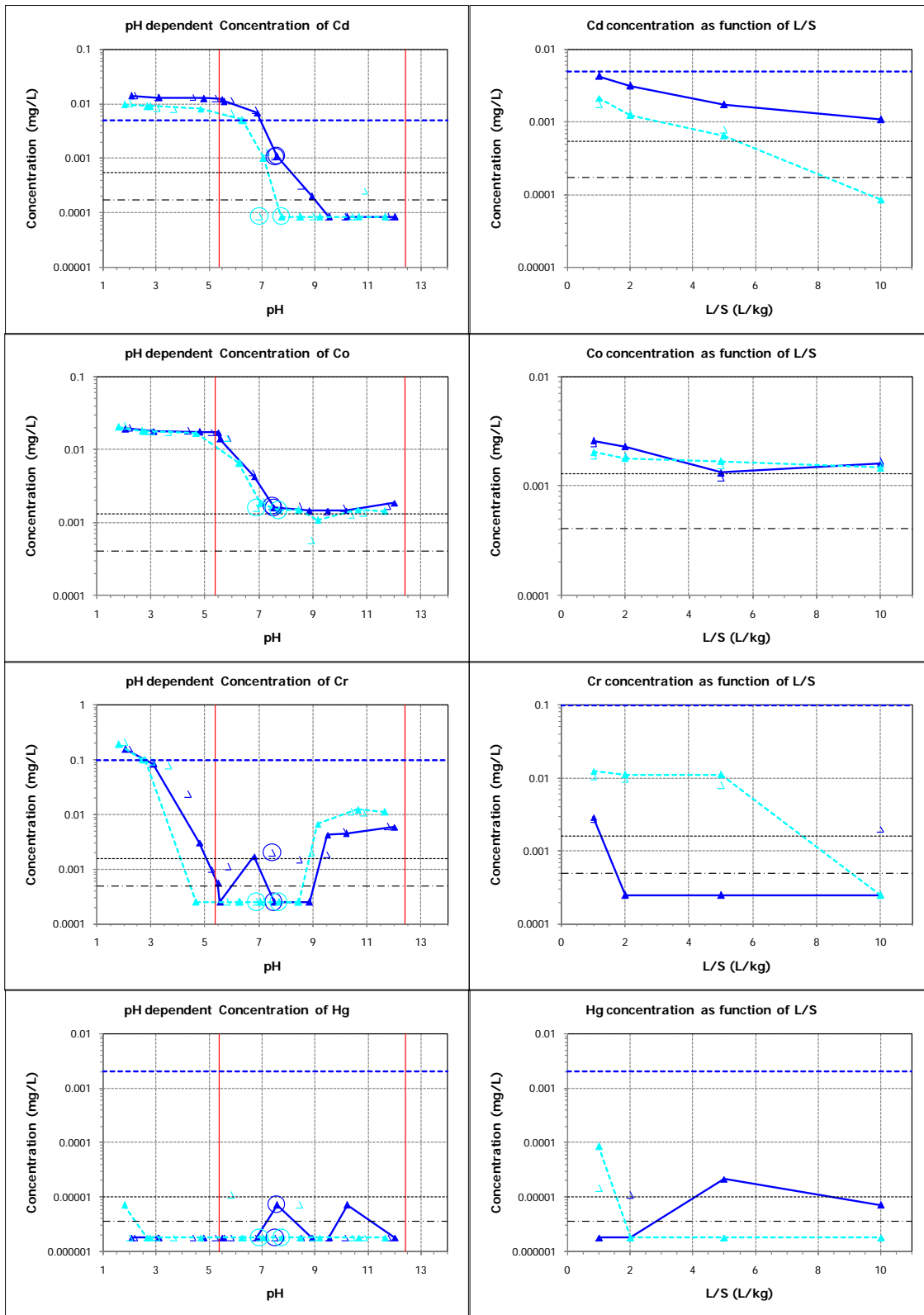
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



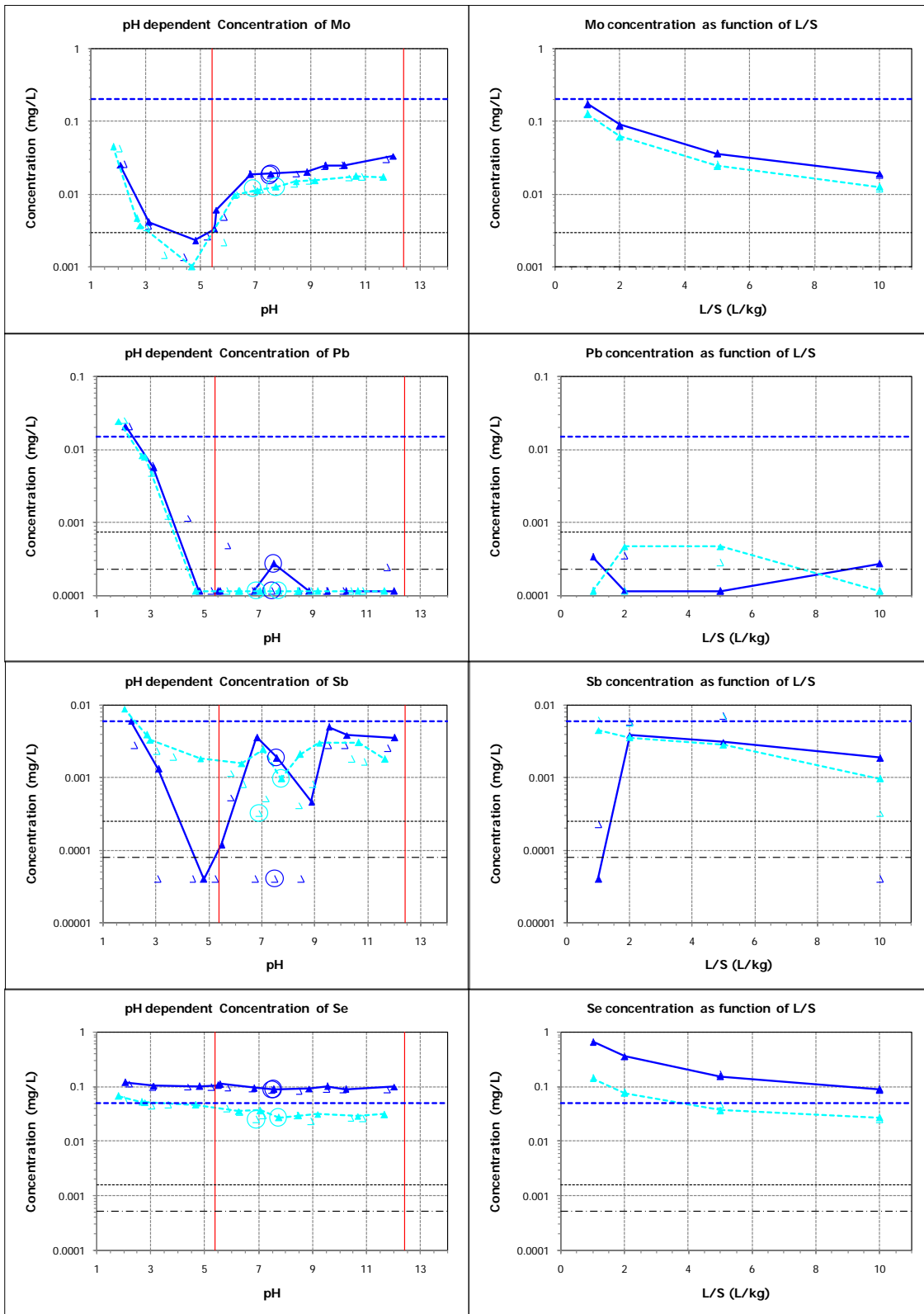
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU - unwashed gypsum; **NAW** - washed gypsum.



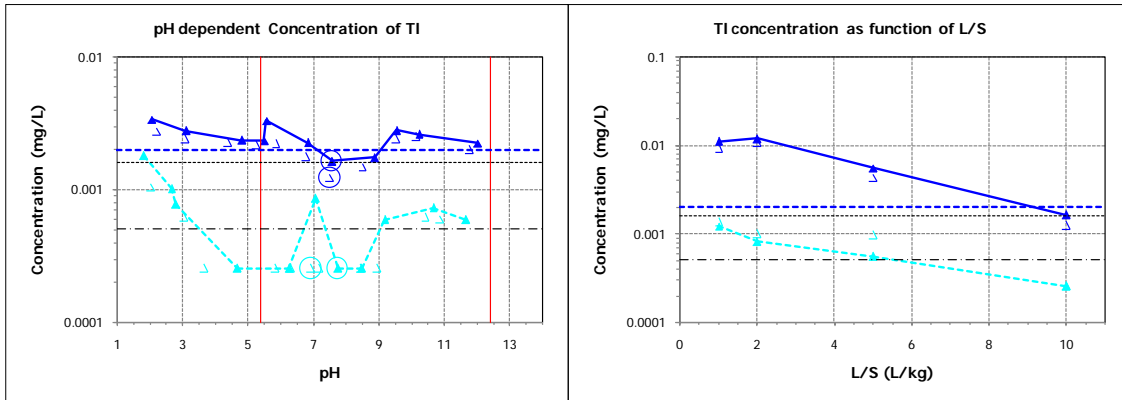
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



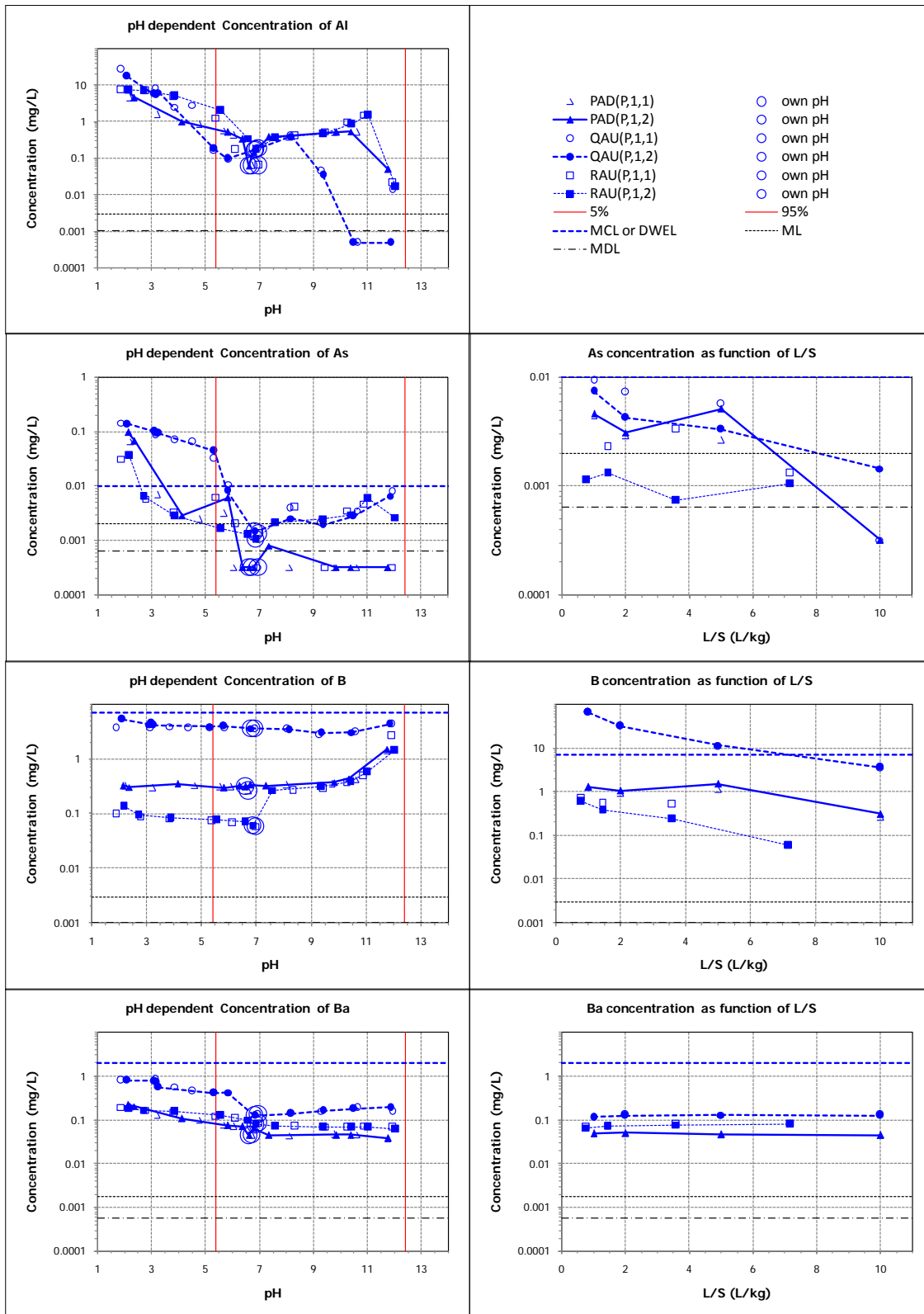
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



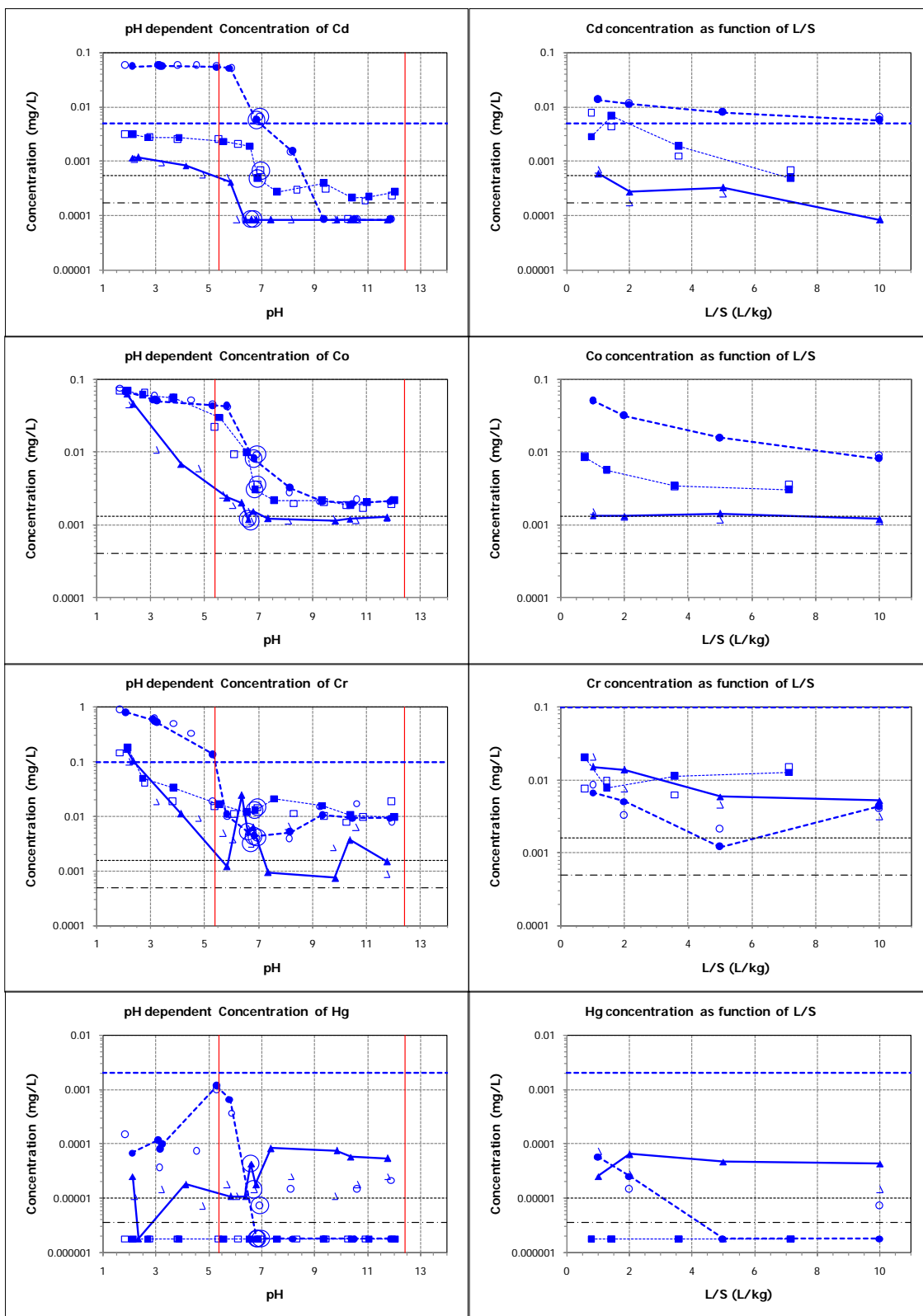
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



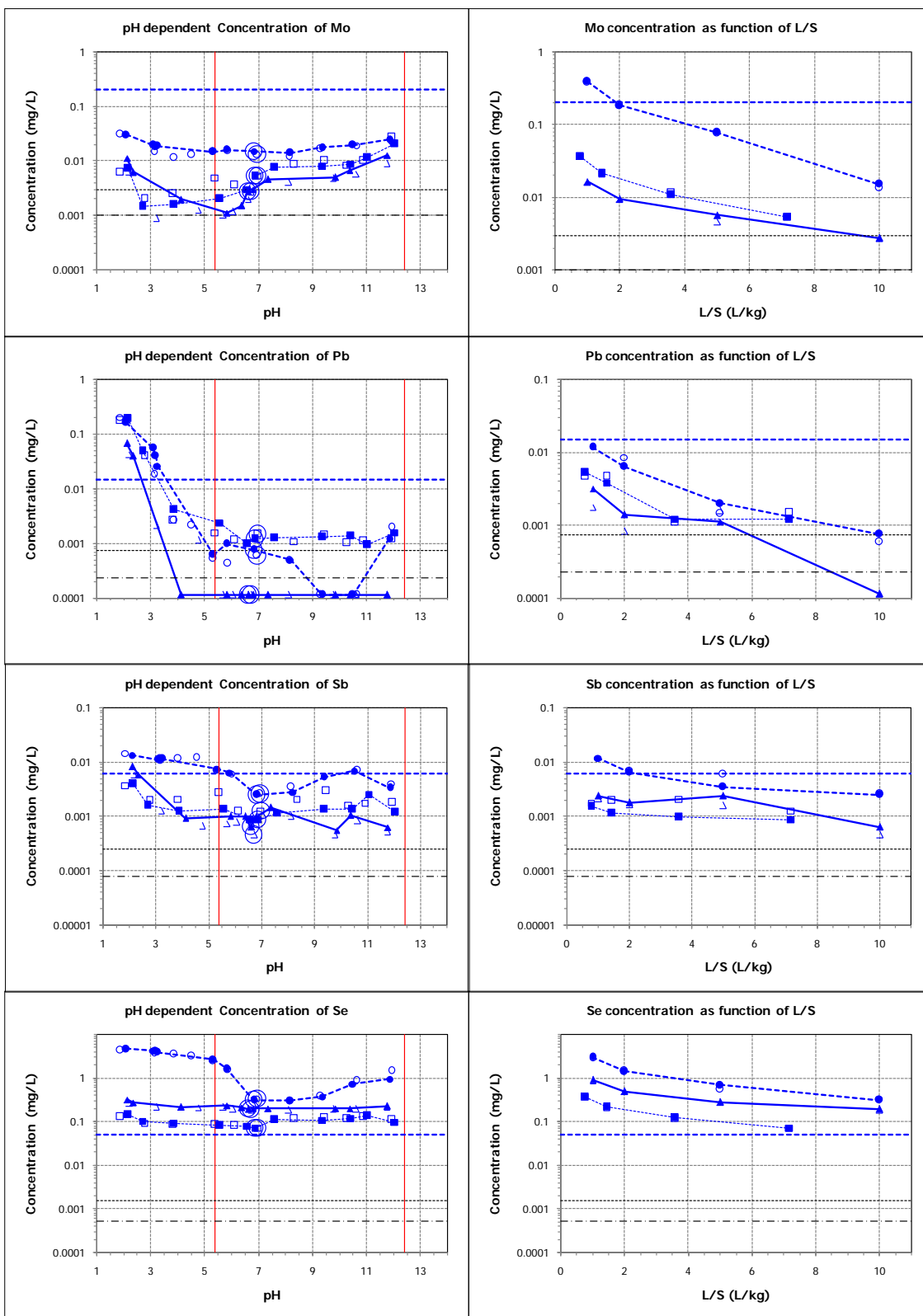
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU - unwashed gypsum; **OAW** - washed gypsum.



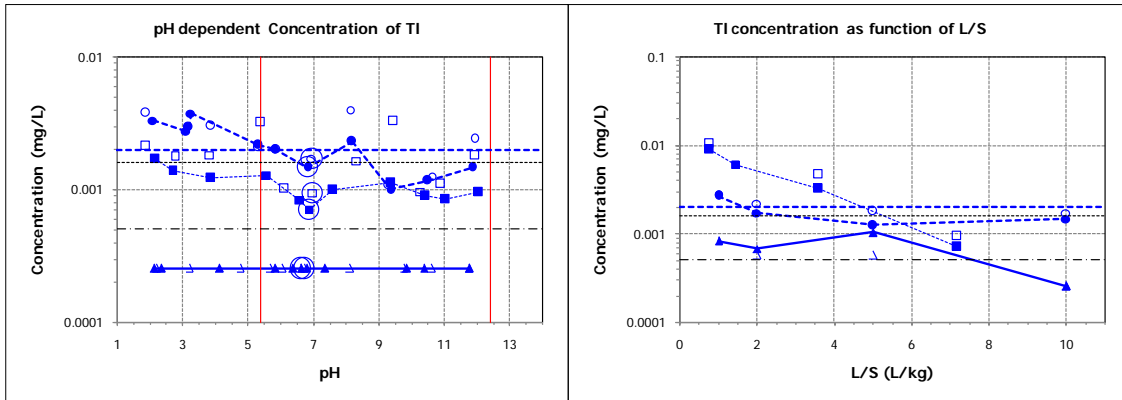
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



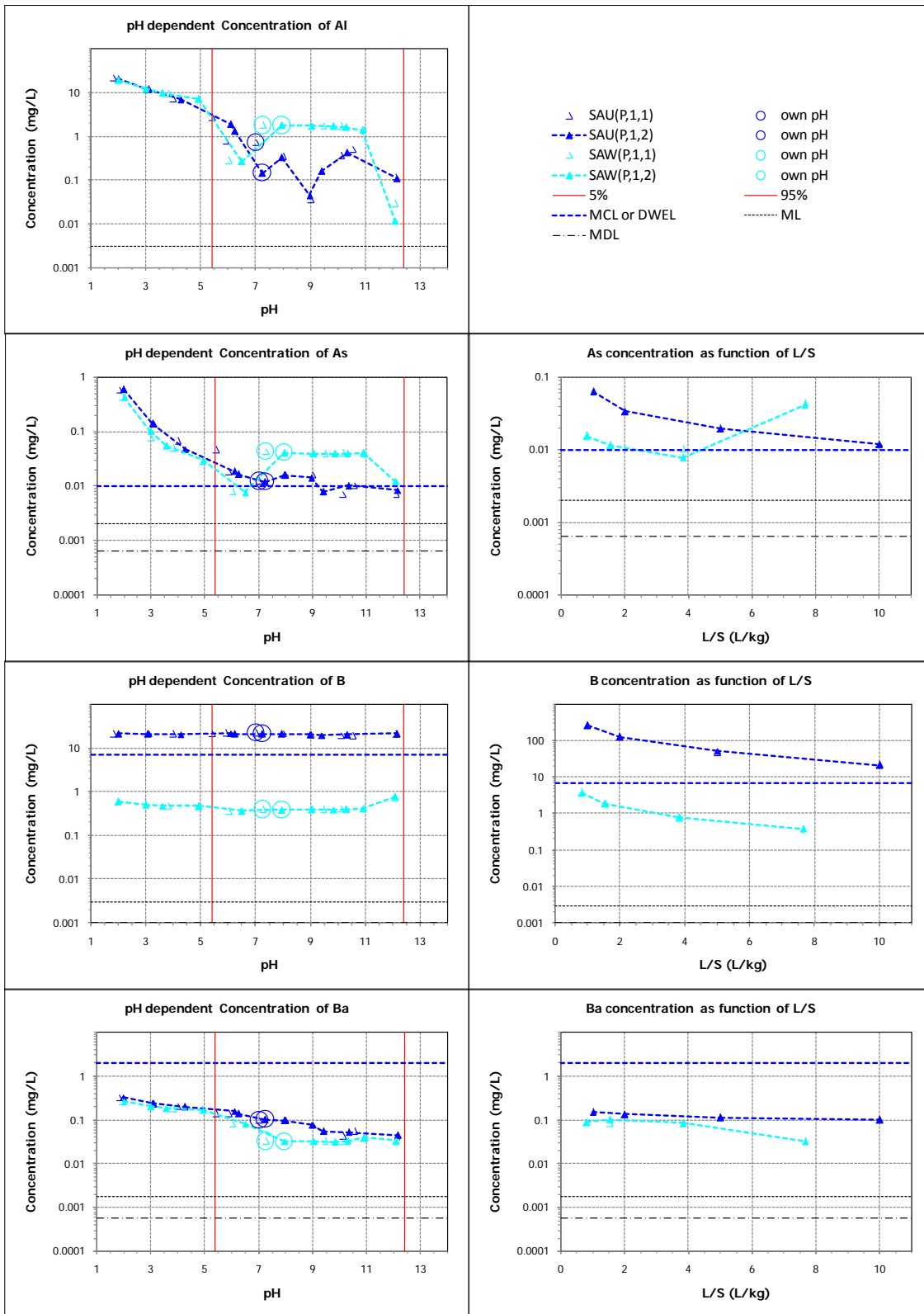
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



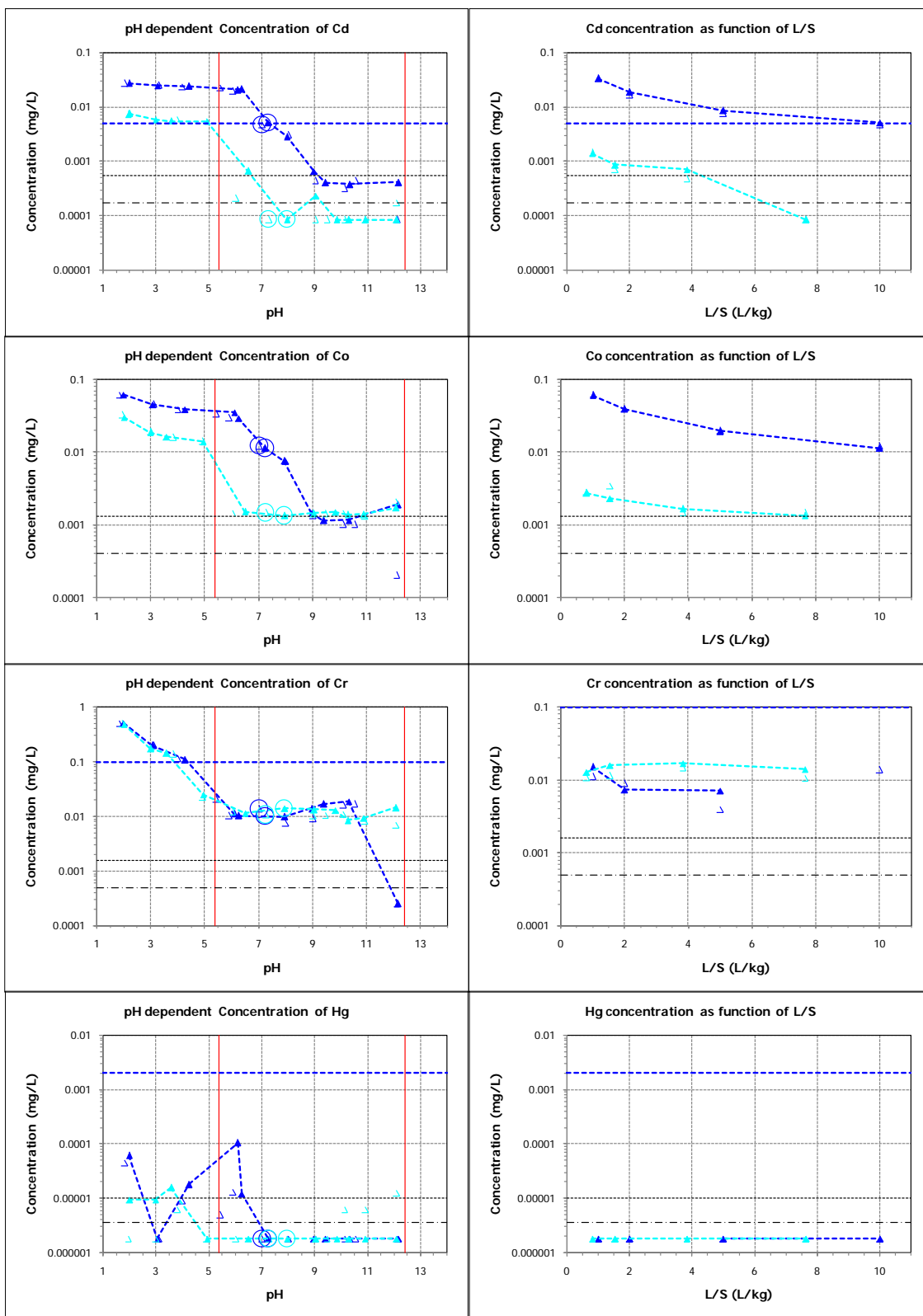
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



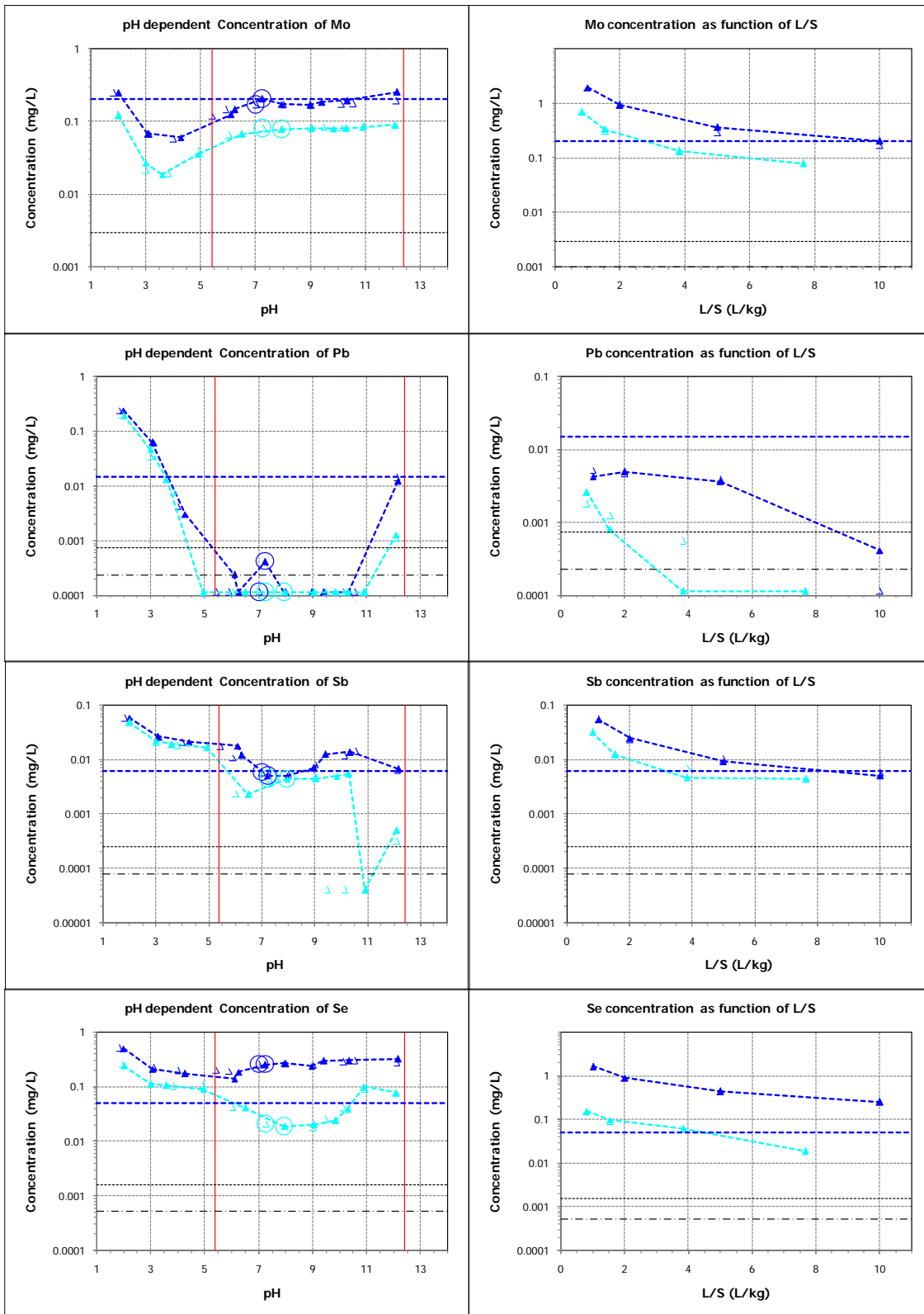
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** - unwashed gyp.
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** - unwashed gypsum.
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** - unwashed gypsum.



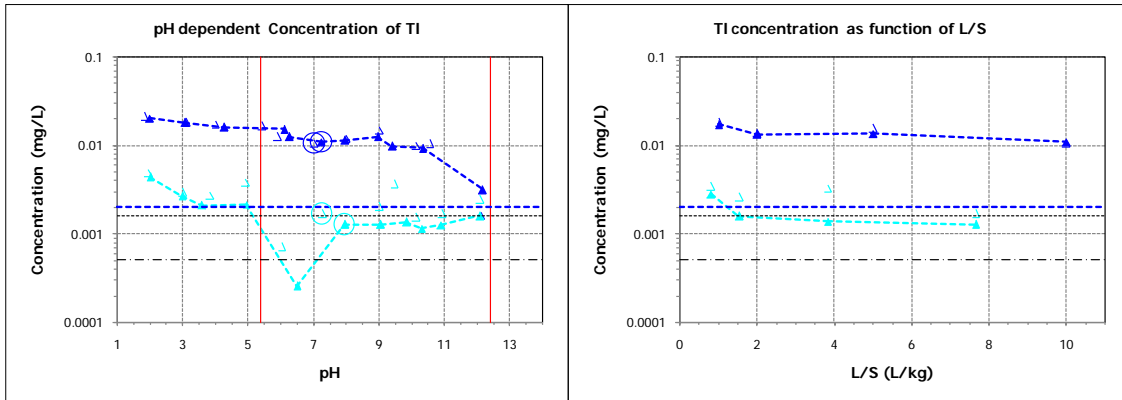
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



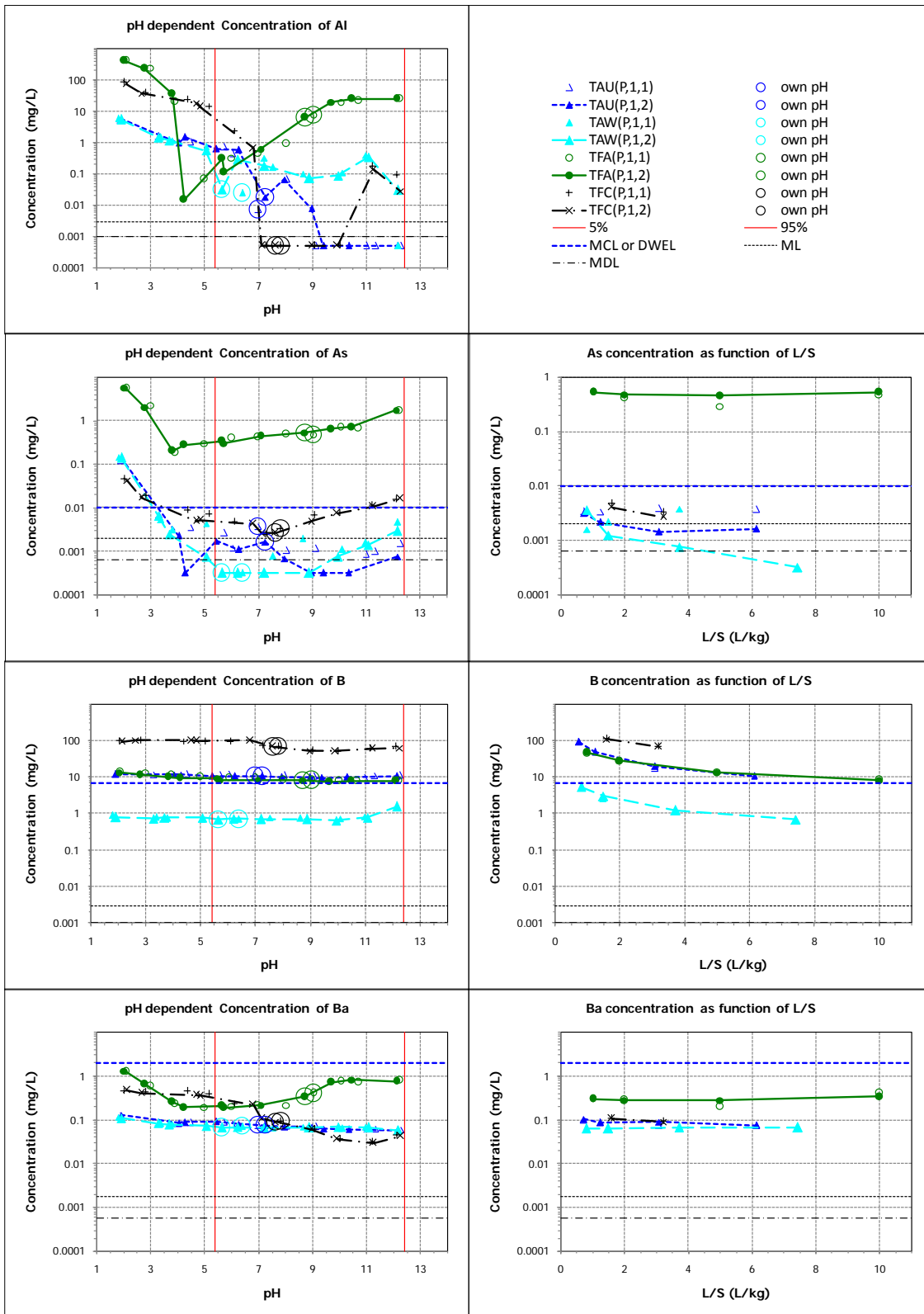
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



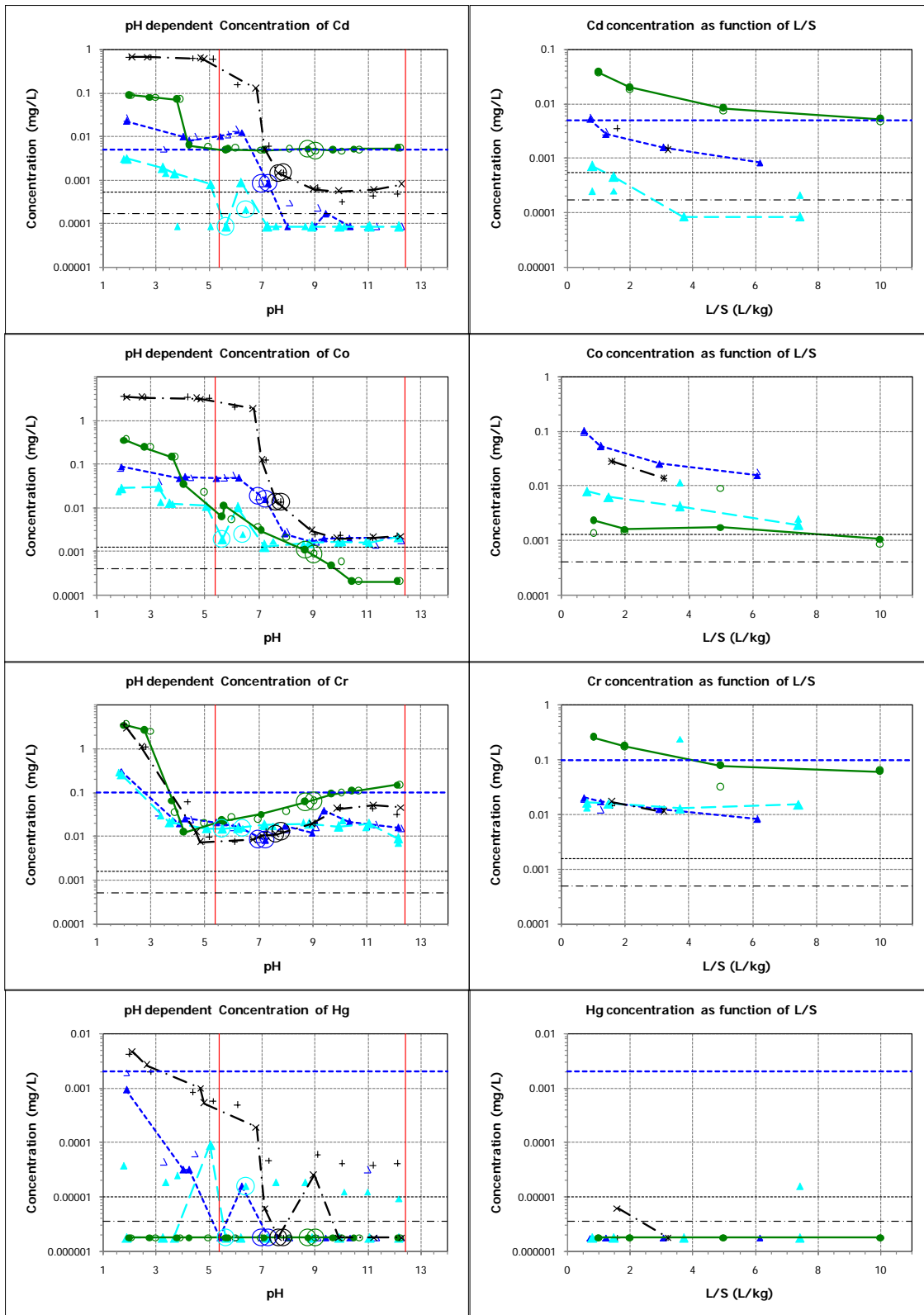
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



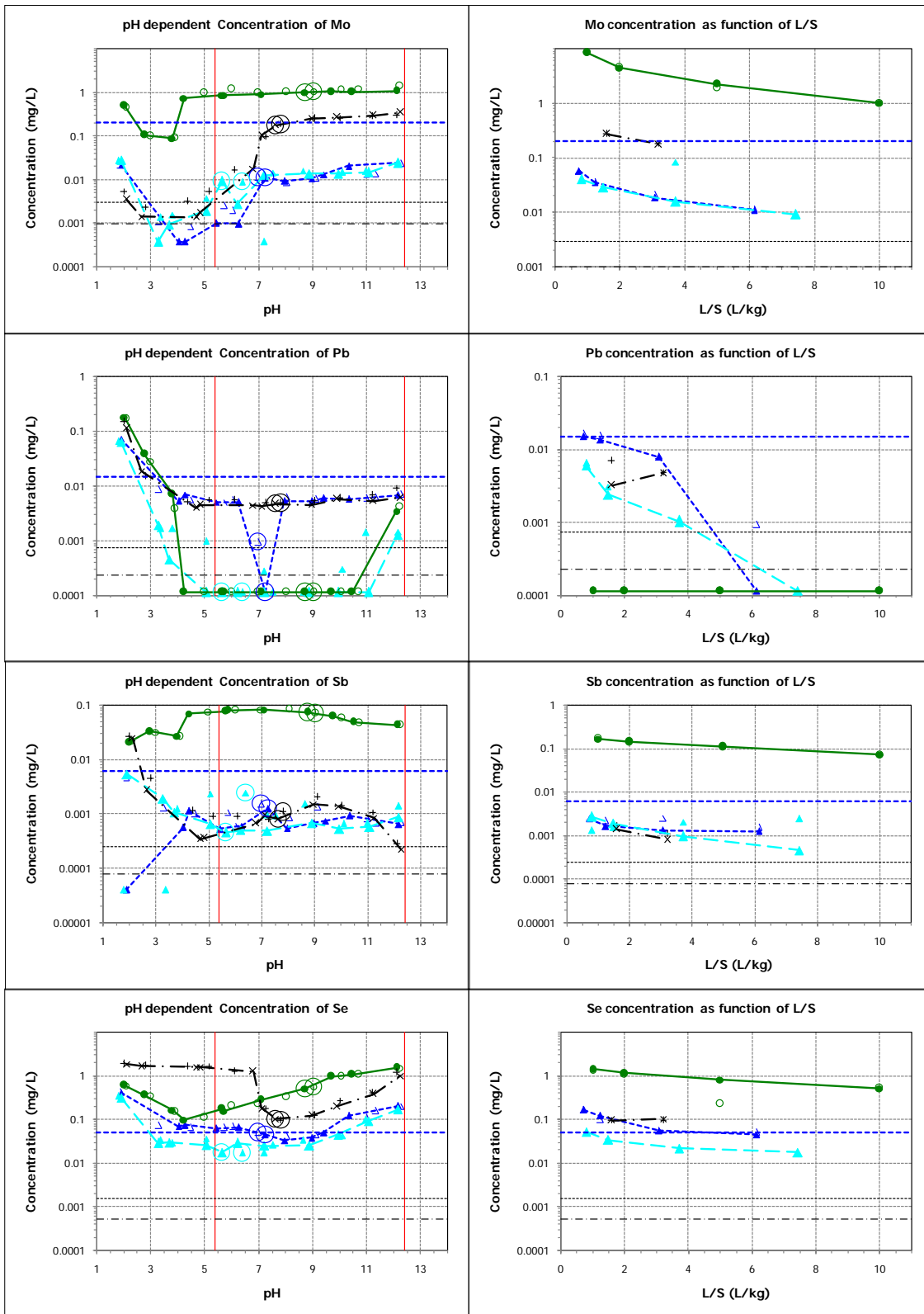
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU - unwashed gypsum; **SAW** - washed gypsum.



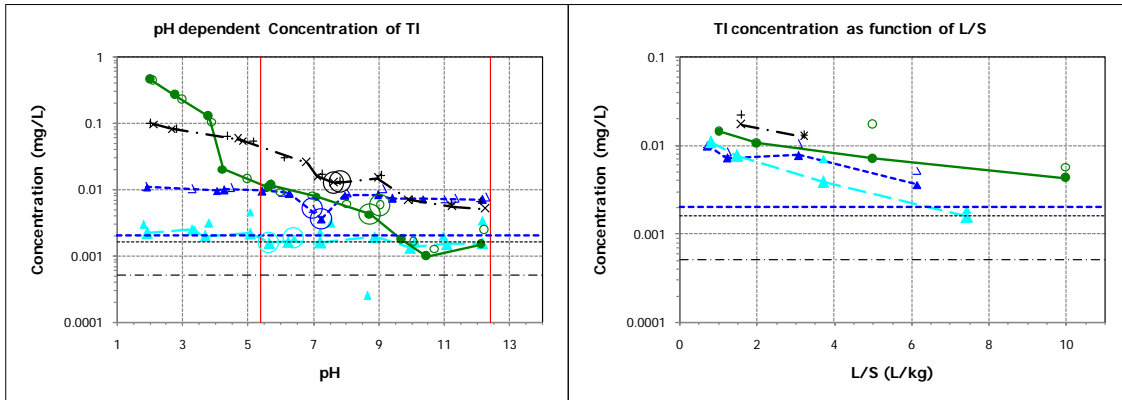
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



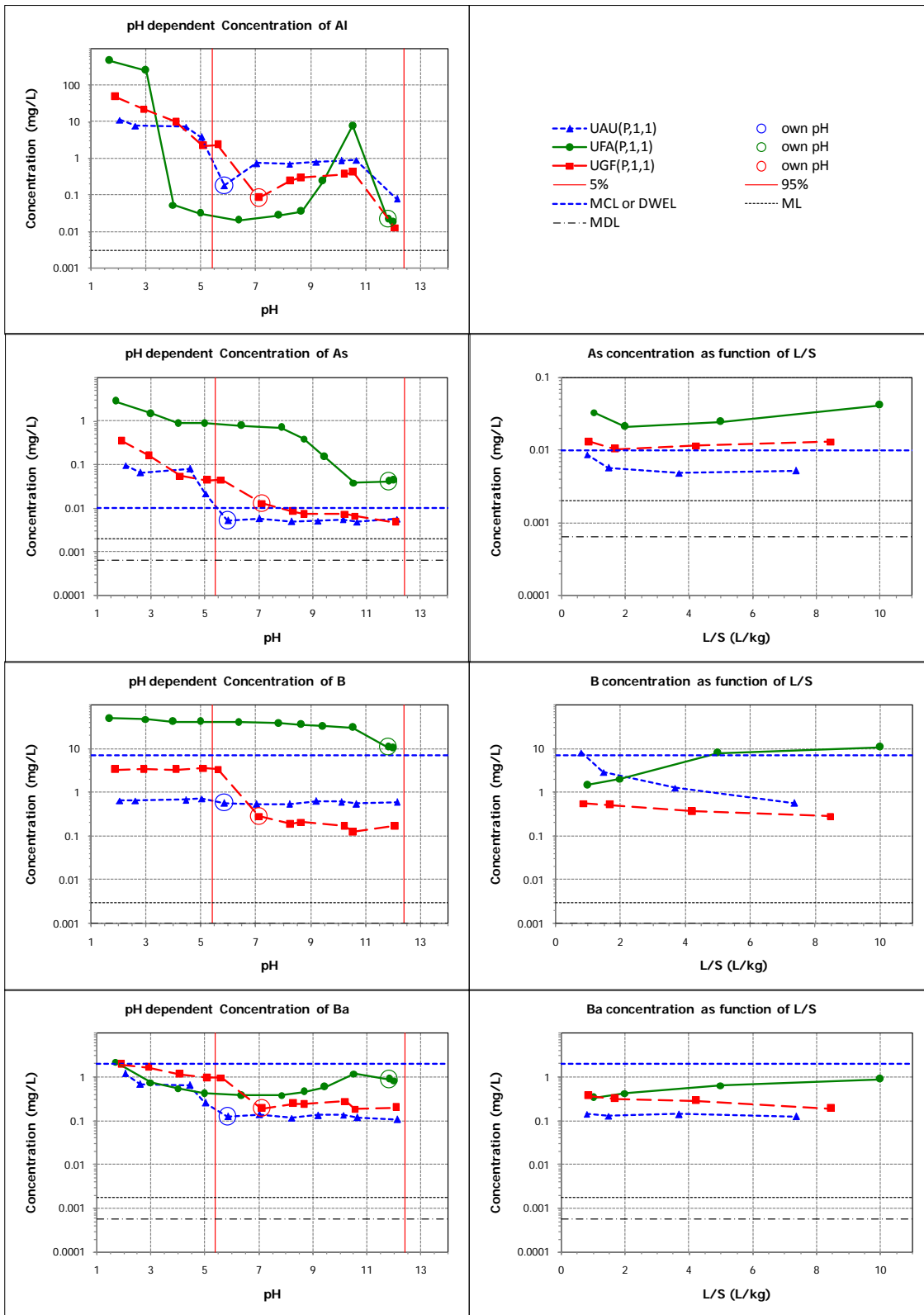
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



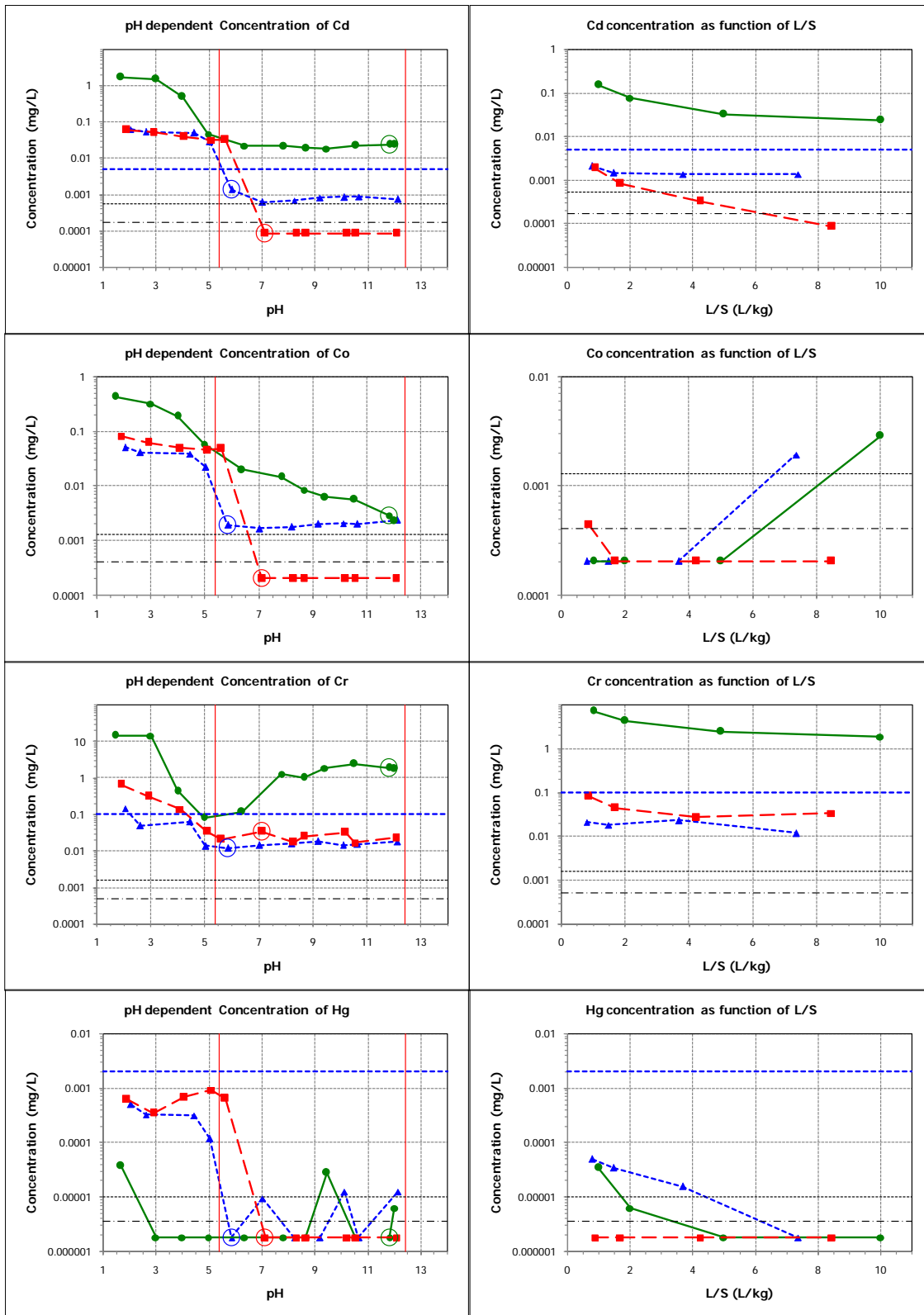
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



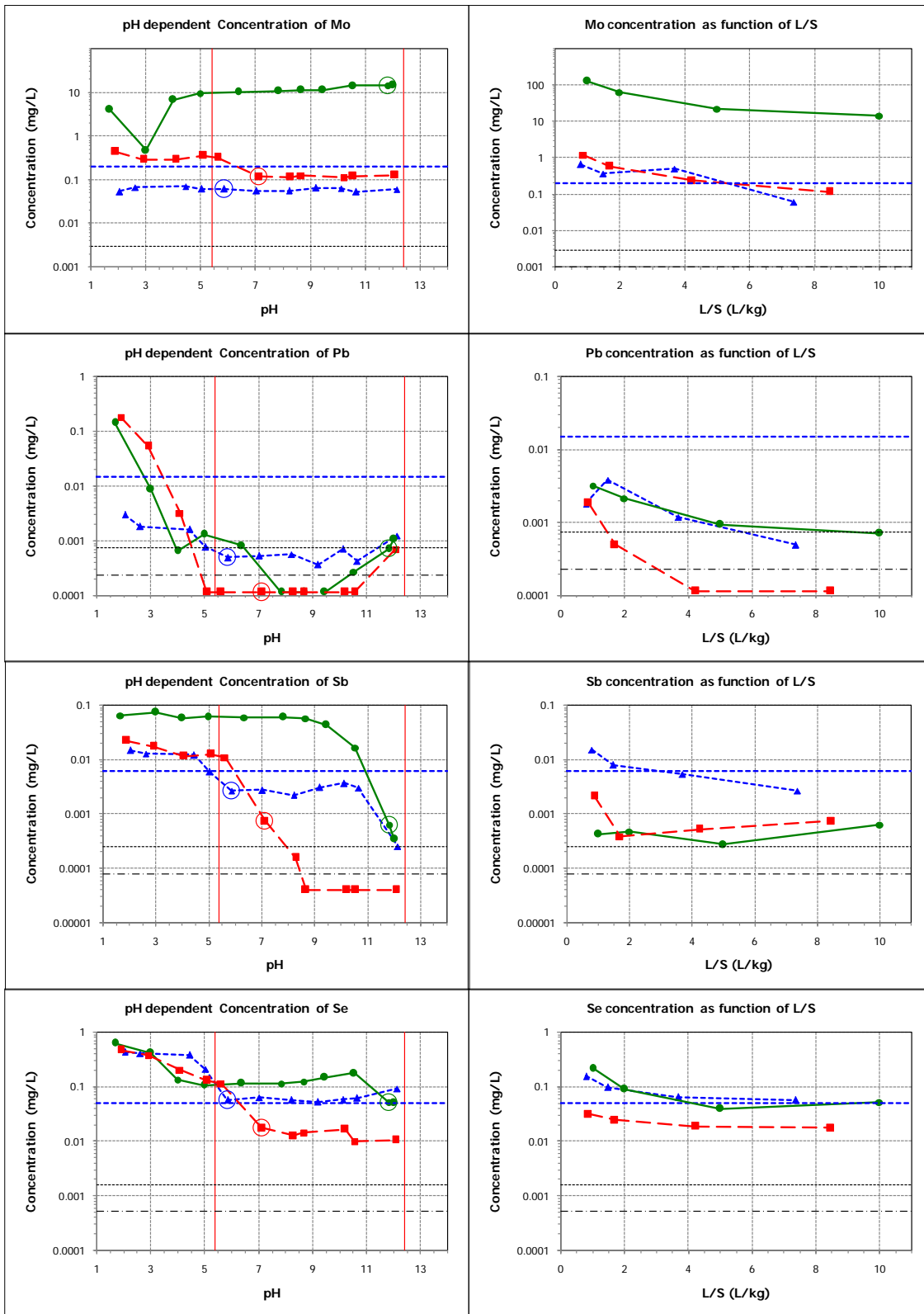
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA - fly ash; **TAU** - unwashed gypsum; **TAW** - washed gypsum; **TFC** - filter cake.



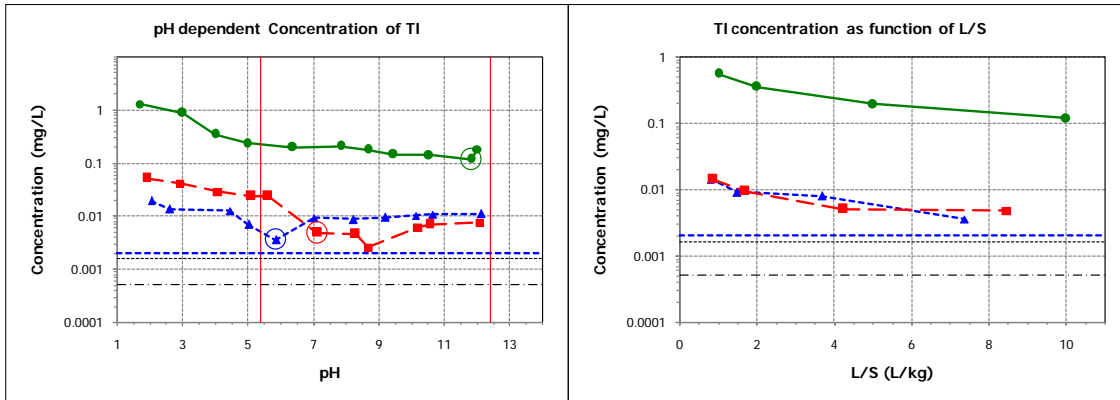
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



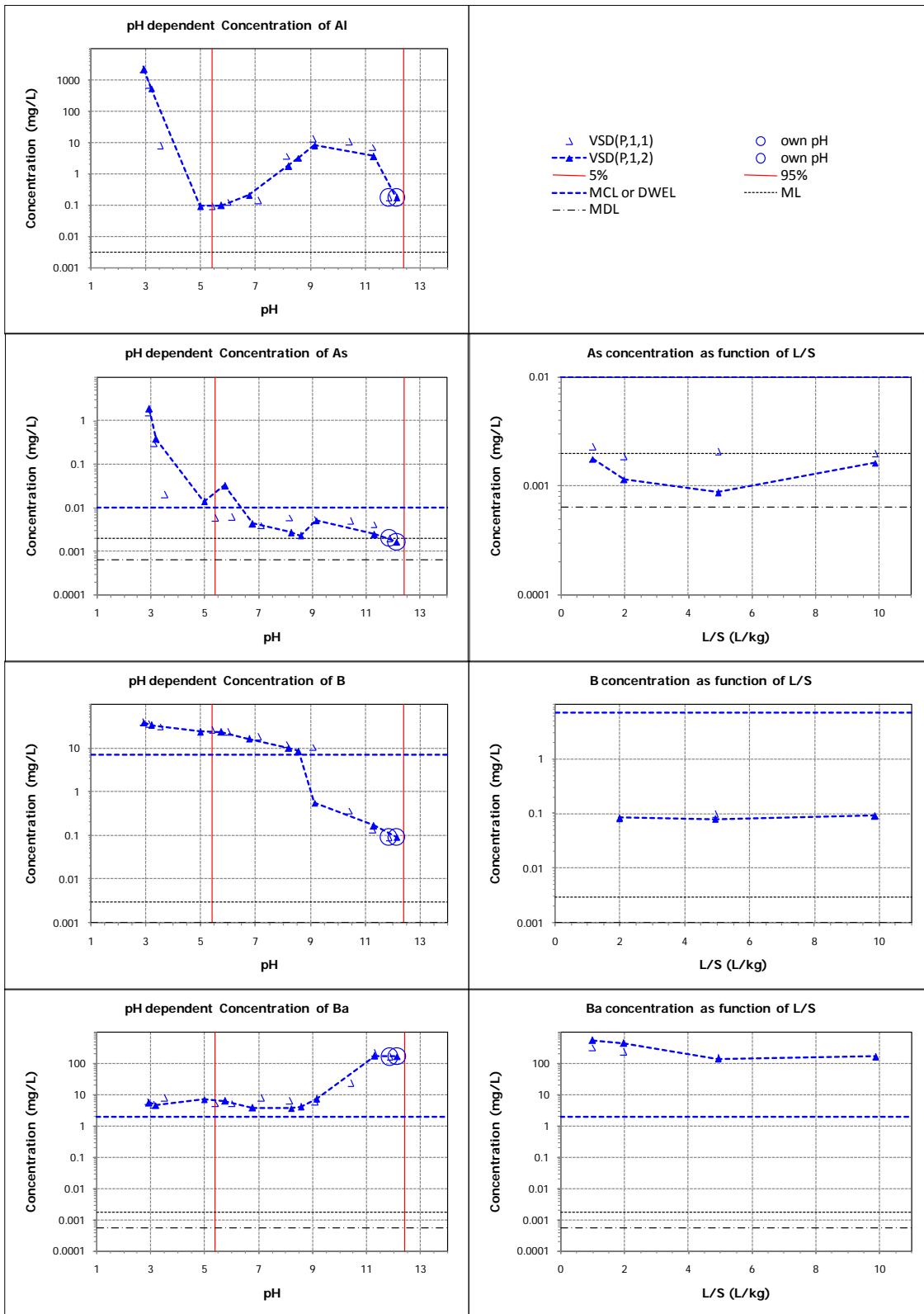
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



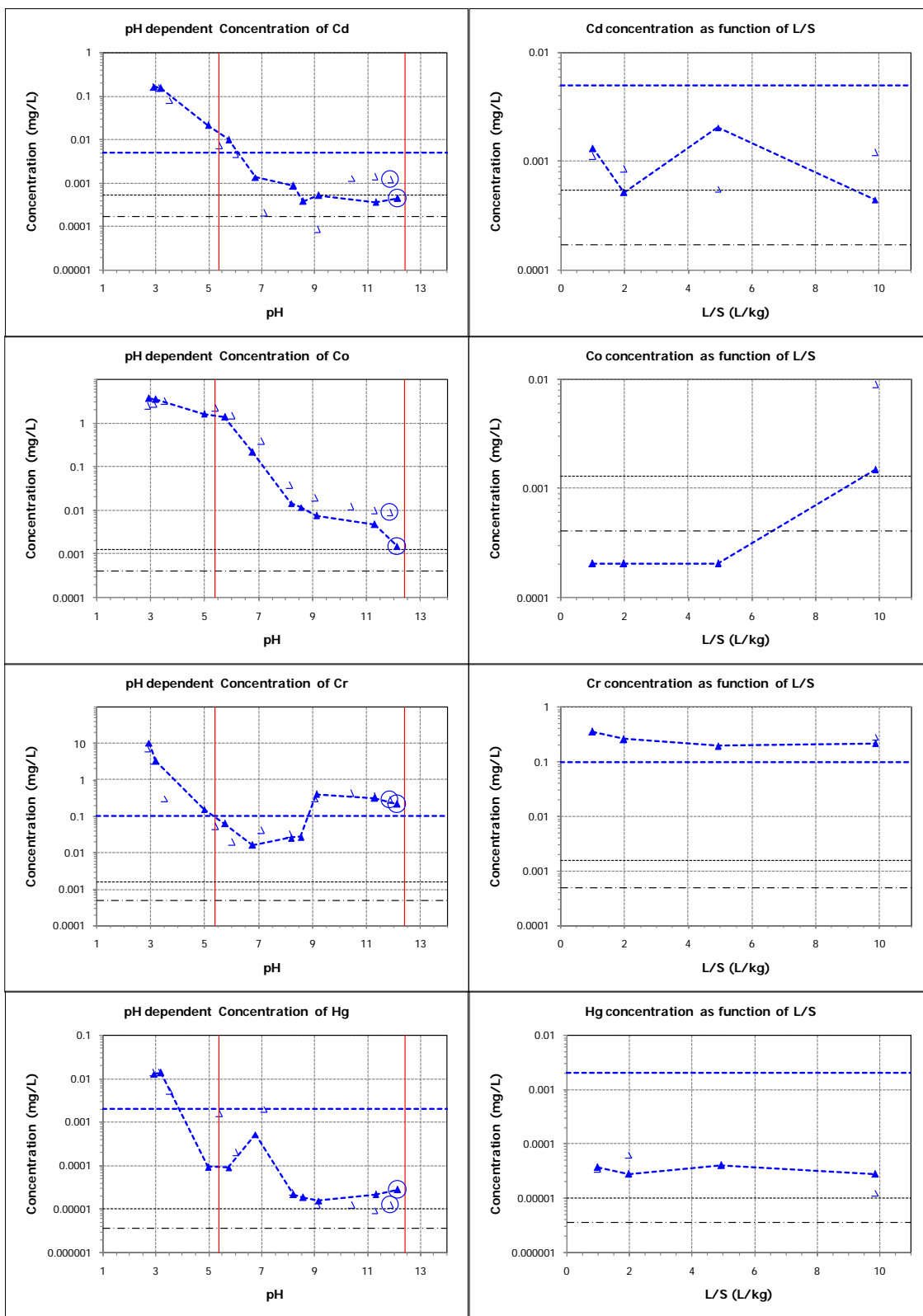
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



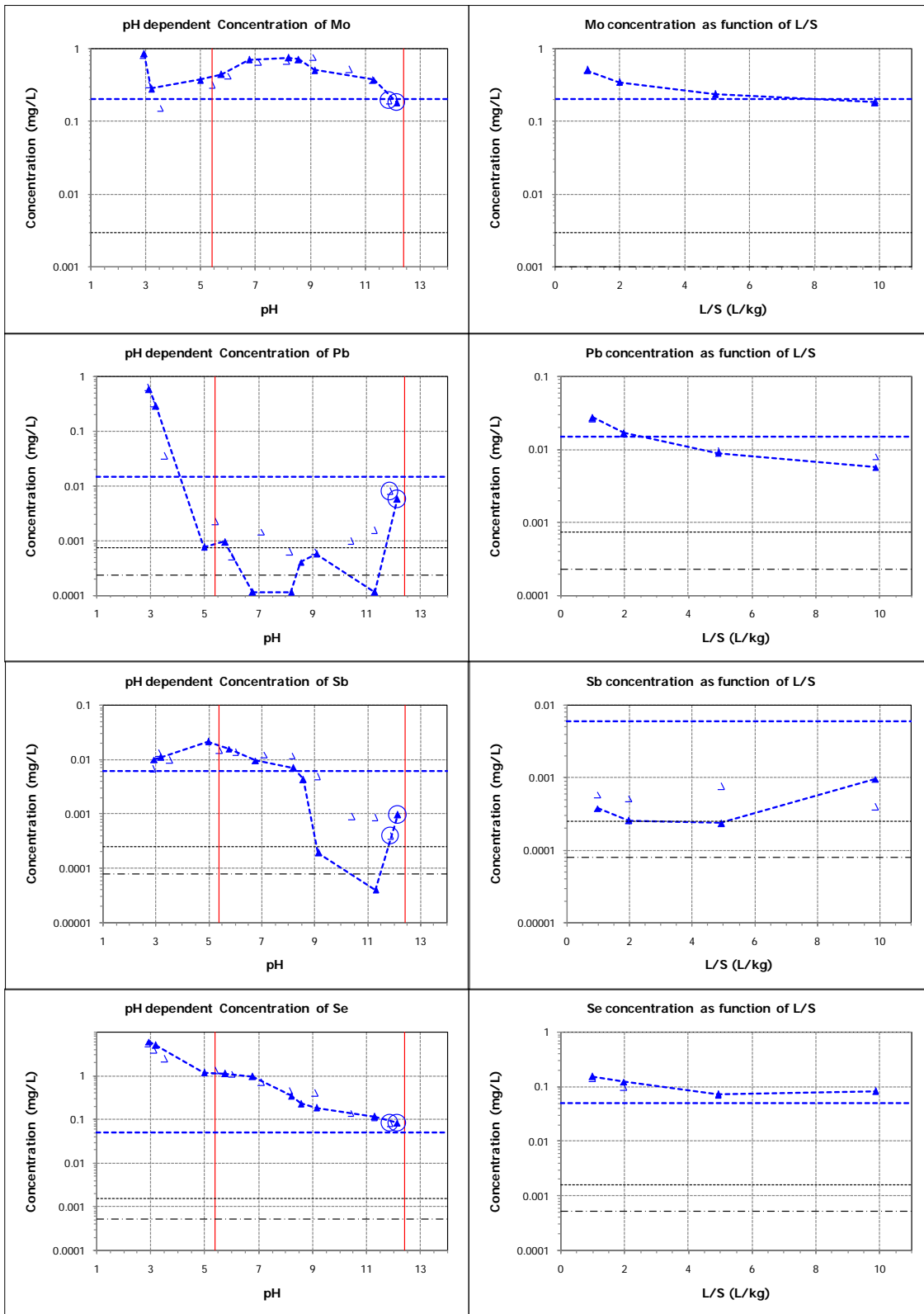
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA - fly ash; **UAU** - unwashed gypsum; **UGF** - gypsum/flyash.



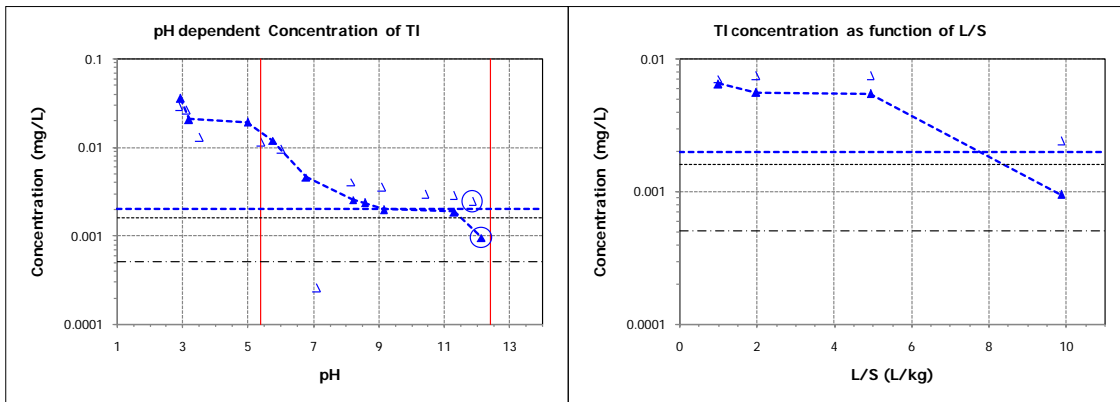
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



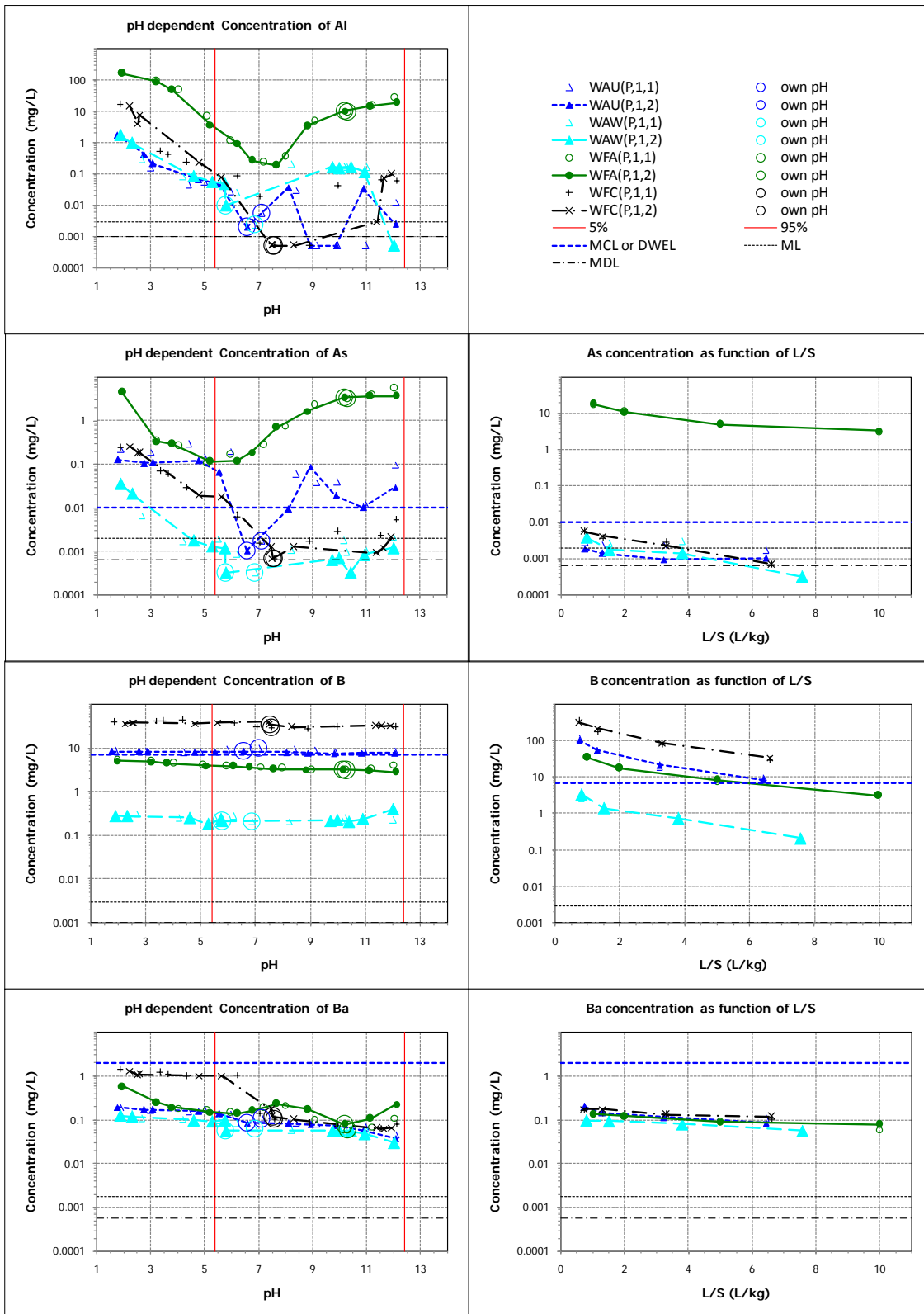
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



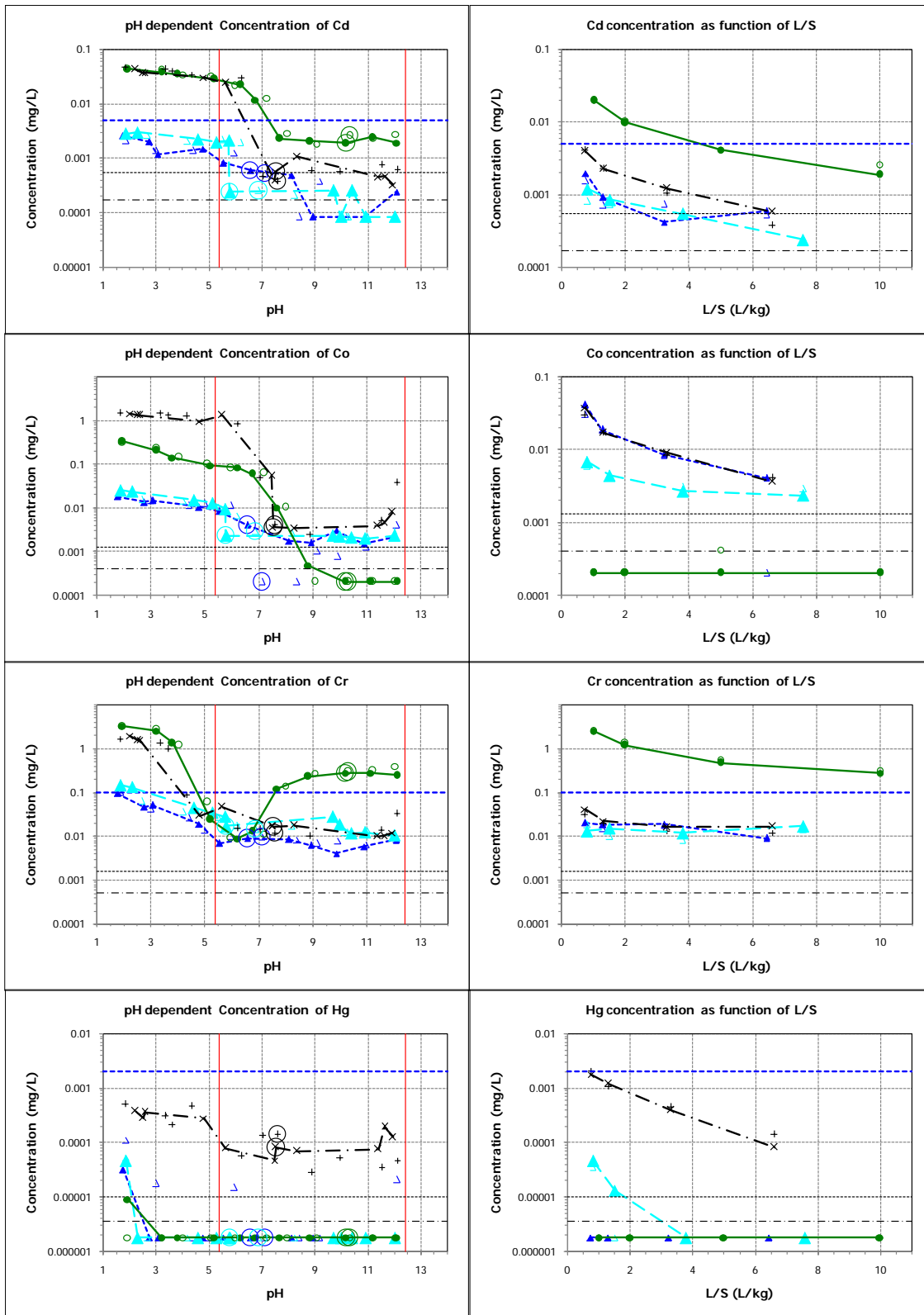
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



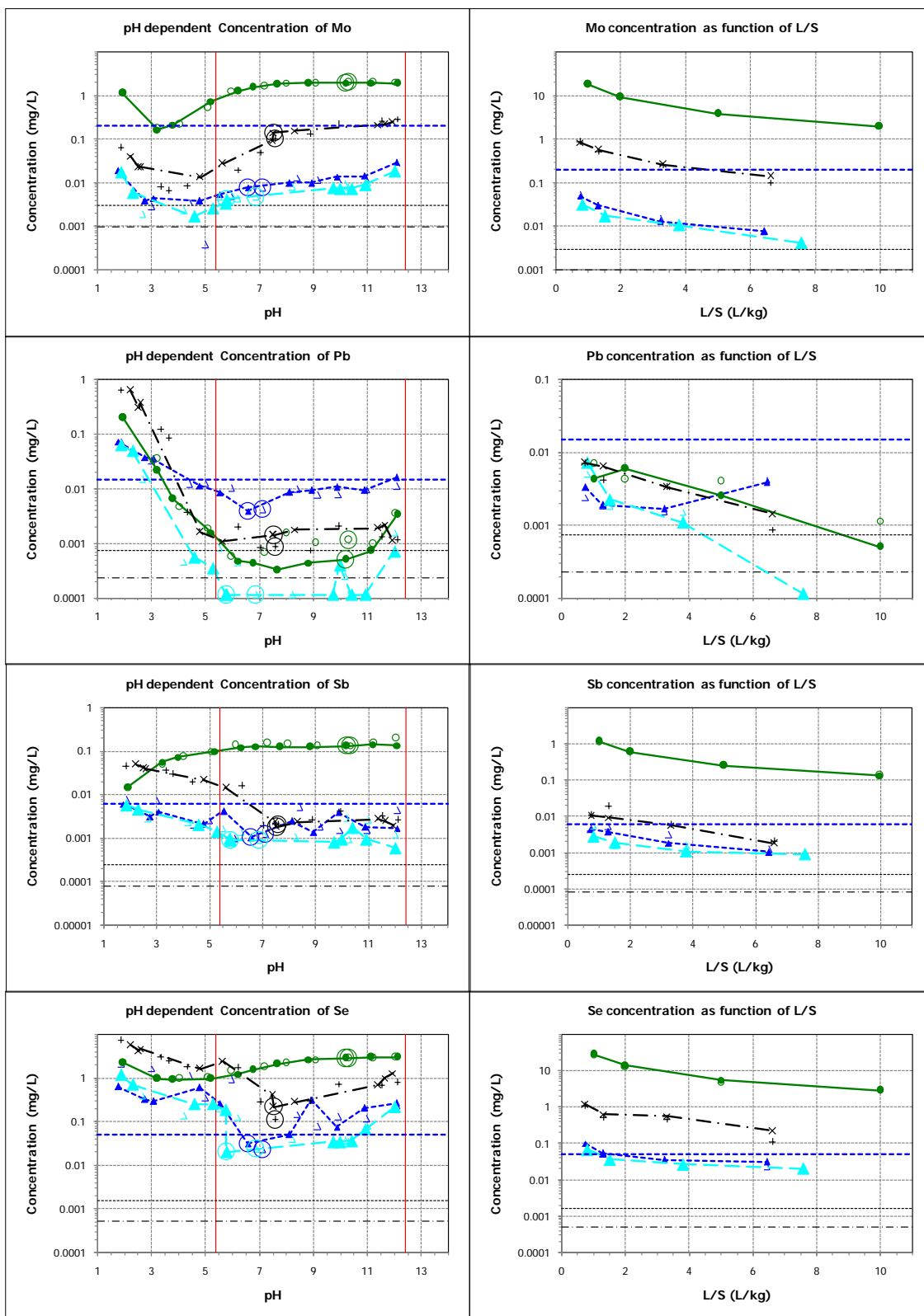
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** - spray dryer ash.



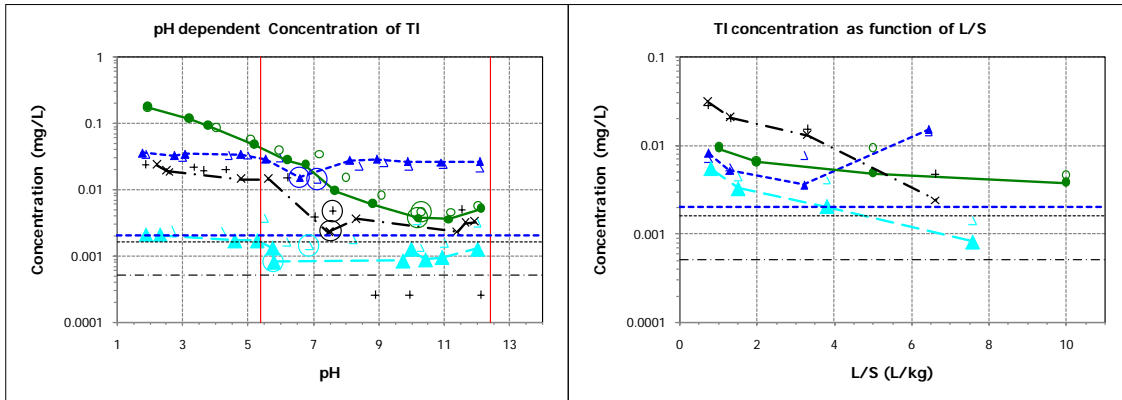
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



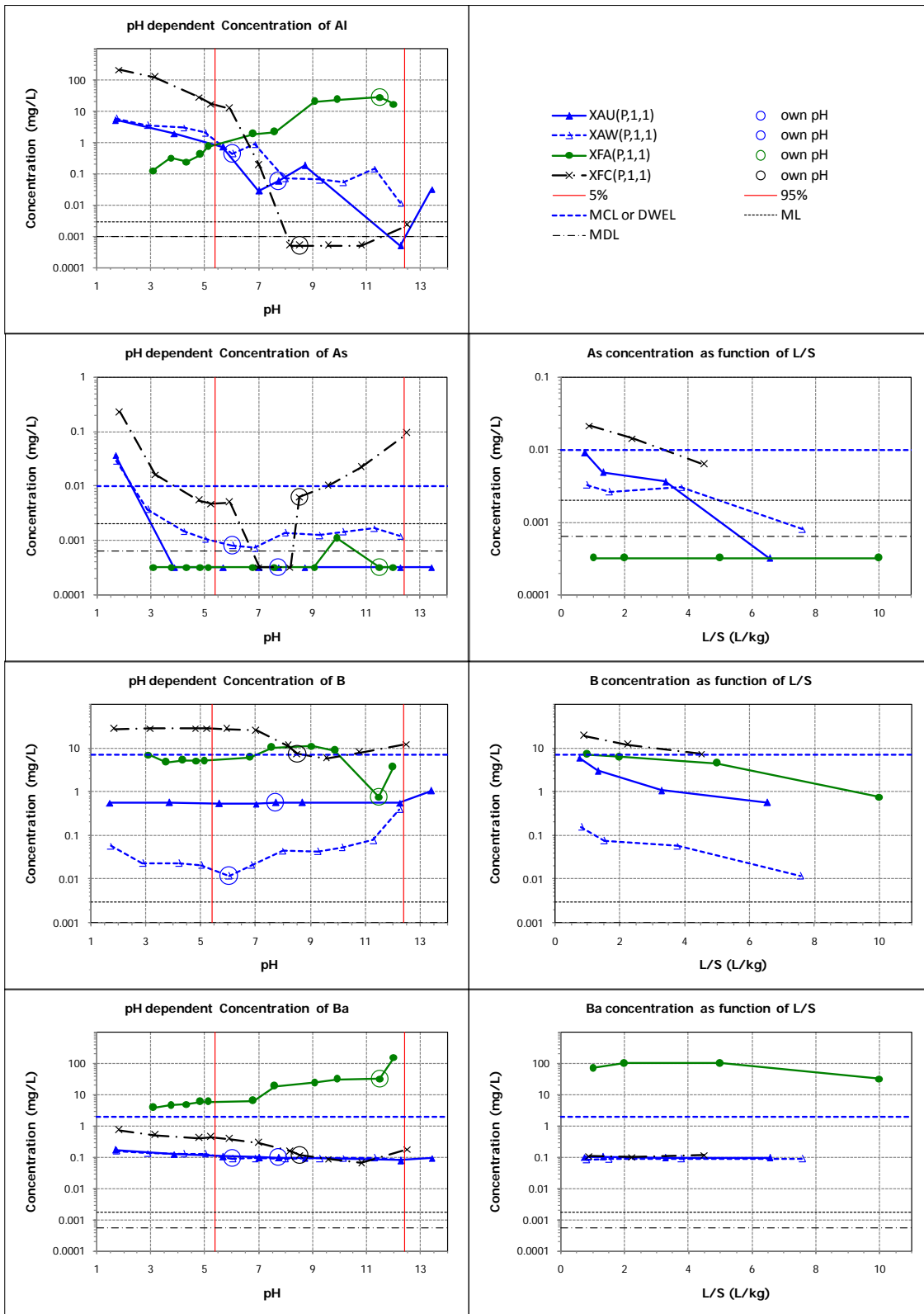
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



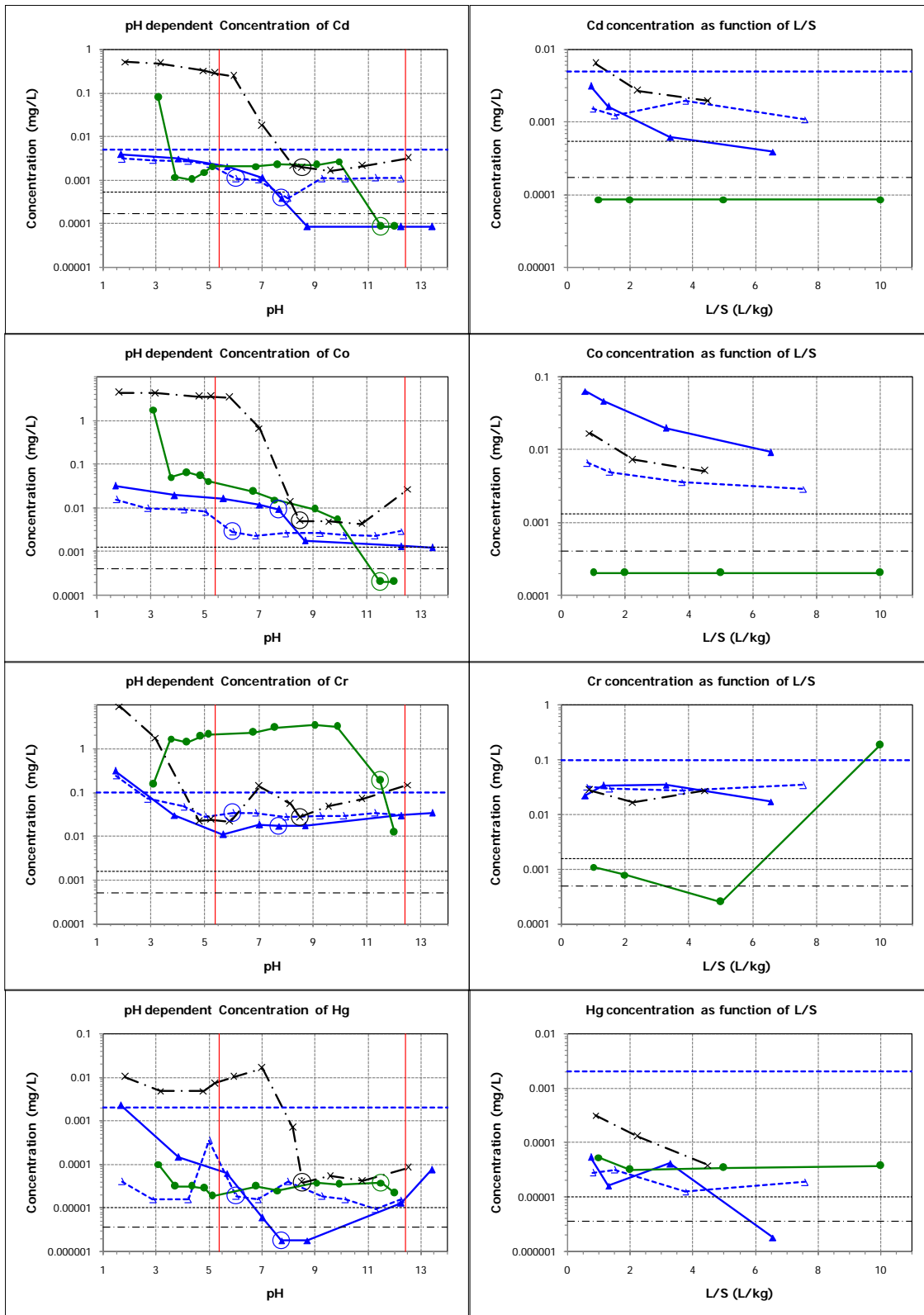
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



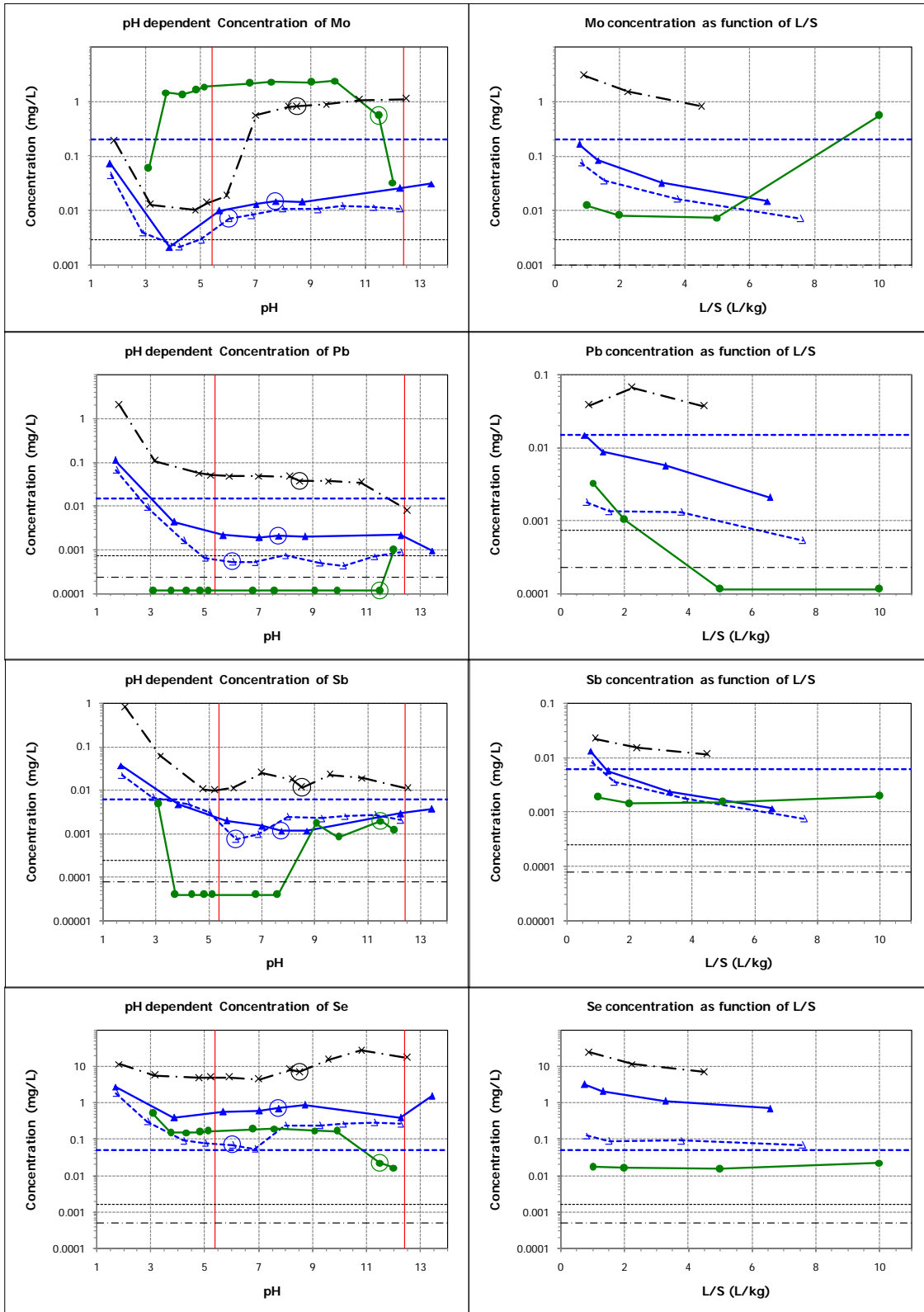
Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** - fly ash; **WAU** - unwashed gypsum; **WAW** - washed gypsum; **WFC** - filter cake.



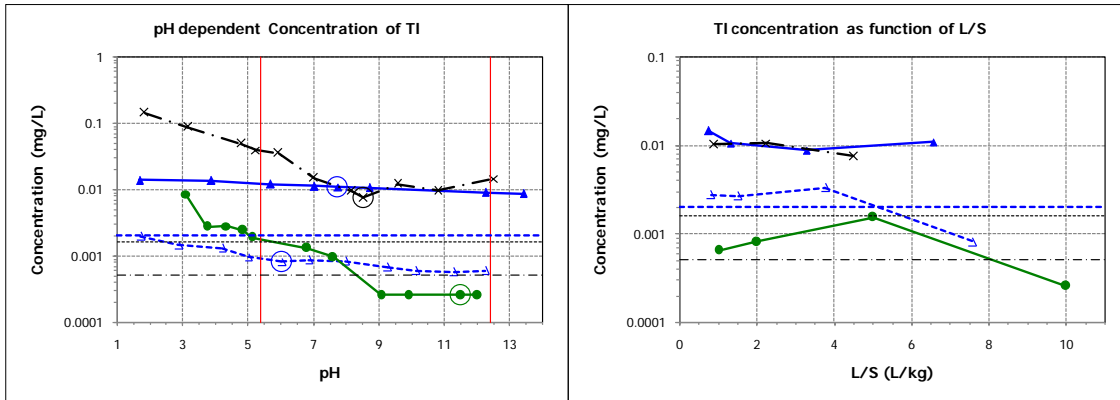
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



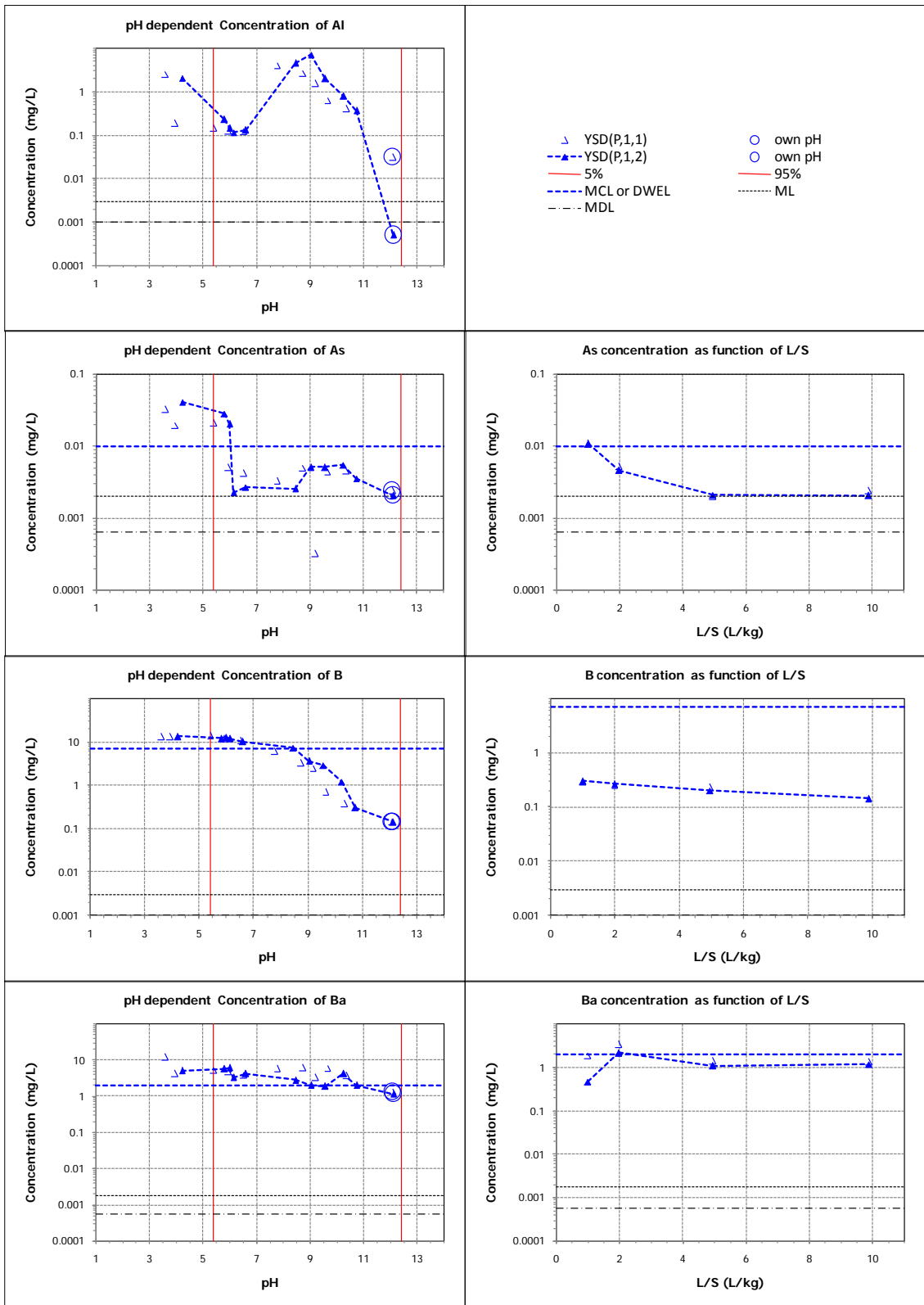
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



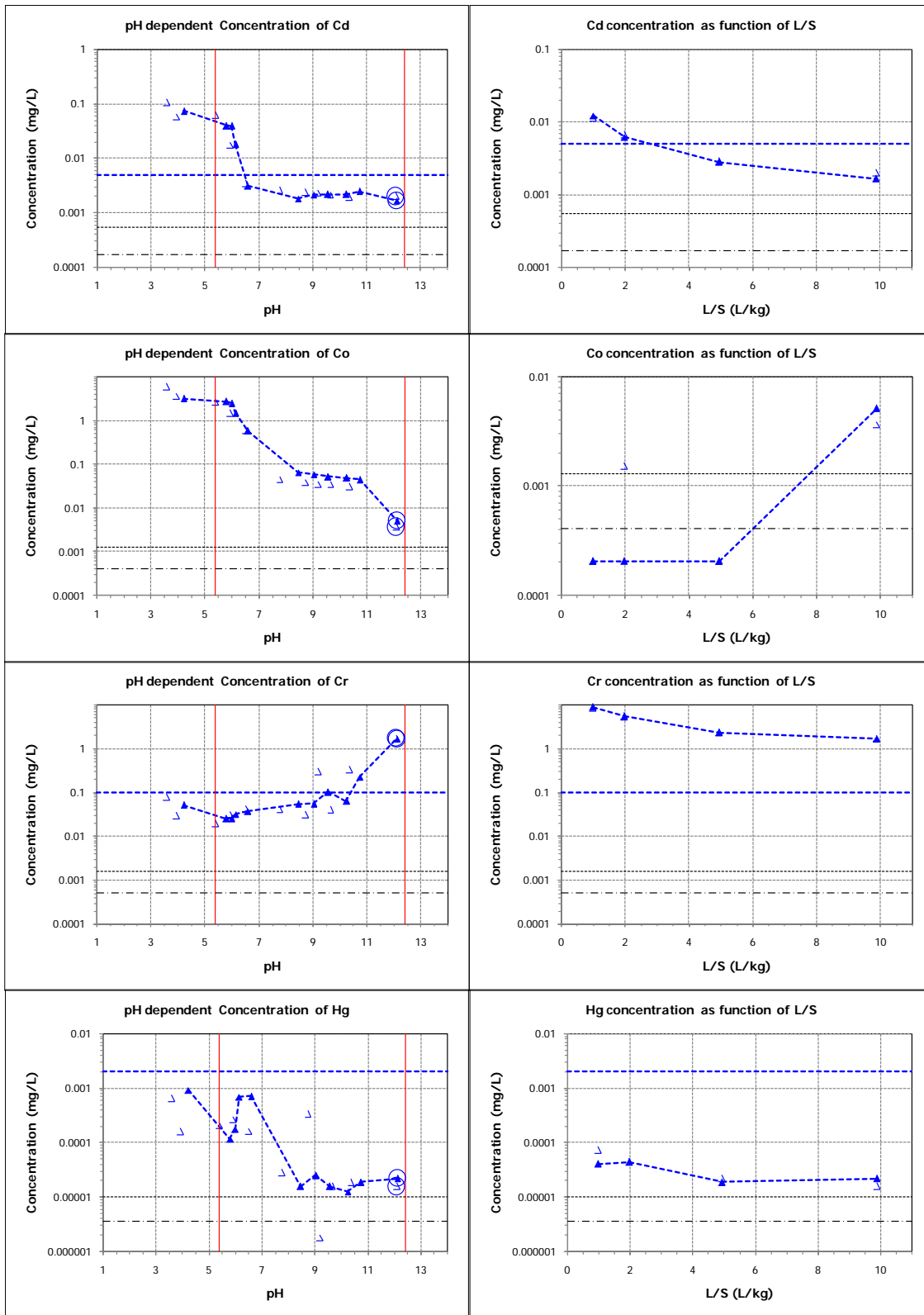
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



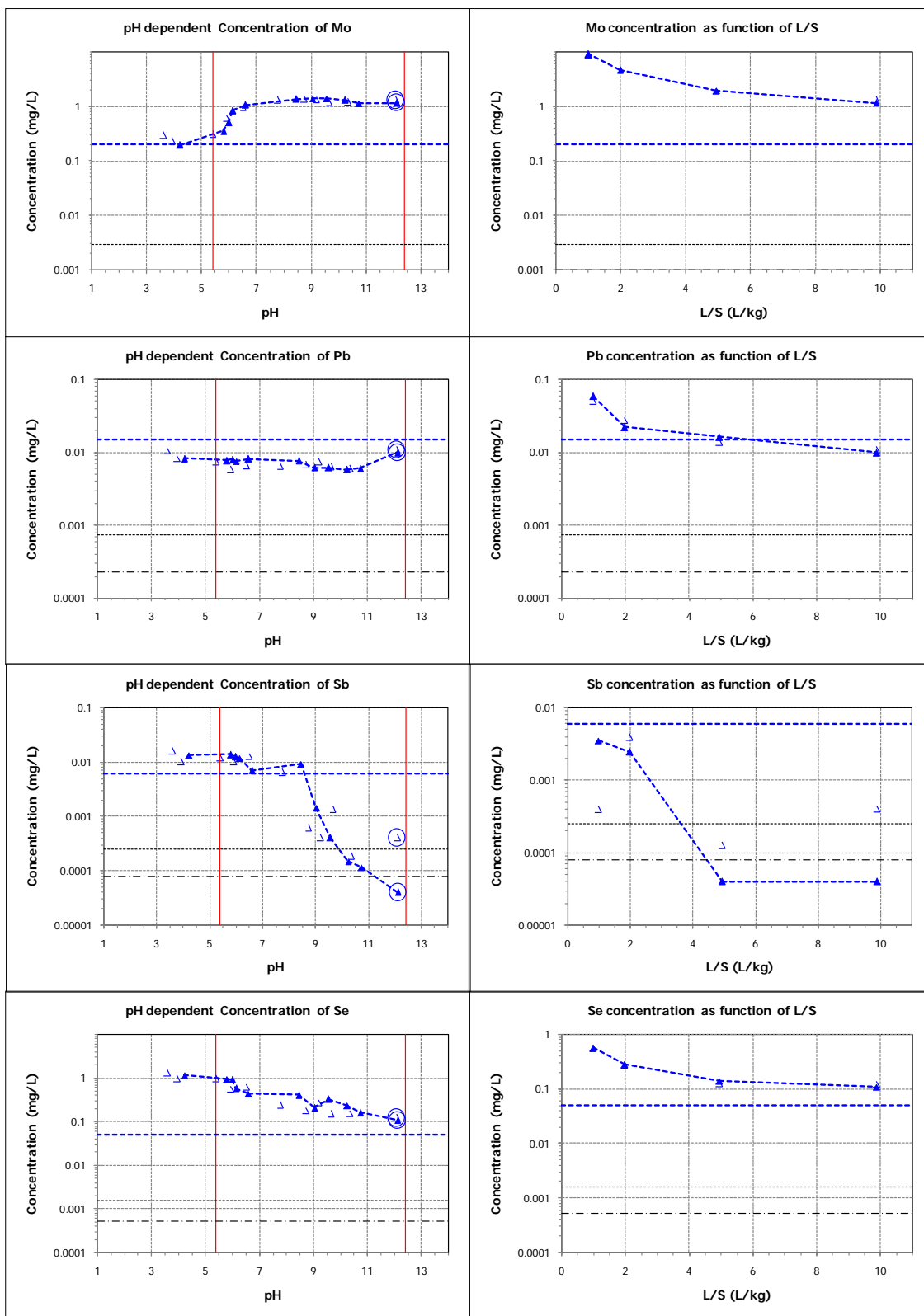
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XFA - fly ash; **XAU** - unwashed gypsum; **XAW** - washed gypsum; **XFC** - filter cake.



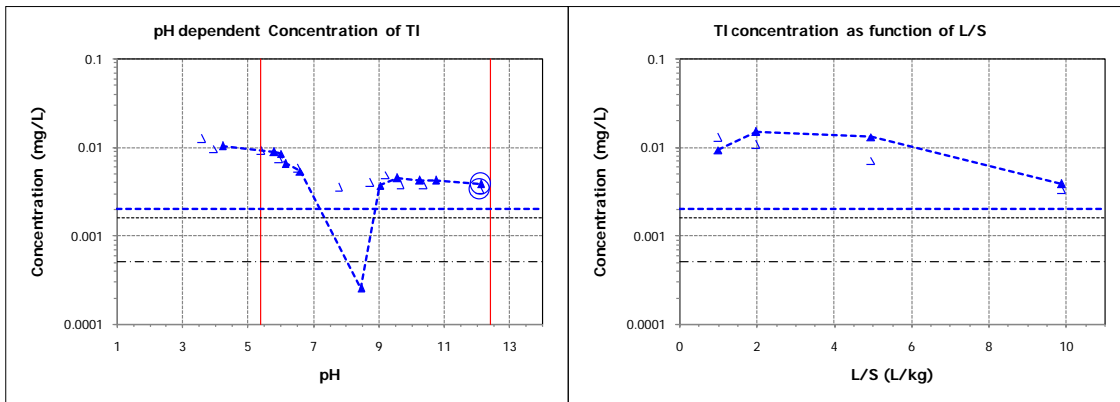
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



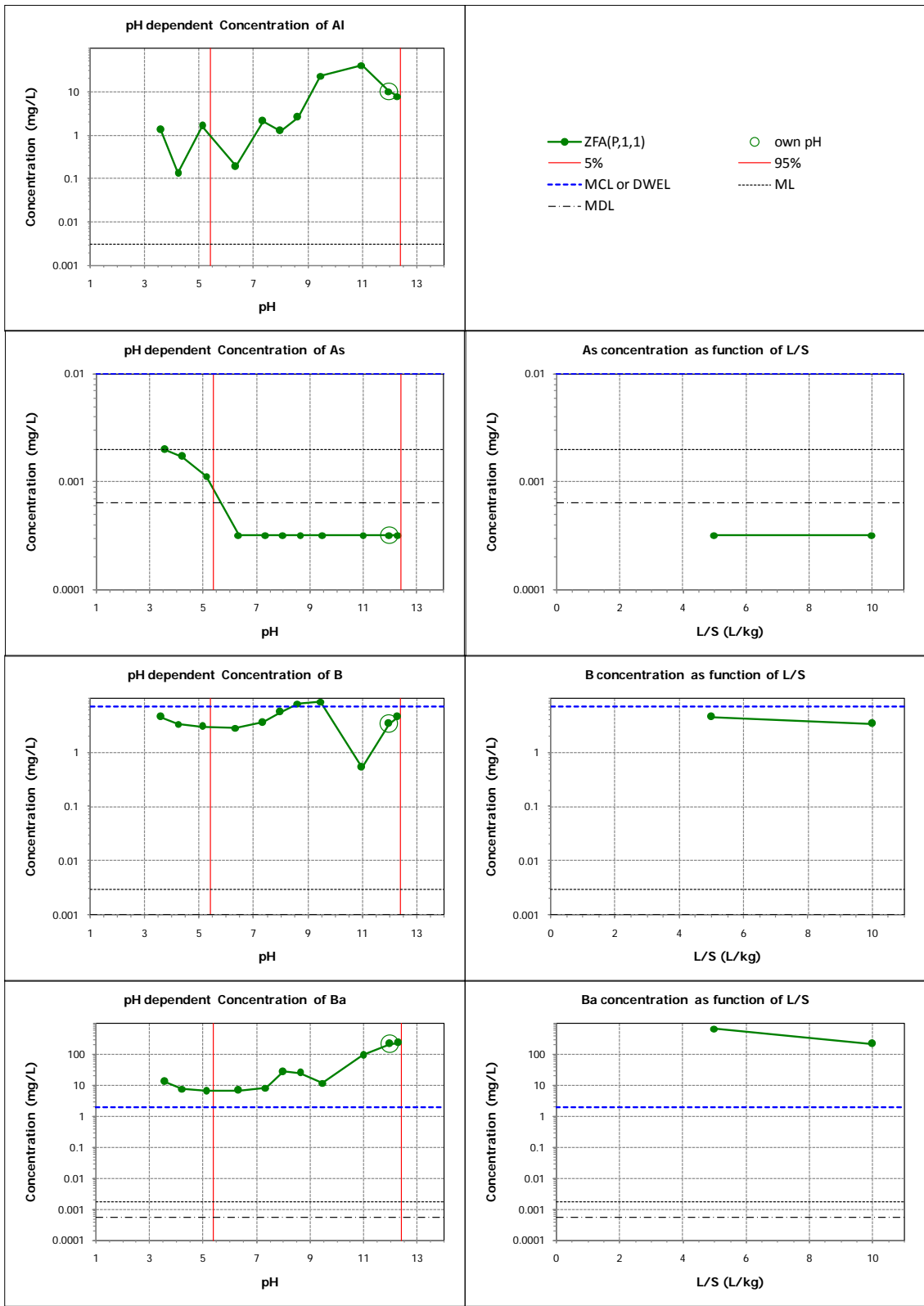
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



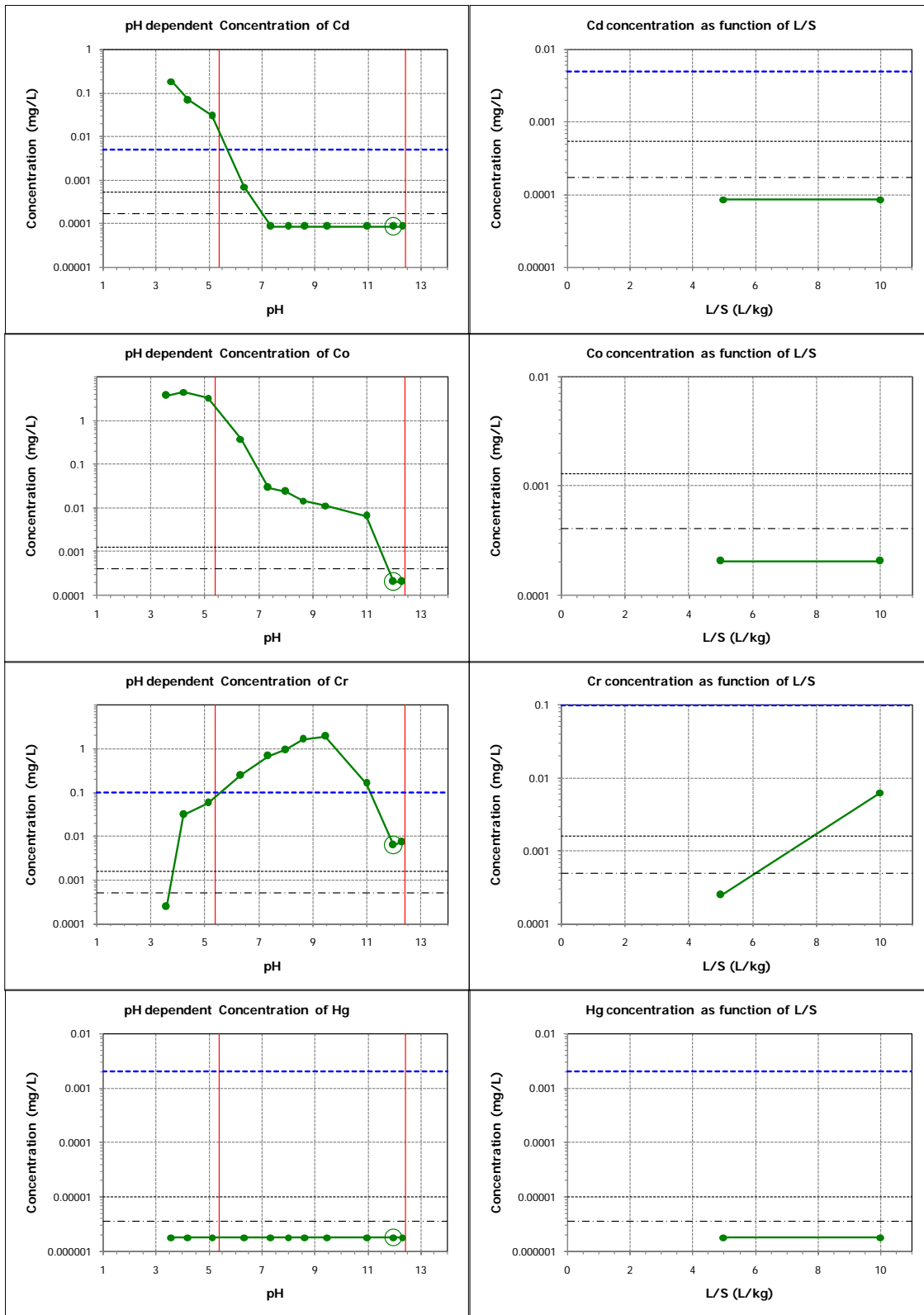
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



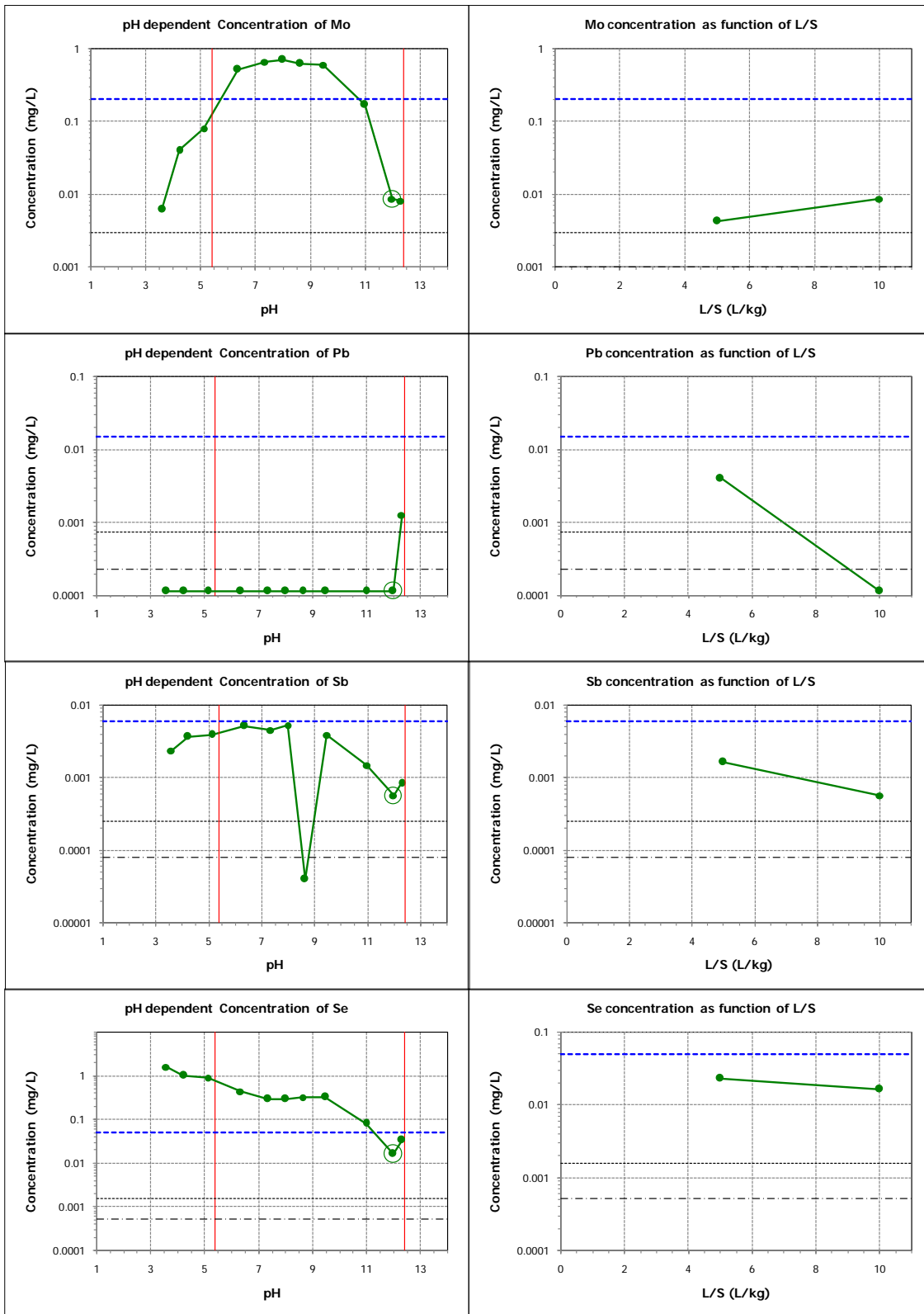
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** - spray dryer ash.



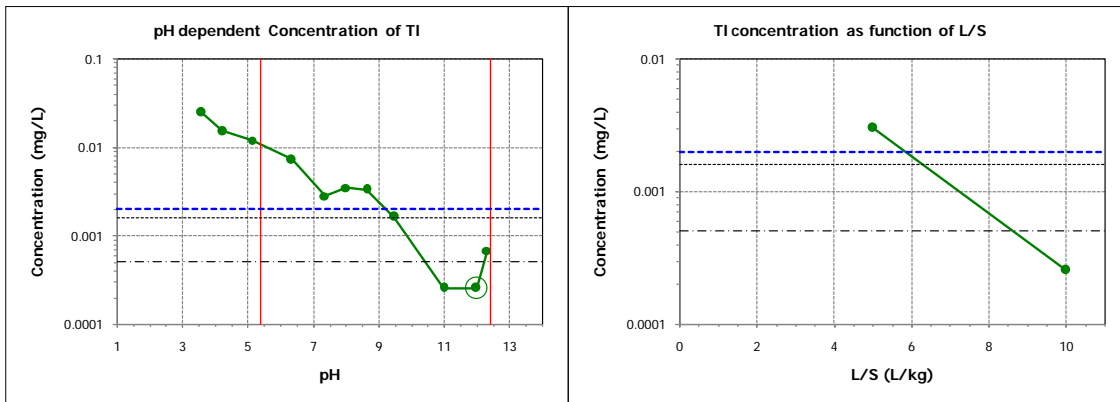
Facility Z (PRB, CS-ESP). ZFA - fly ash.



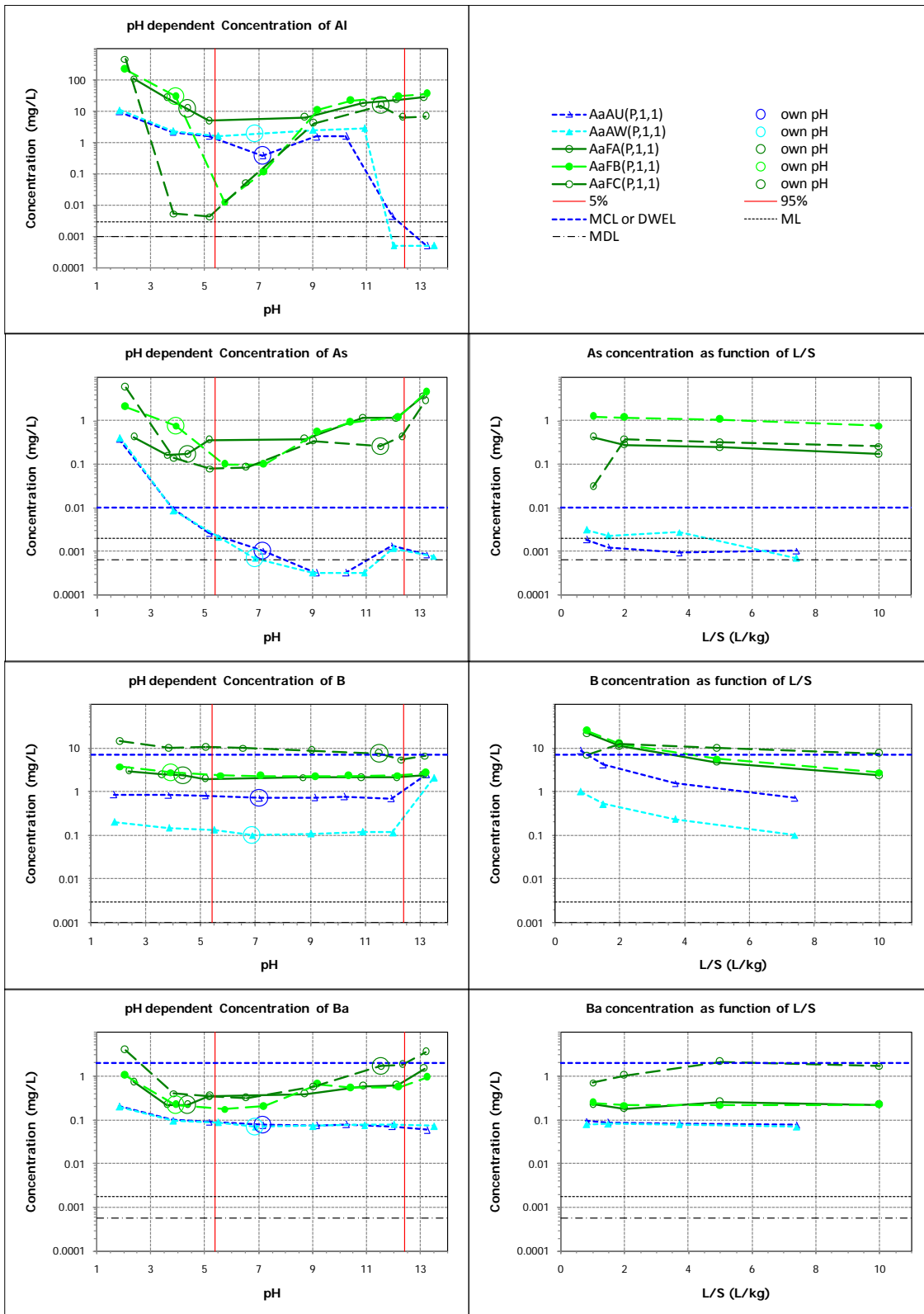
Facility Z (PRB, CS-ESP). ZFA - fly ash.



Facility Z (PRB, CS-ESP). ZFA - fly ash.



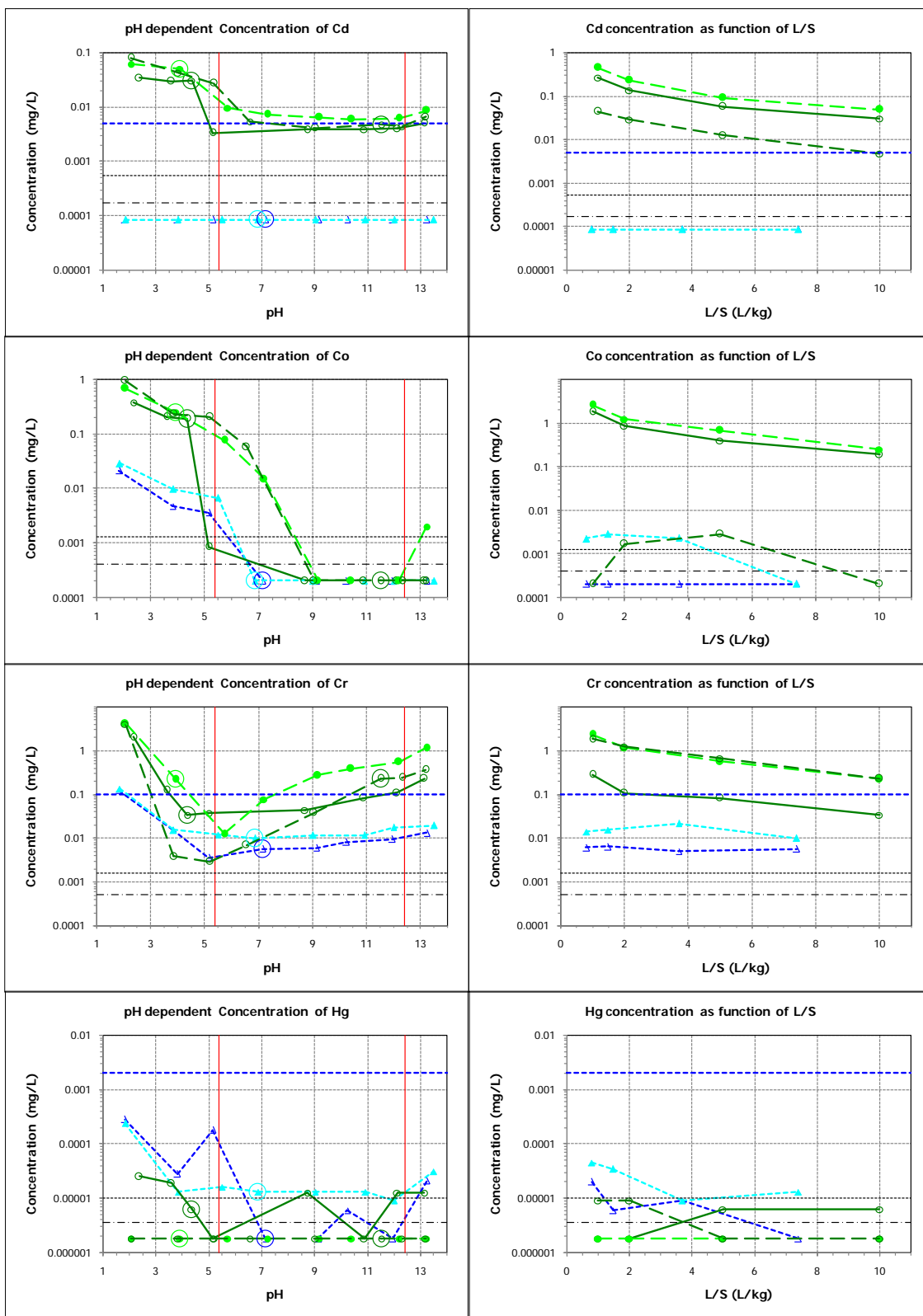
Facility Z (PRB, CS-ESP). ZFA - fly ash.



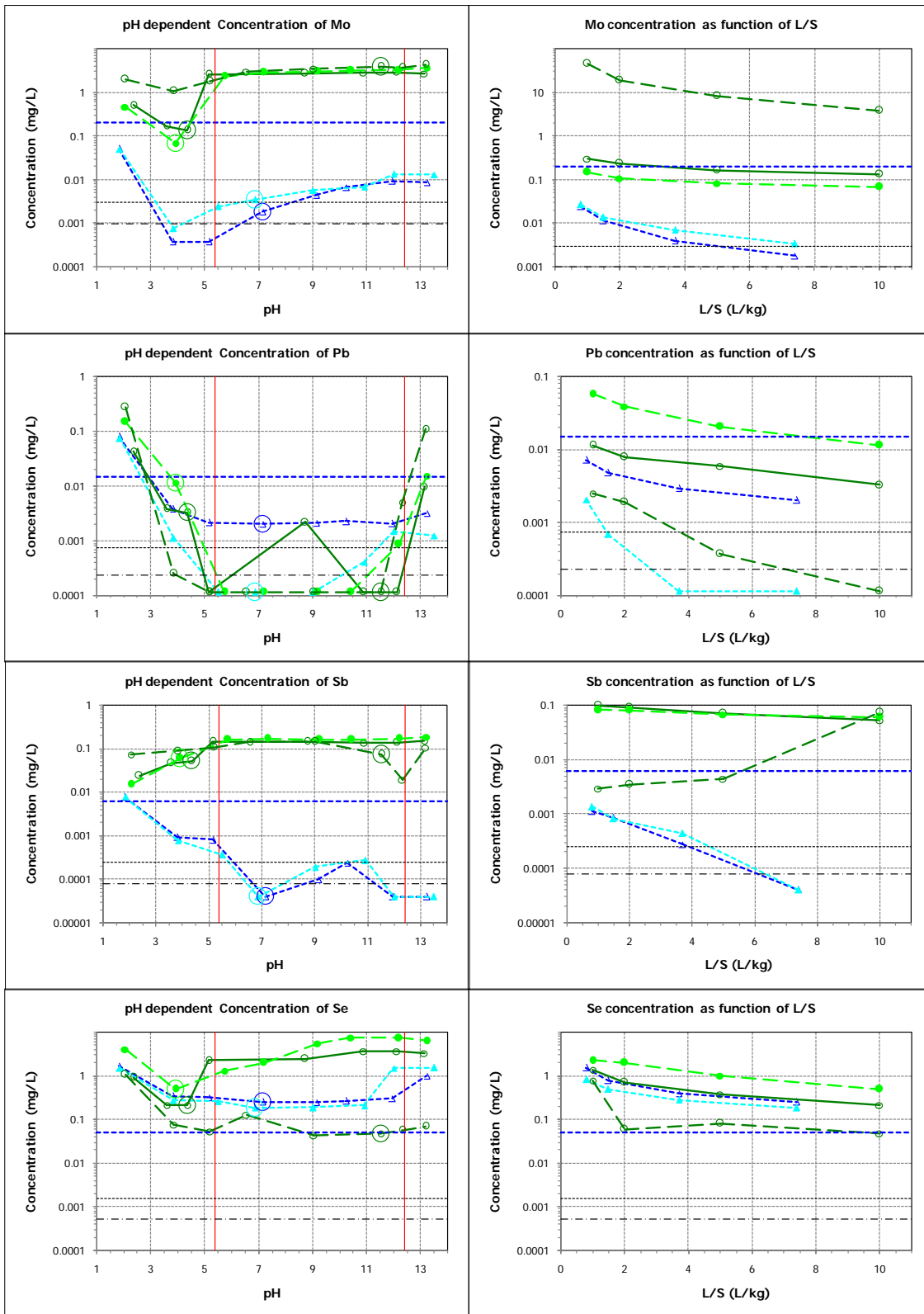
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).

AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP);

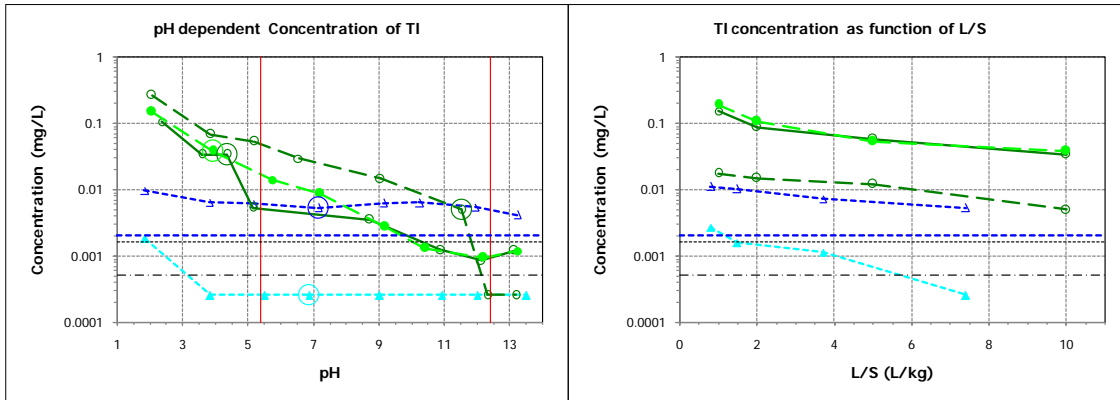
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



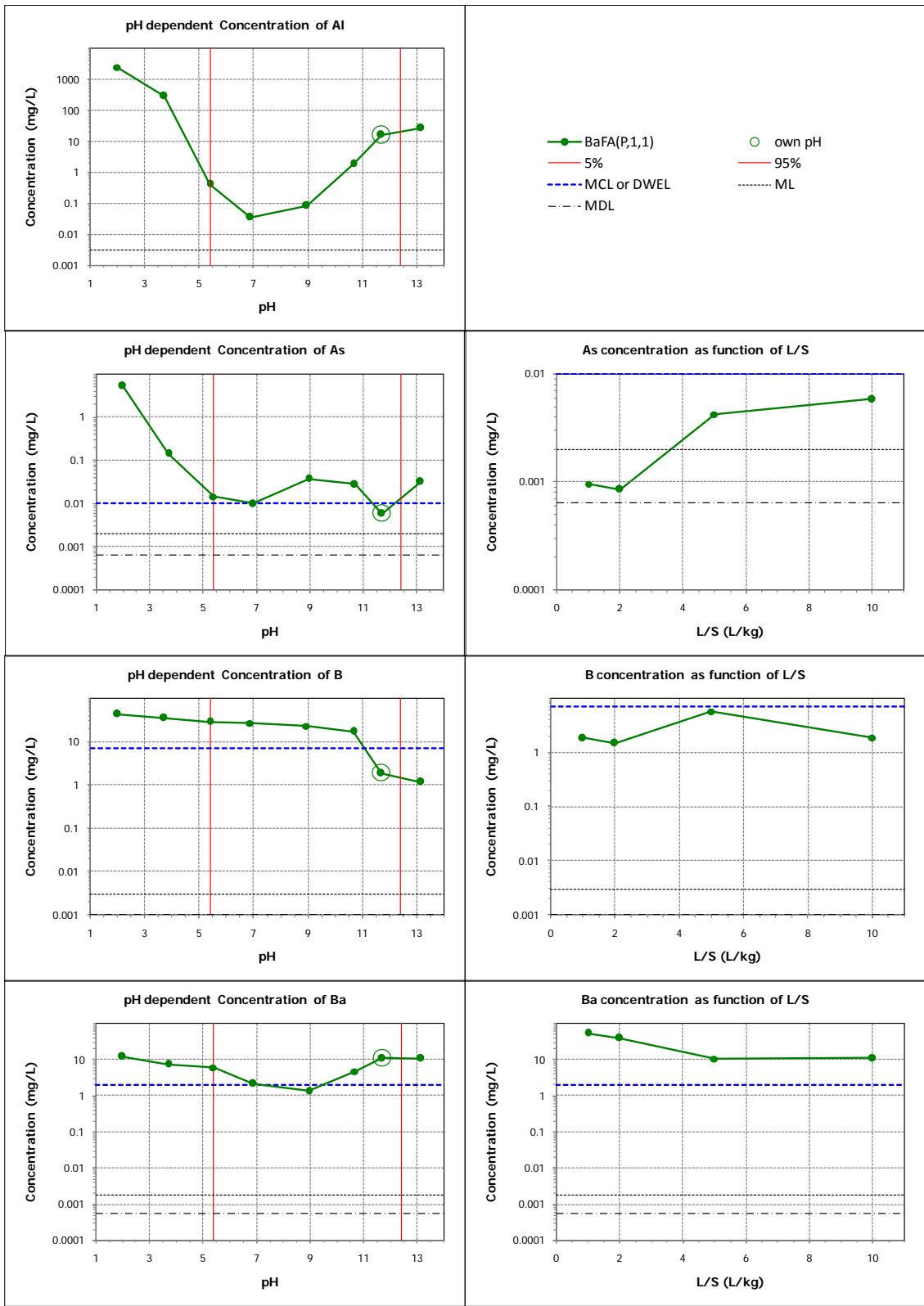
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP);
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



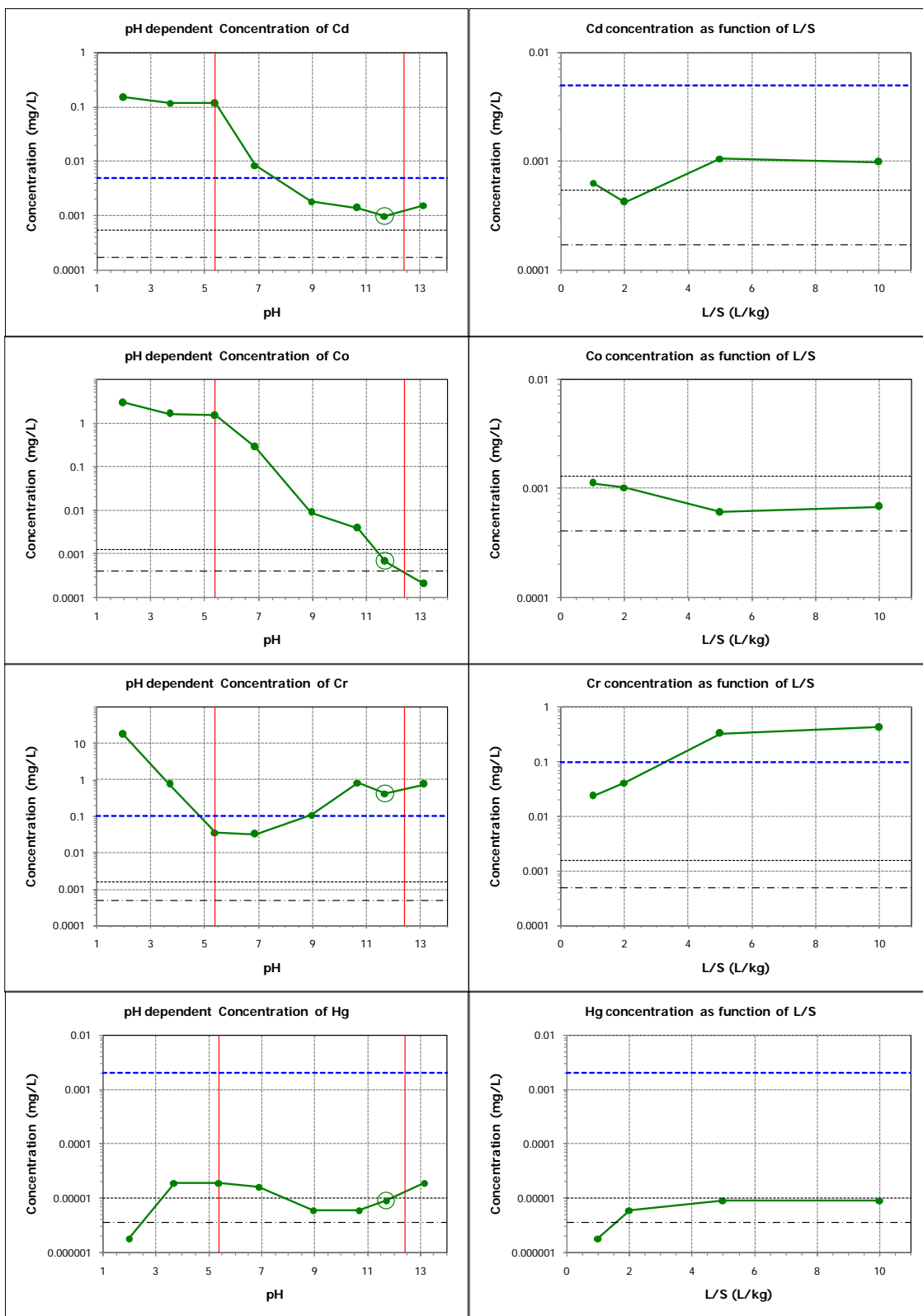
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP);
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



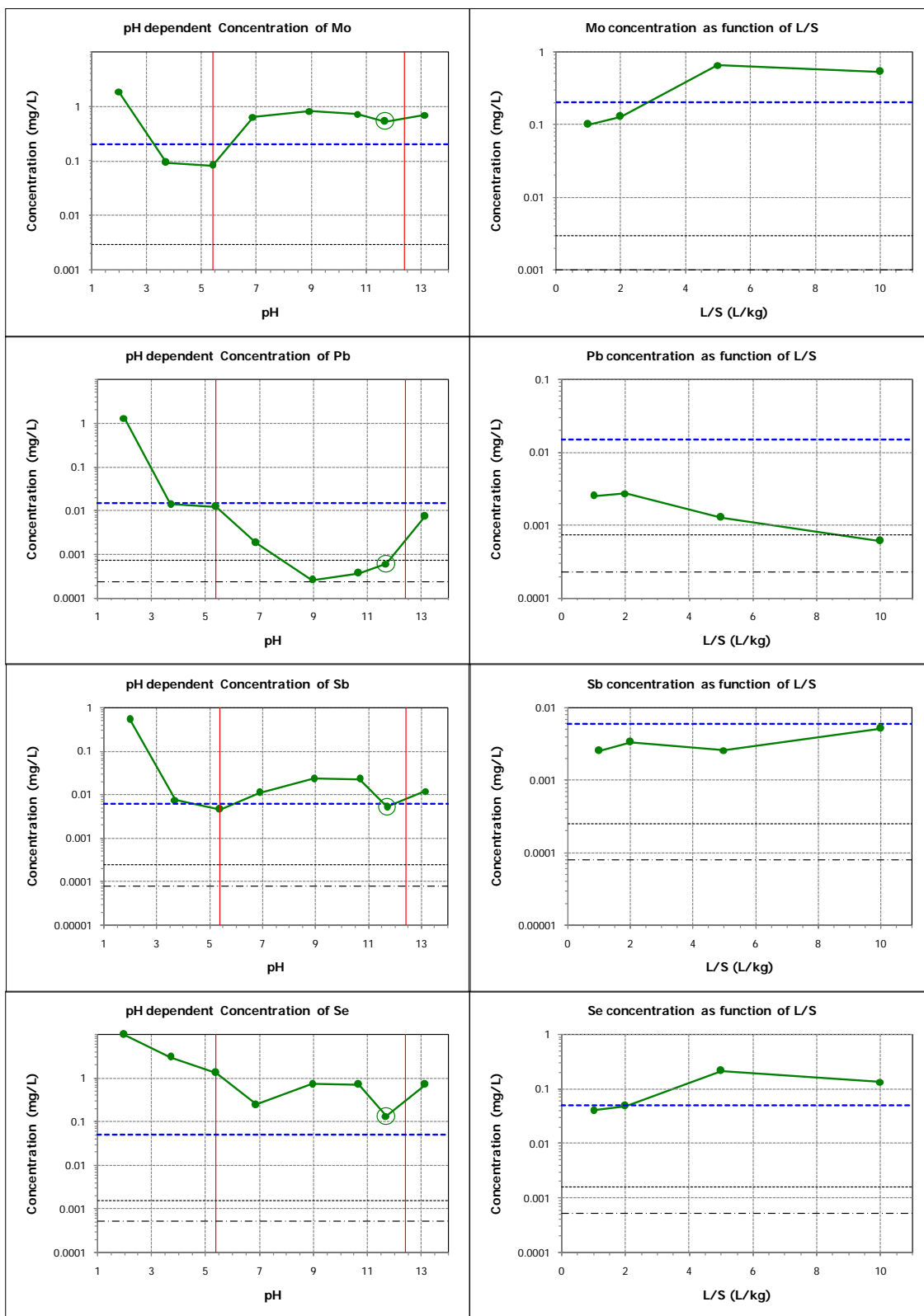
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB - fly ash (CS-ESP); **AaFC** - fly ash (HS-ESP);
AaAU - unwashed gypsum; **AaAW** - washed gypsum.



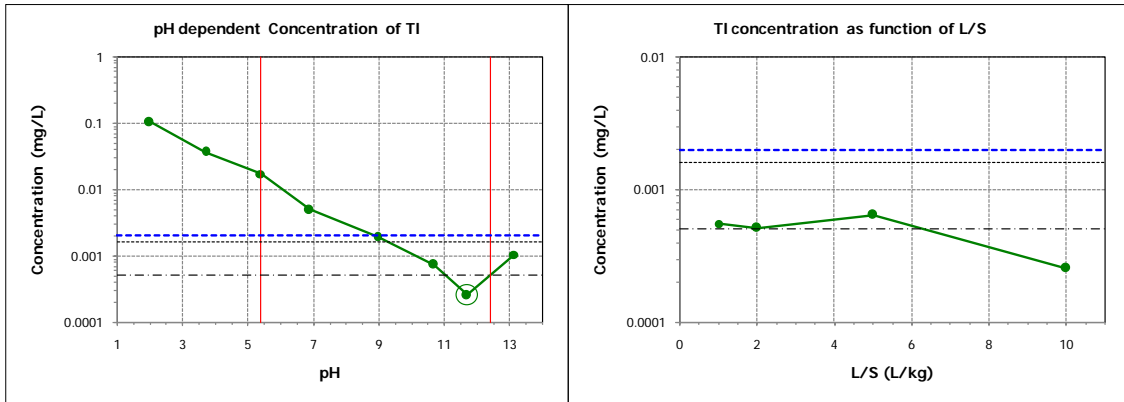
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). BaFA - fly ash.



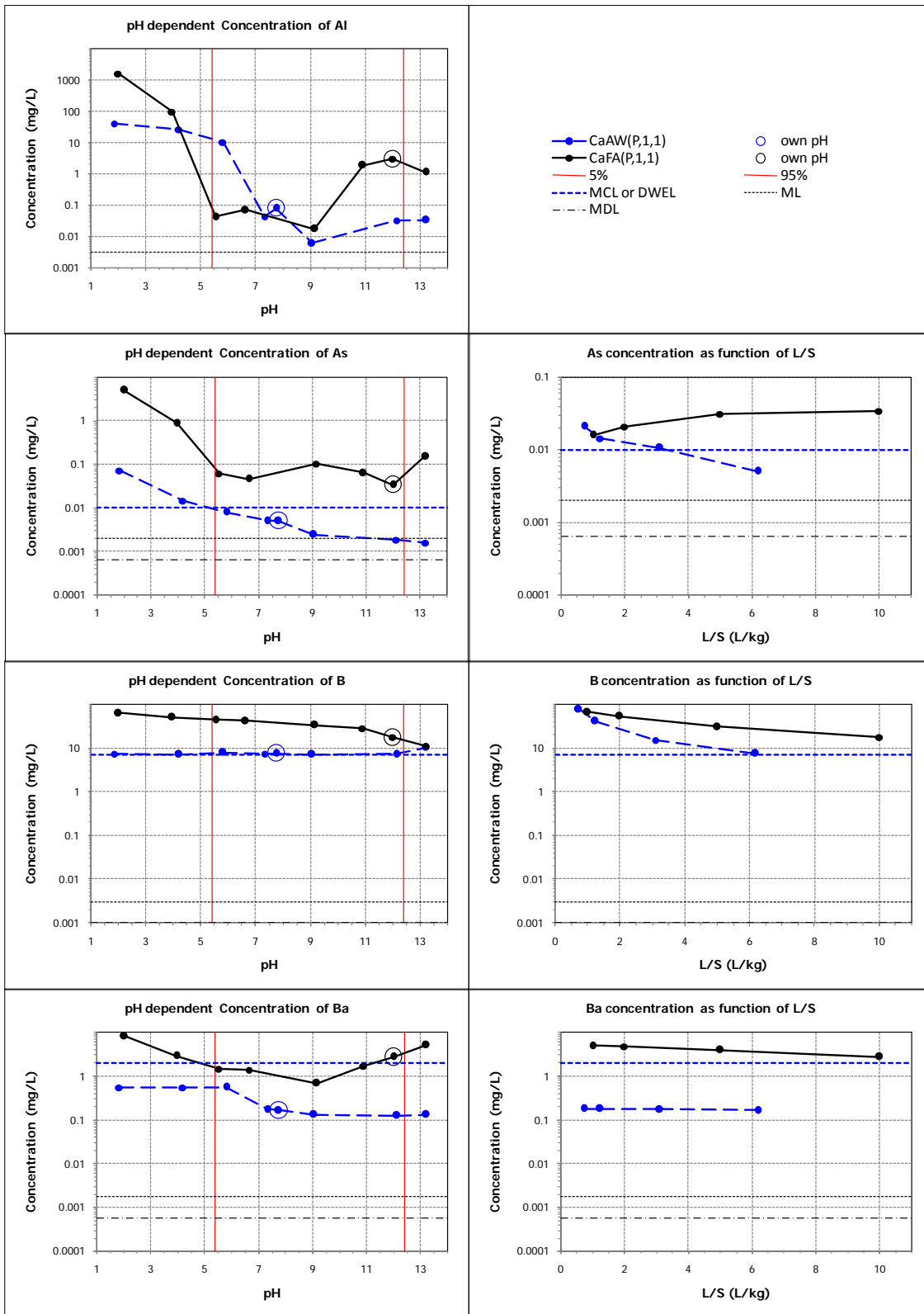
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



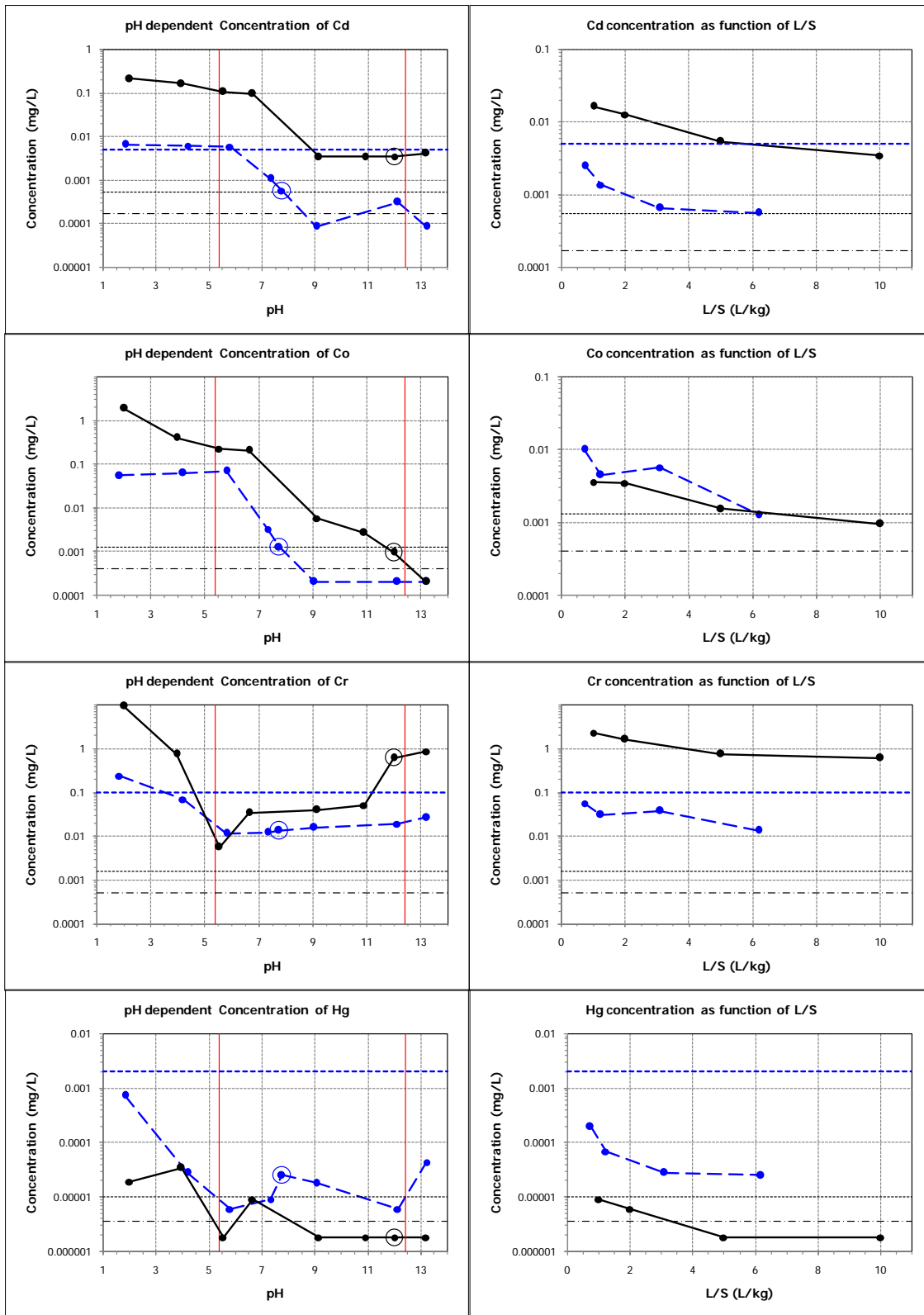
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



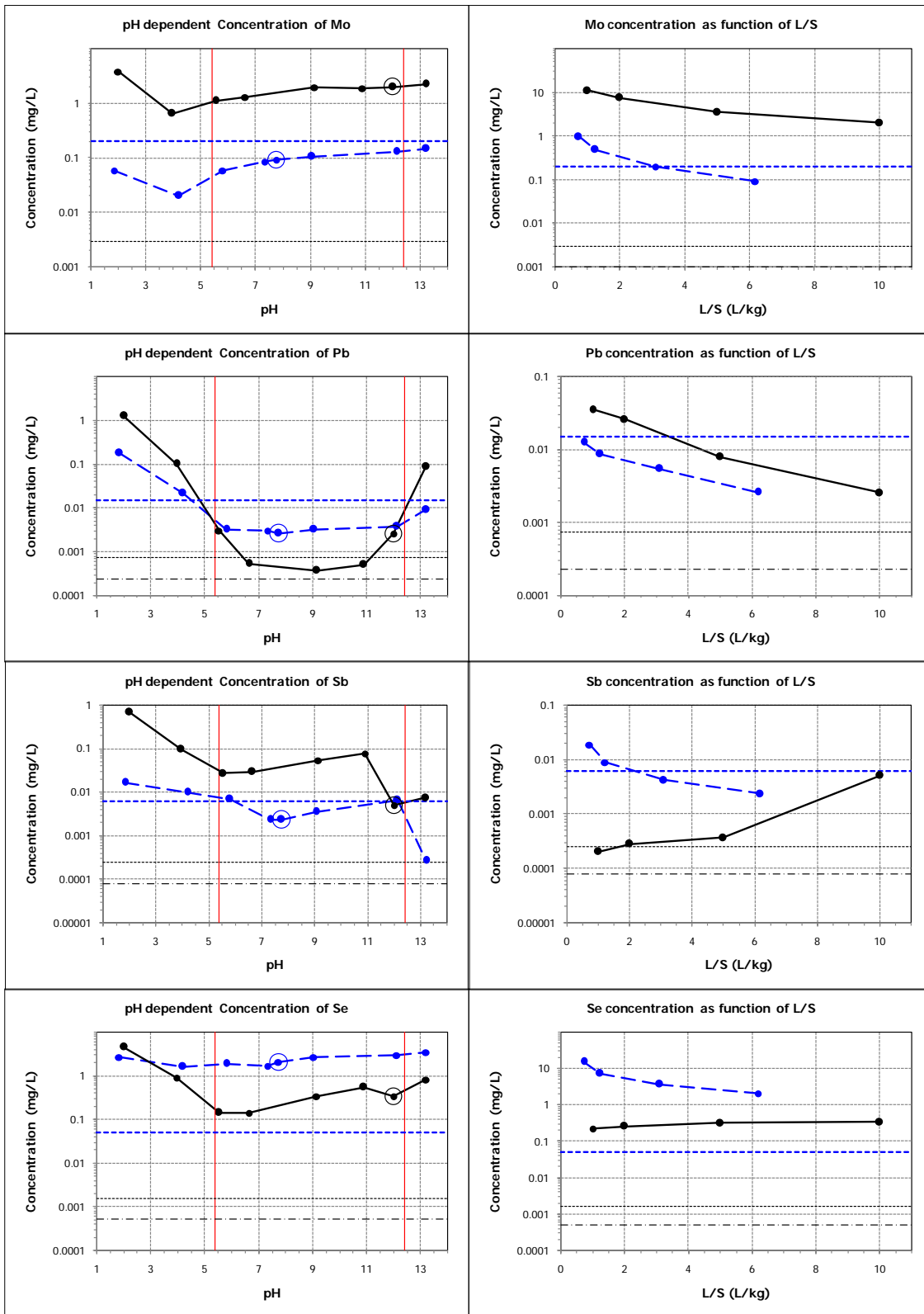
Facility Ba (PRB-Lignite Blend, CS-ESP w/ COHPAC Ammonia Inj.). **BaFA** - fly ash.



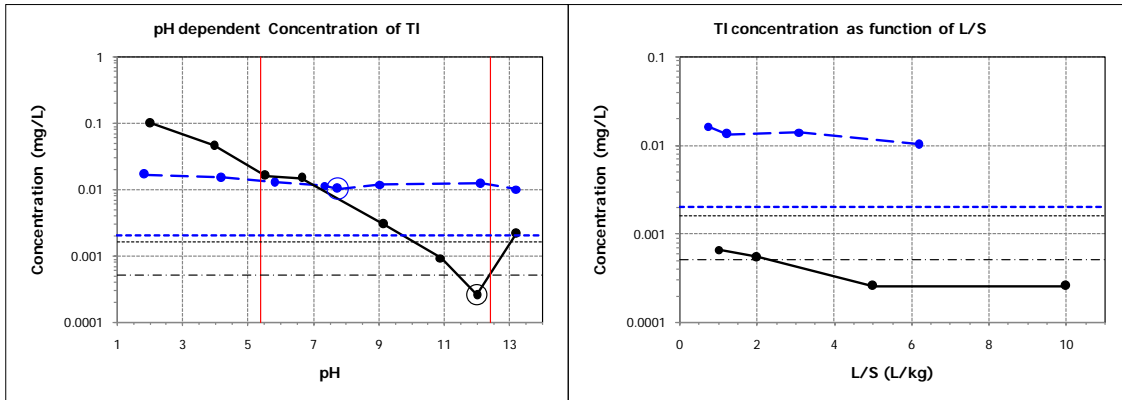
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



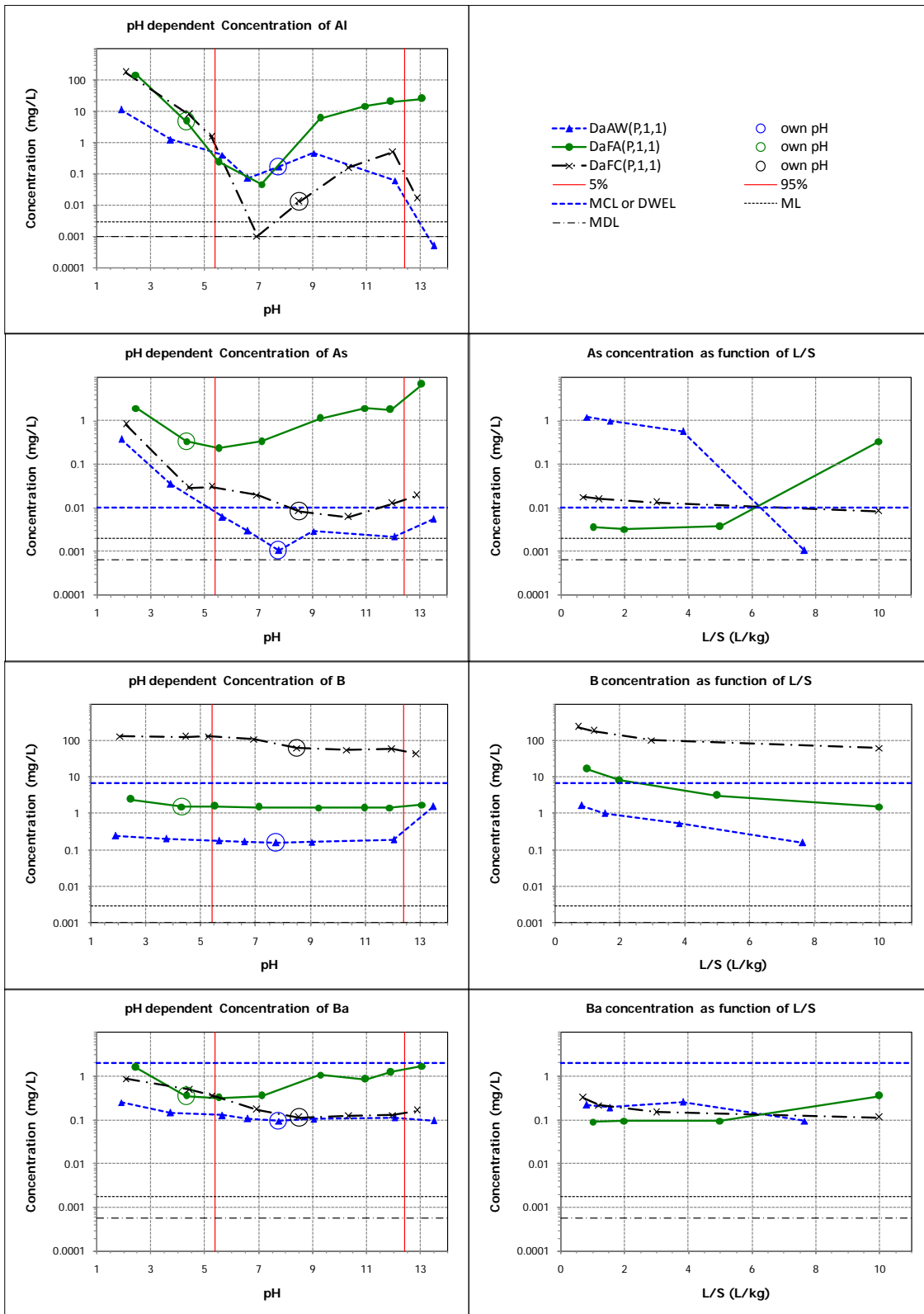
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



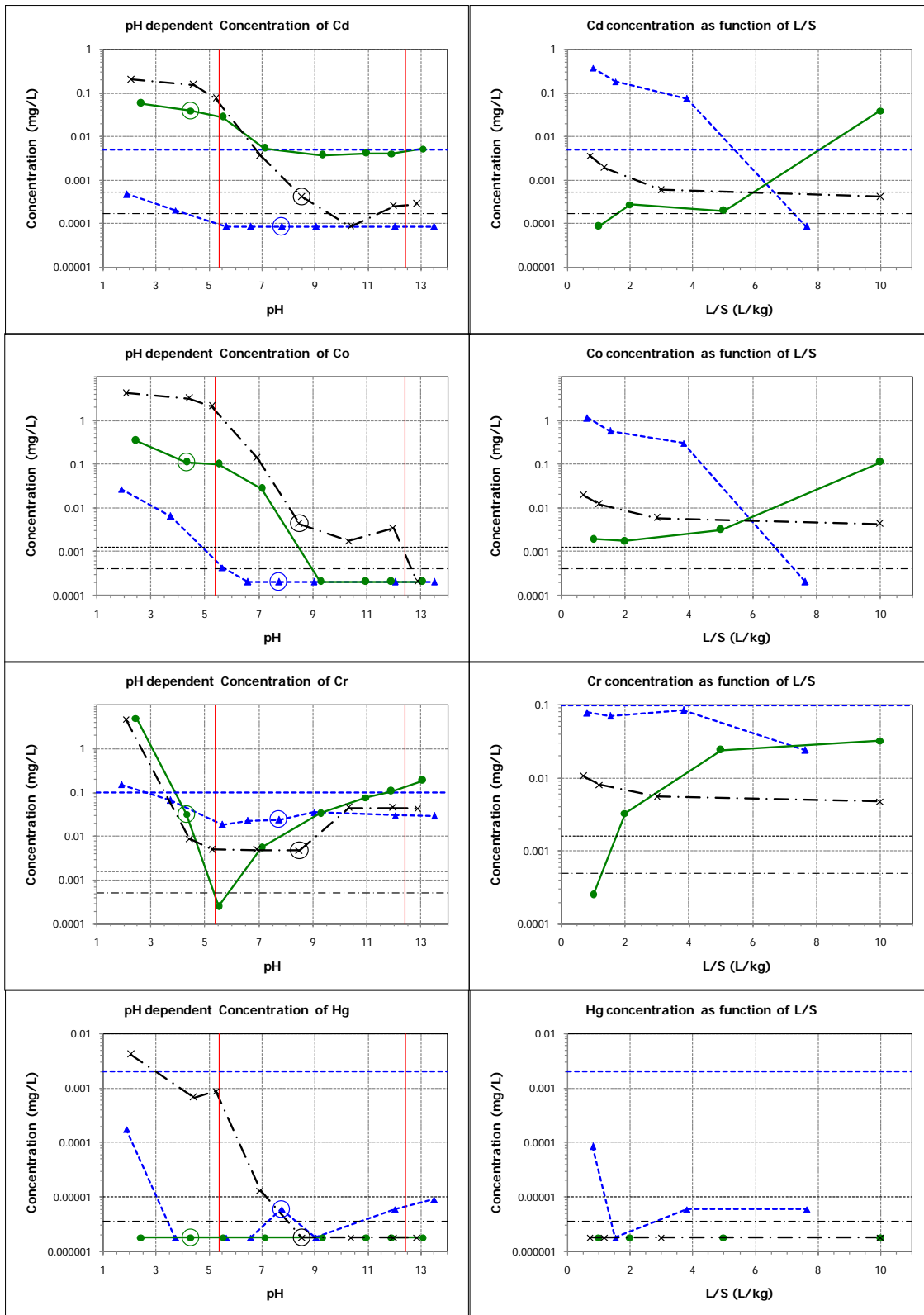
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



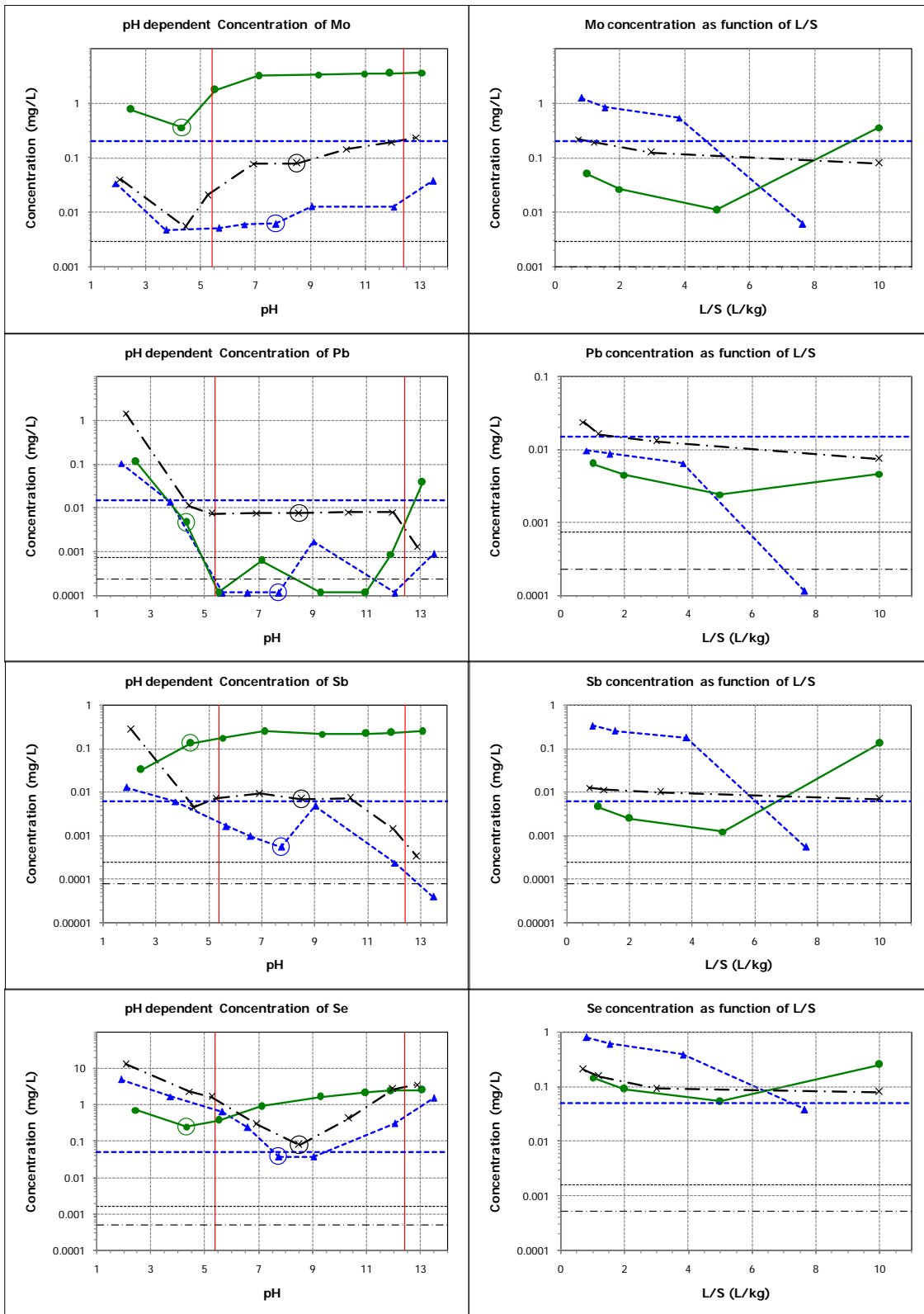
Facility Ca (Gulf Coast Lignite, CS-ESP, Limestone, Forced Oxidation).
CaFA - fly ash; **CaAW** - washed gypsum.



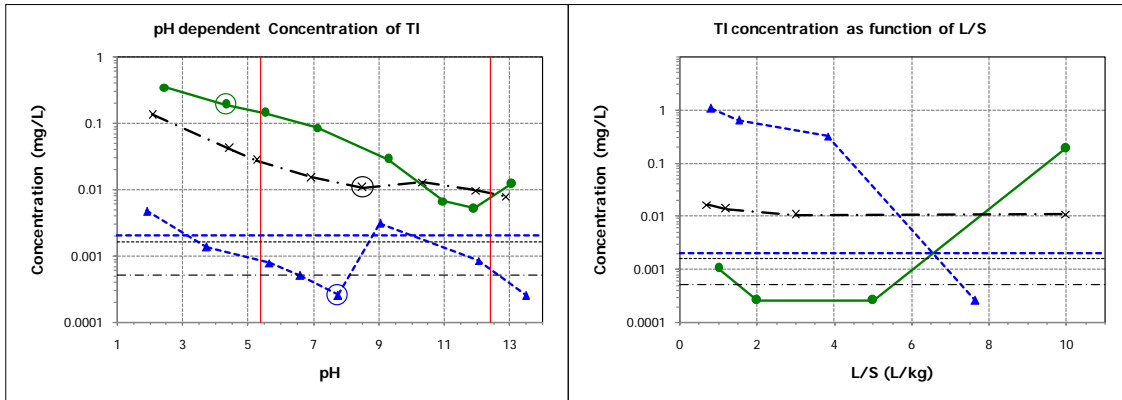
Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.



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.



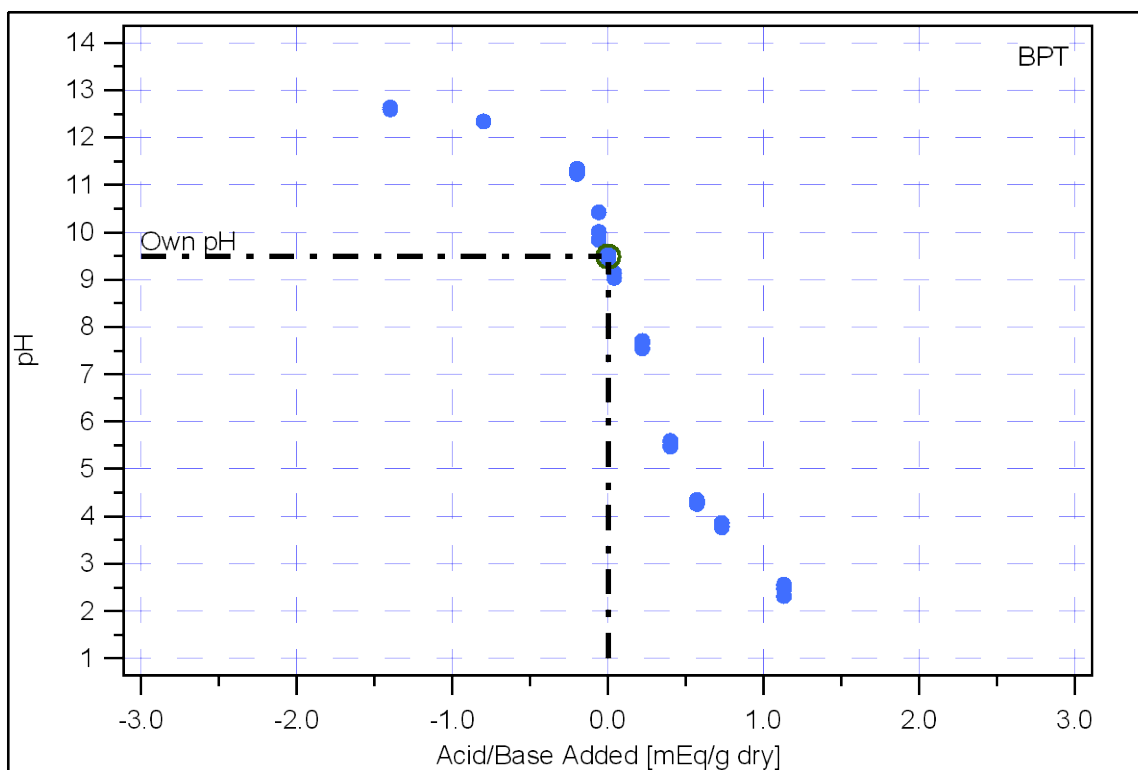
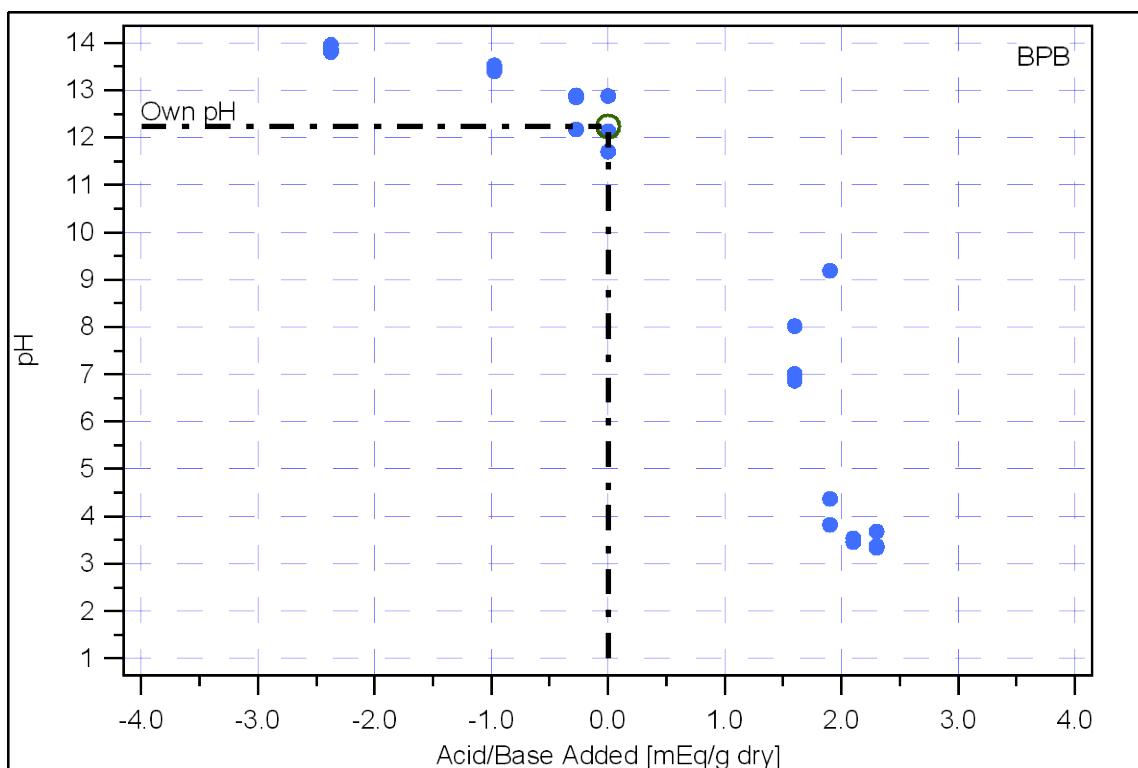
Facility Da (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
DaFA - fly ash; **DaAW** - washed gypsum; **DaFC** - filter cake.

Appendix G

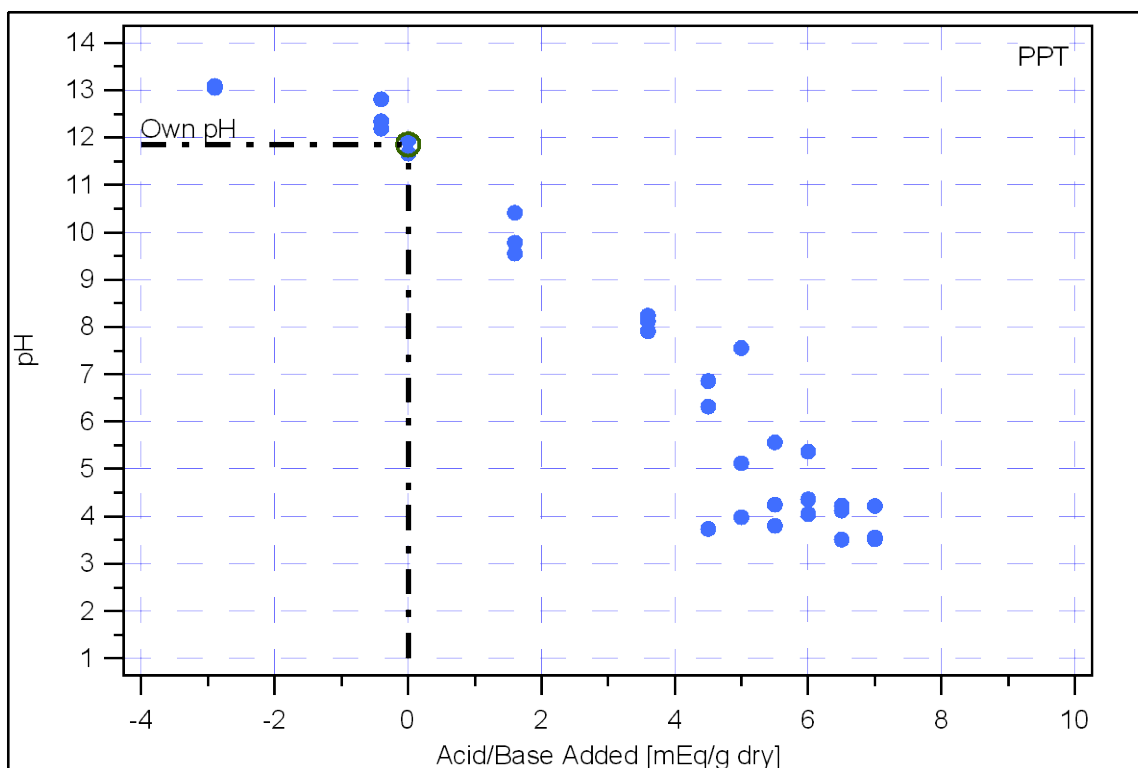
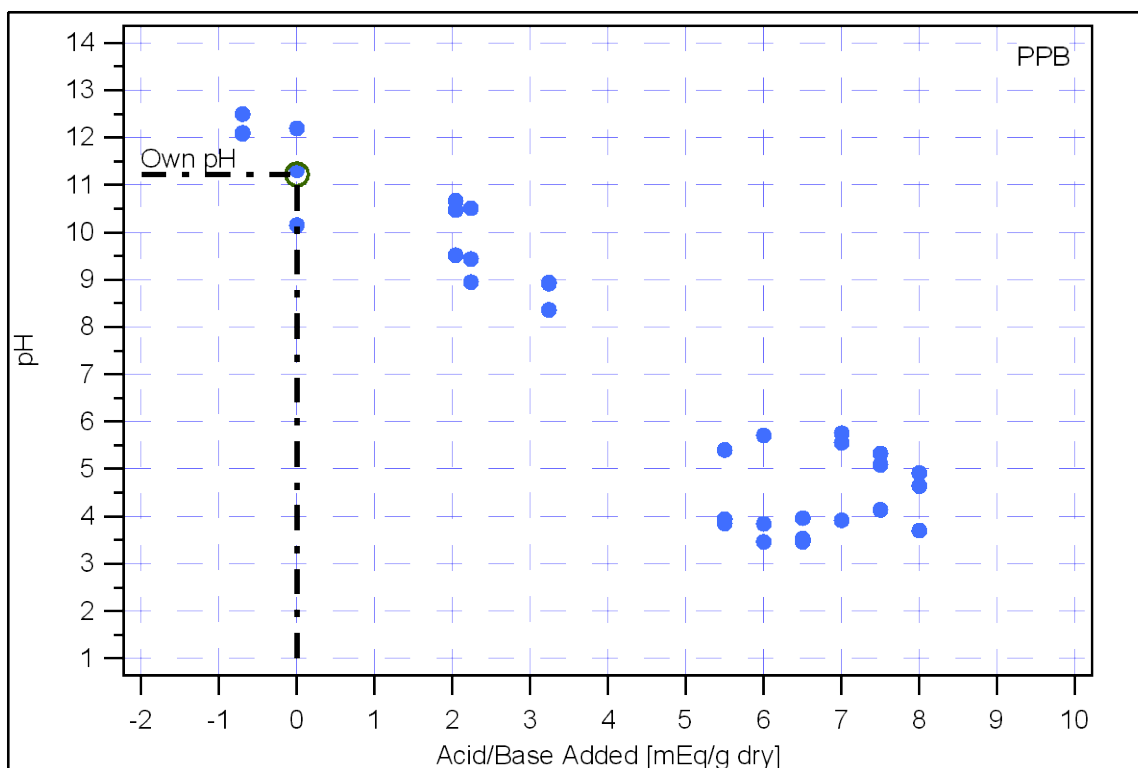
CCR pH Titration Curves

Brayton Point - Fly ash without and with ACI (Samples BPB, BPT)	G-1
Pleasant Prairie - Fly ash without and with ACI (Samples PPB, PPT)	G-2
Salem Harbor - Fly ash without and with ACI (Samples SHB, SHT)	G-3
Facility A - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SNCR-BP (Samples CFA, CGD, CCC)	G-4
Facility A - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SNCR on (Samples AFA, AGD, ACC)	G-6
Facility B - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SCR-BP (Samples BFA, BGD, BCC)	G-8
Facility B - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge – SCR on (Samples DFA, DGD, DCC)	G-10
Facility C - Fly ash without and with ACI (Samples GAB, GAT)	G-12
Facility E - Fly ash, SCR on and SCR-BP (Samples EFA, EFC, EFB)	G-13
Facilities F, G, and H - Fly ash (Samples FFA, GFA, HFA)	G-14
Facility J - Fly ash without and with Br-ACI (Samples JAB, JAT)	G-16
Facility K - Fly ash; Scrubber sludge; Mixed fly ash and scrubber sludge (Samples KFA, KGD, KCC)	G-17
Facility L - Fly ash without and with Br-ACI (Samples LAB, LAT)	G-19
Facility M - Mixed fly ash and scrubber sludge, SCR-BP and SCR on (Samples MAD, MAS)	G-20
Facility N - Gypsum, unwashed and washed (Samples NAU, NAW)	G-21
Facility O - Gypsum, unwashed and washed (Samples OAU, OAW)	G-22
Facilities P, Q, and R - Gypsum, unwashed (Samples PAD, QAU, RAU)	G-23
Facility S - Gypsum, unwashed and washed (Samples SAU, SAW)	G-25

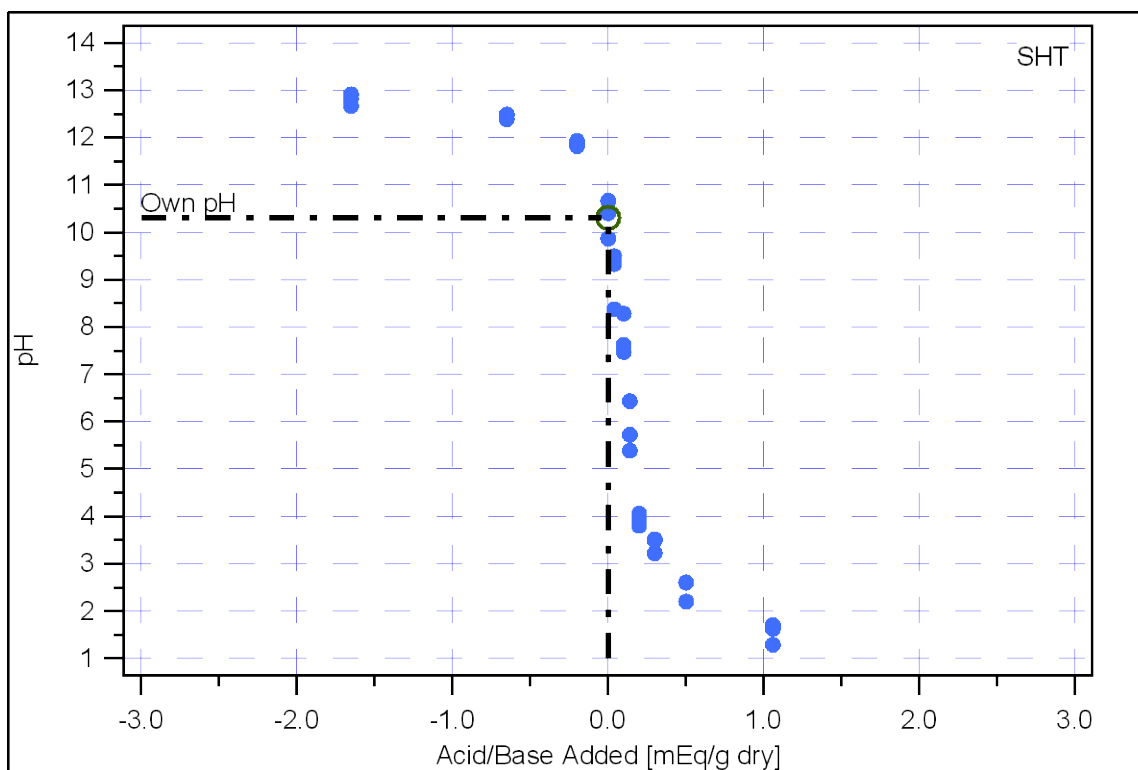
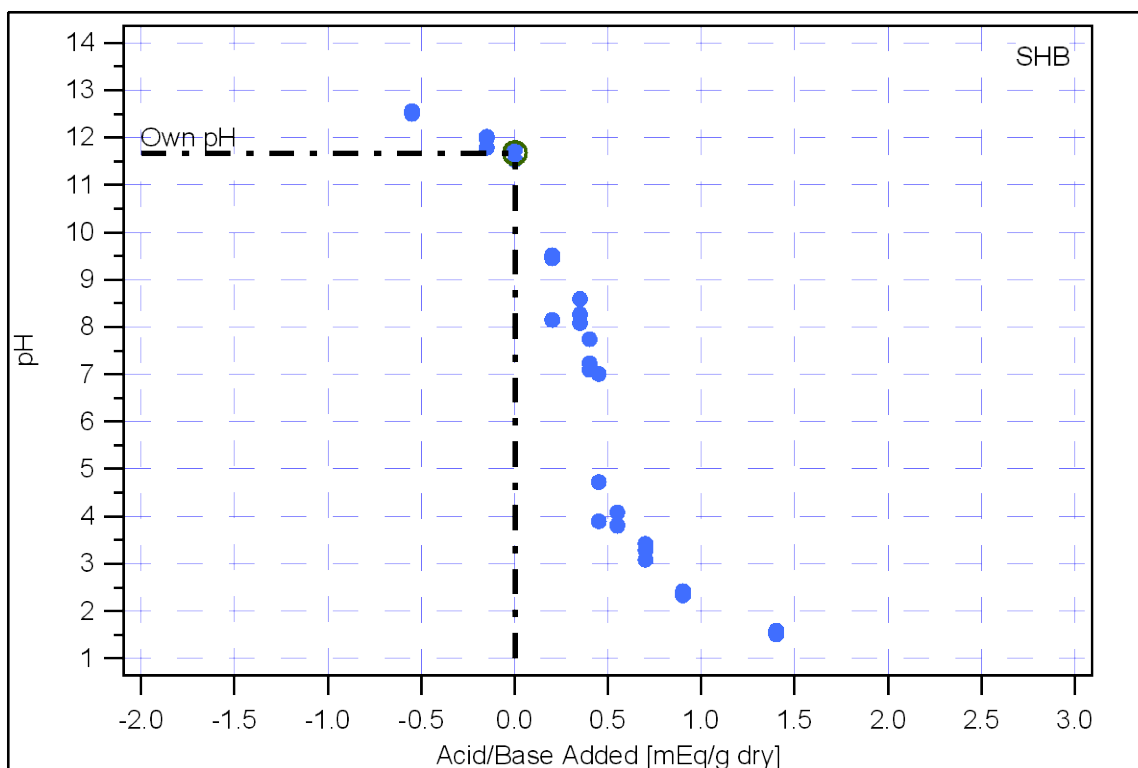
Facility T - Fly ash; Gypsum, unwashed and washed (Samples TFA, TAU, TAW)	G-26
Facility U - Fly ash; Gypsum, unwashed; Mixed fly ash and gypsum (Samples UFA, UAU, UGF)	G-28
Facility V - Spray dryer ash (Sample VSD)	G-29
Facility W - Fly ash; Gypsum, unwashed and washed (Samples WFA, WAU, WAW)	G-30
Facility X - Fly ash; Gypsum, unwashed and washed (Samples XFA, XAU, XAW)	G-32
Facility Y - Spray dryer ash (Sample YSD)	G-34
Facility Z - Fly ash (Sample ZFA)	G-34
Facility Aa - Fly ash; Gypsum, unwashed and washed (Samples AaFA, AaFB, AaFC, AaAU, AaAW)	G-35
Facility Ba - Fly ash (Samples BaFA)	G-38
Facility Ca - Fly ash; Gypsum, washed (Samples CaFA, CaAW)	G-39
Facility Da - Fly ash; Gypsum, washed (Samples DaFA, DaAW)	G-40



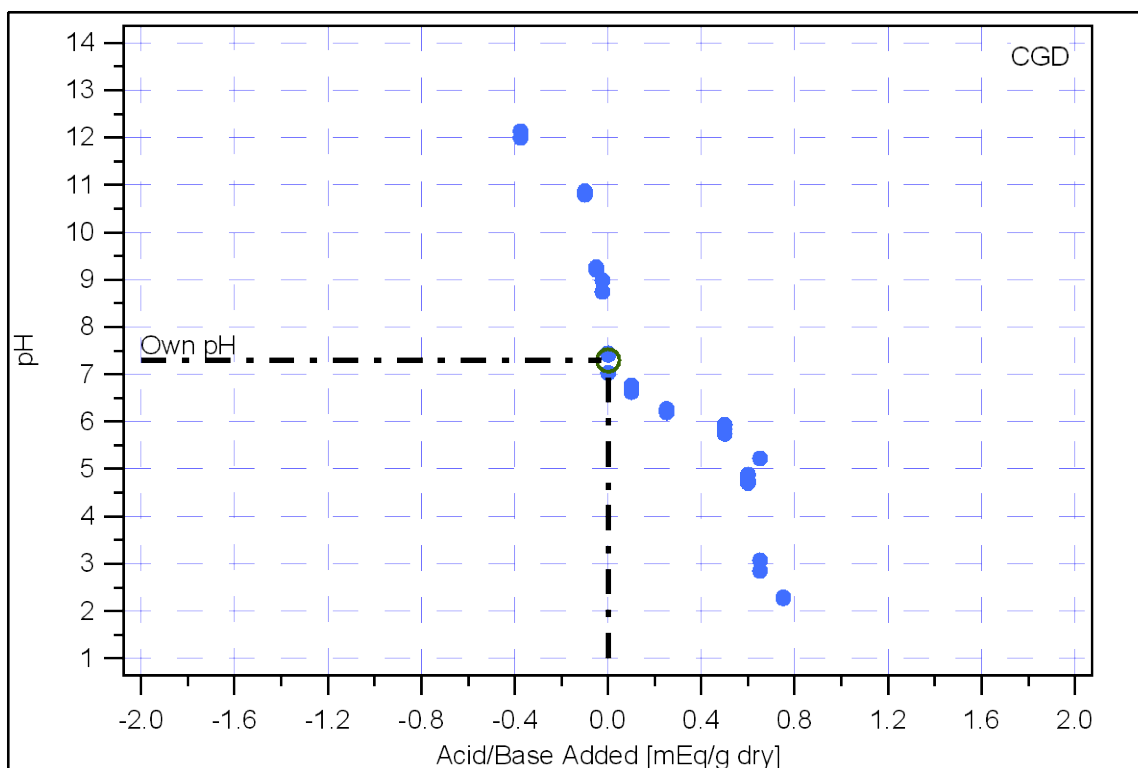
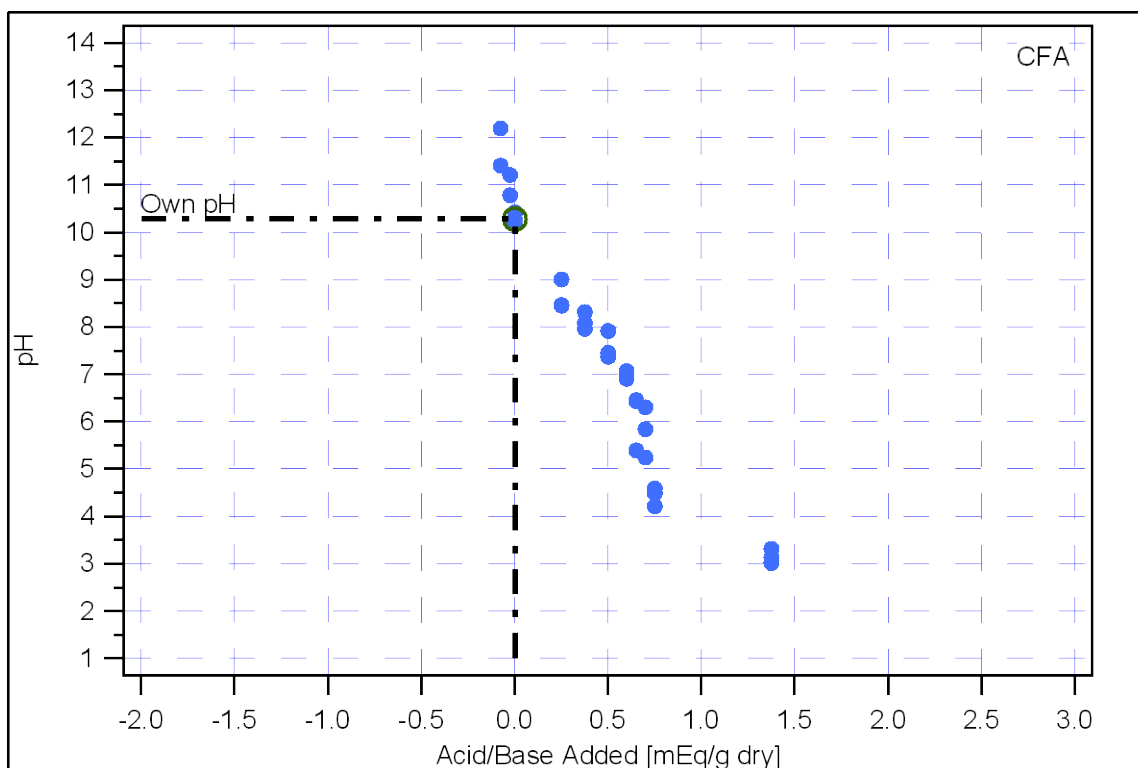
Brayton Point (East-Bit., CS-ESP). **BPB** – fly ash without ACI; **BPT** – fly ash with ACI.



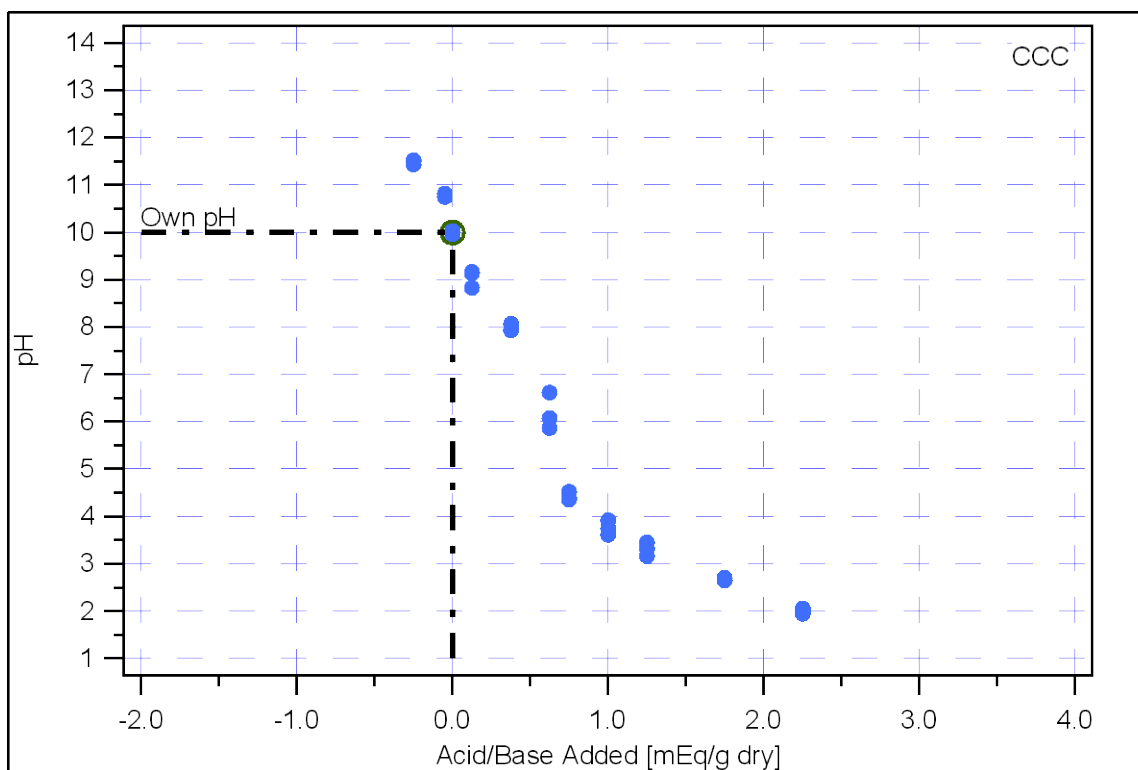
Pleasant Prairie (PRB, CS-ESP). **PPB** – fly ash without ACI; **PPT** – fly ash with ACI.



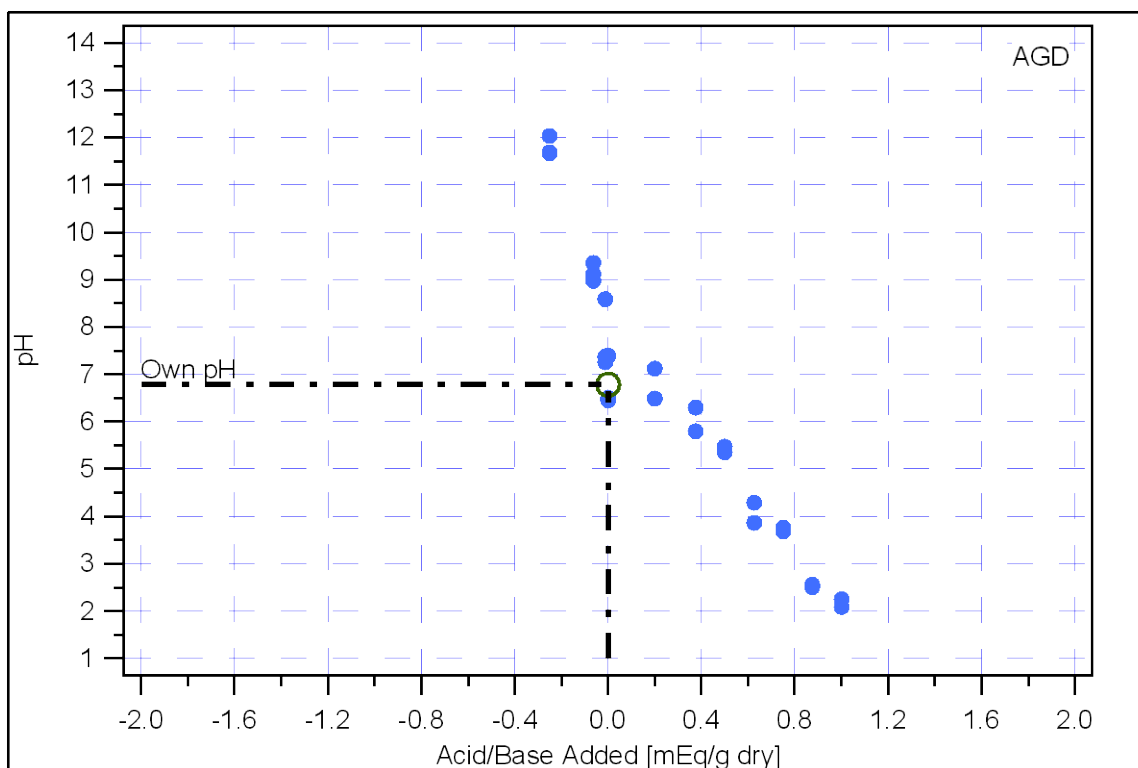
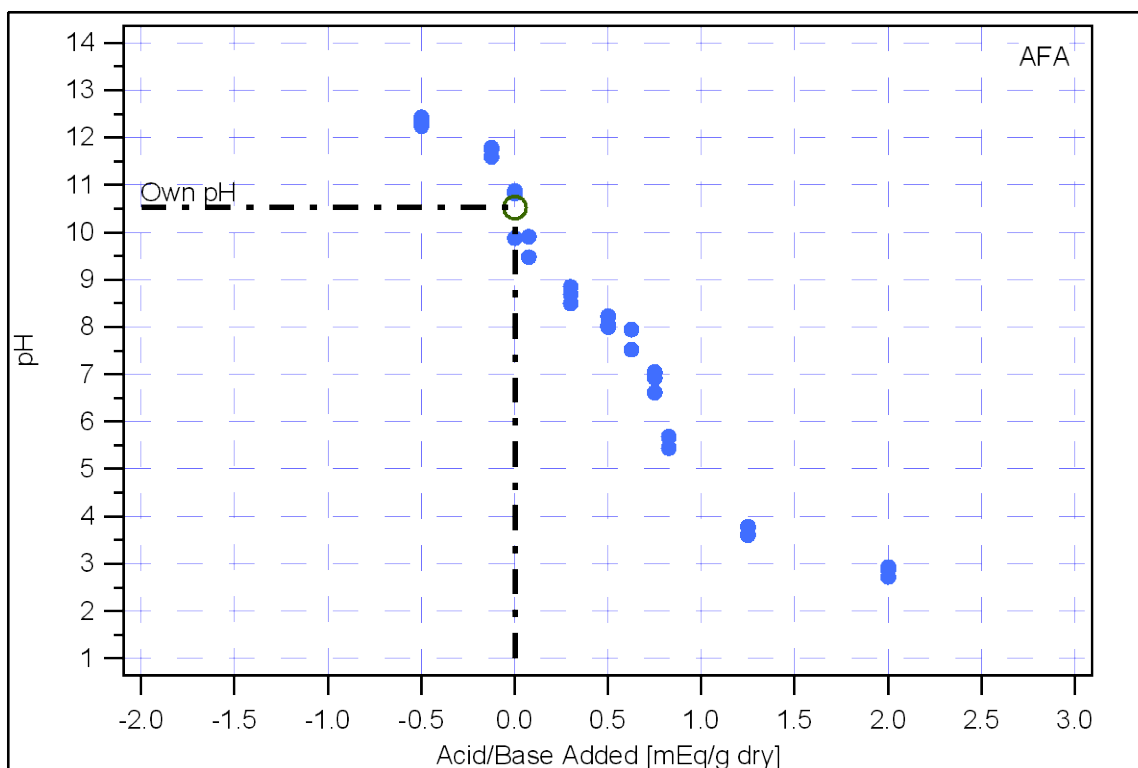
Salem Harbor (Low S East-Bit., SNCR, CS-ESP). **SHB** – fly ash without ACI; **SHT** – fly ash with ACI.



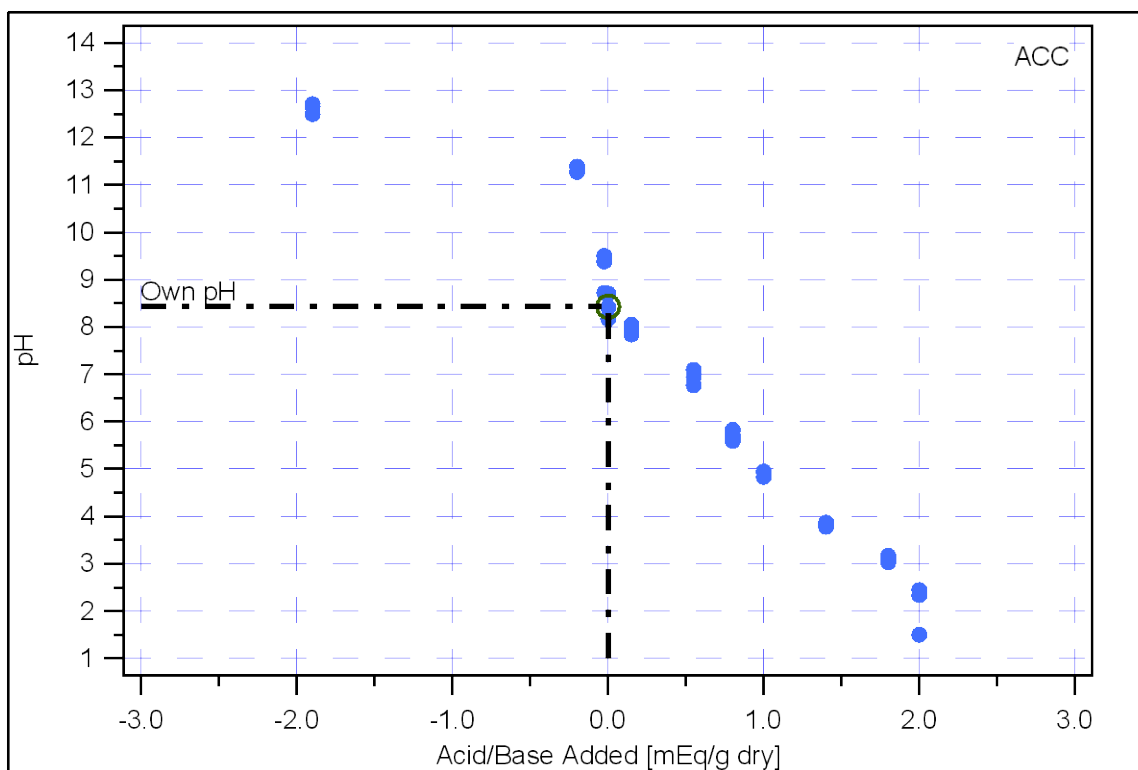
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CFA – fly ash; **CGD** – scrubber sludge.



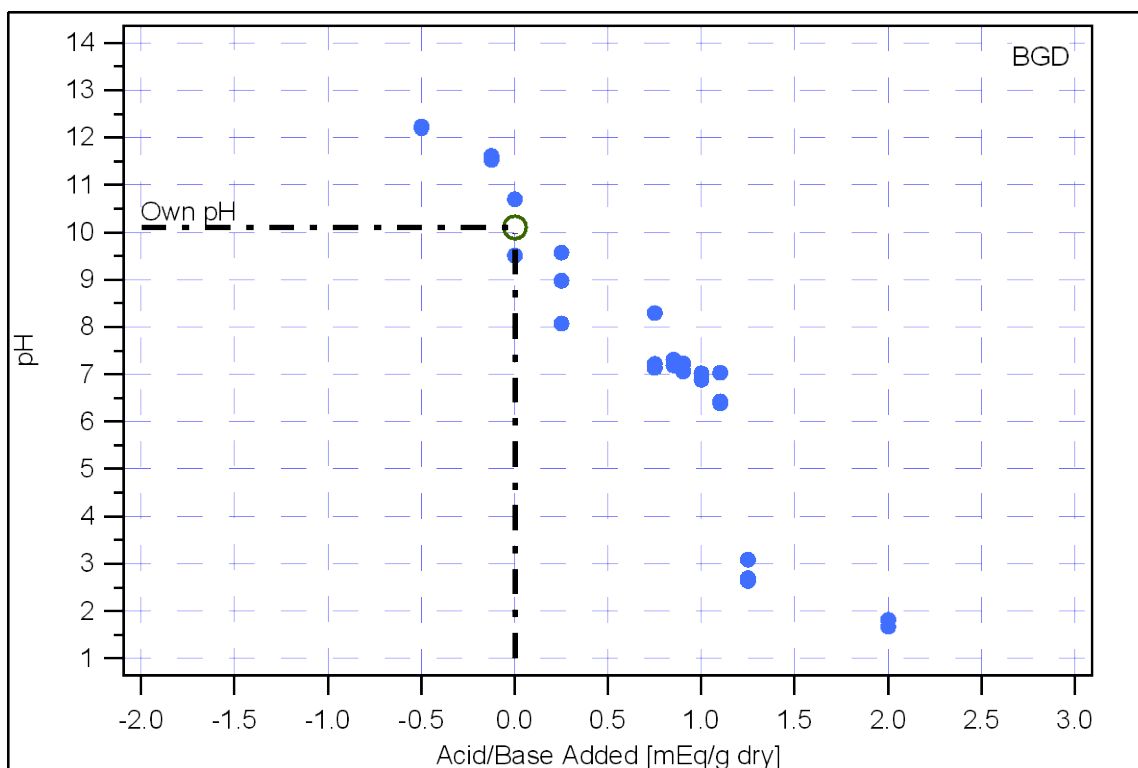
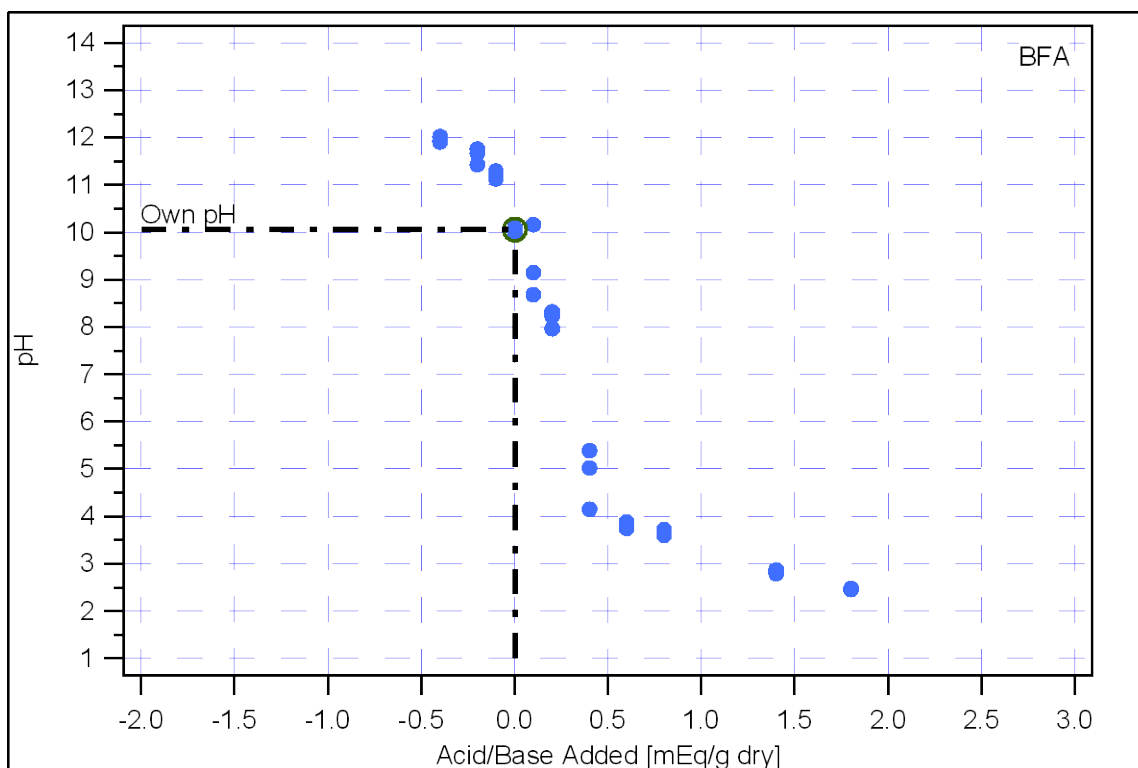
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR-BP.
CCC – mixed fly ash and scrubber sludge (as managed).



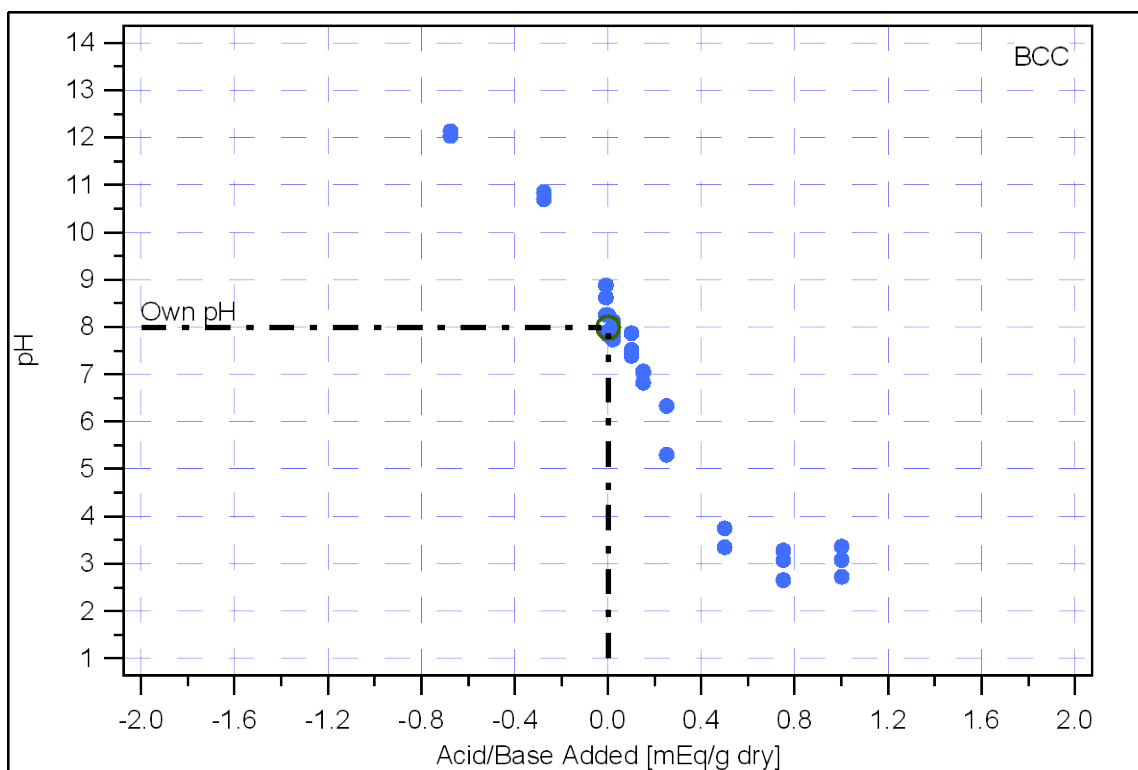
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
AFA – fly ash; **AGD** – scrubber sludge.



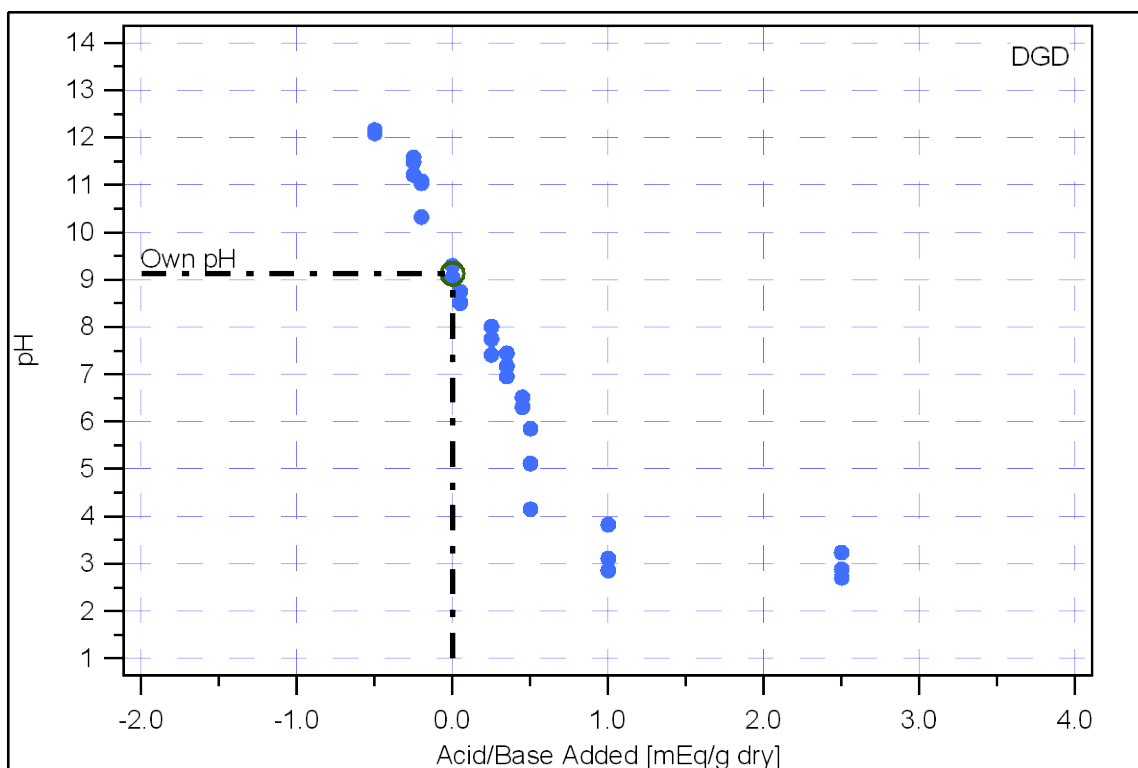
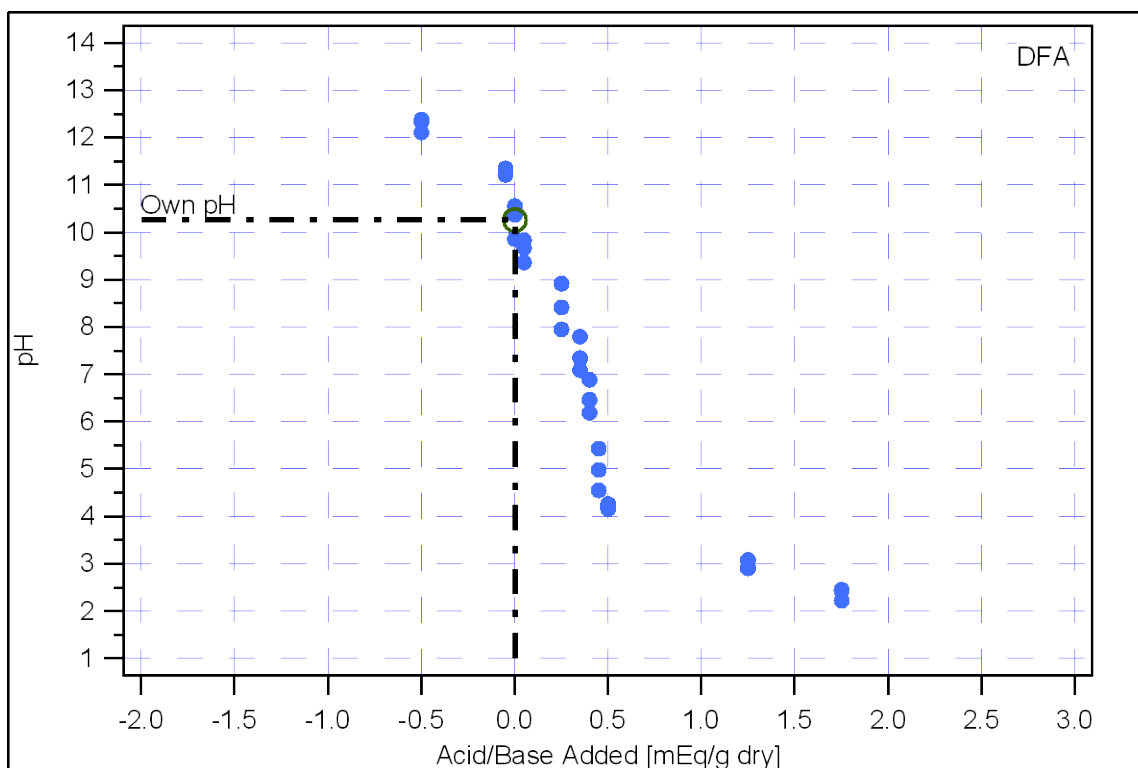
Facility A (Low S East-Bit., Fabric F., Limestone, Natural Oxidation). SNCR on.
ACC – mixed fly ash and scrubber sludge (as managed).



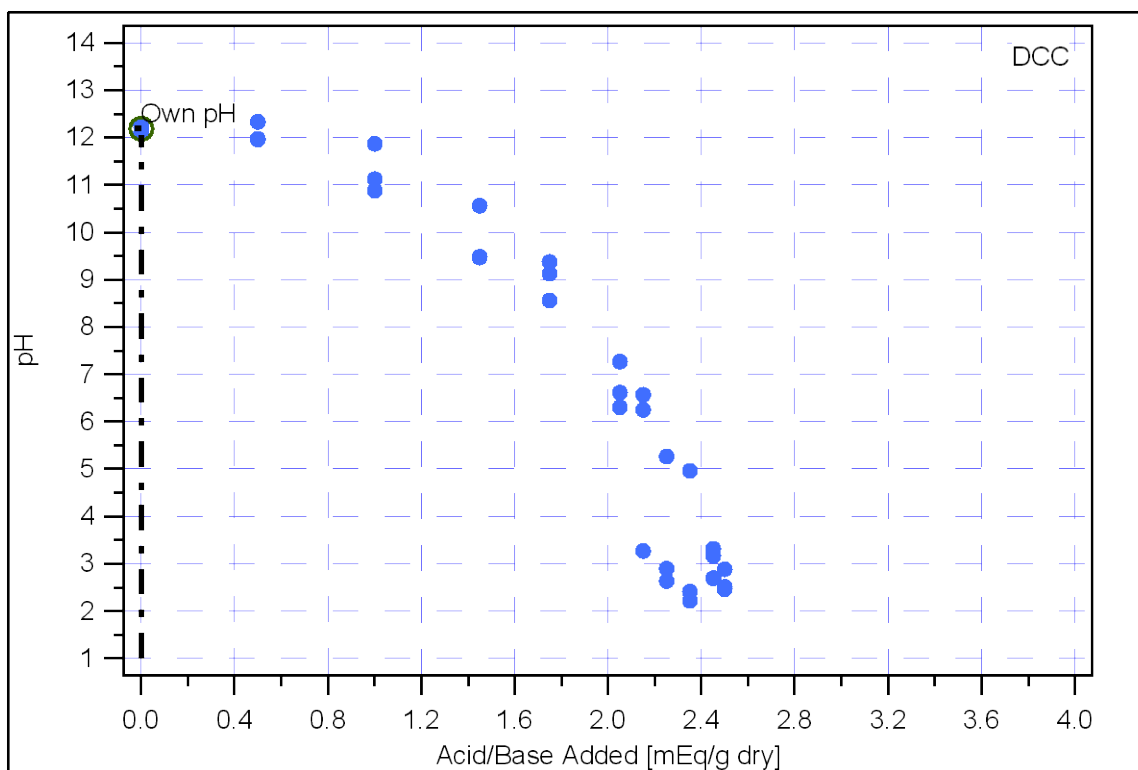
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BFA – fly ash; **BGD** – scrubber sludge.



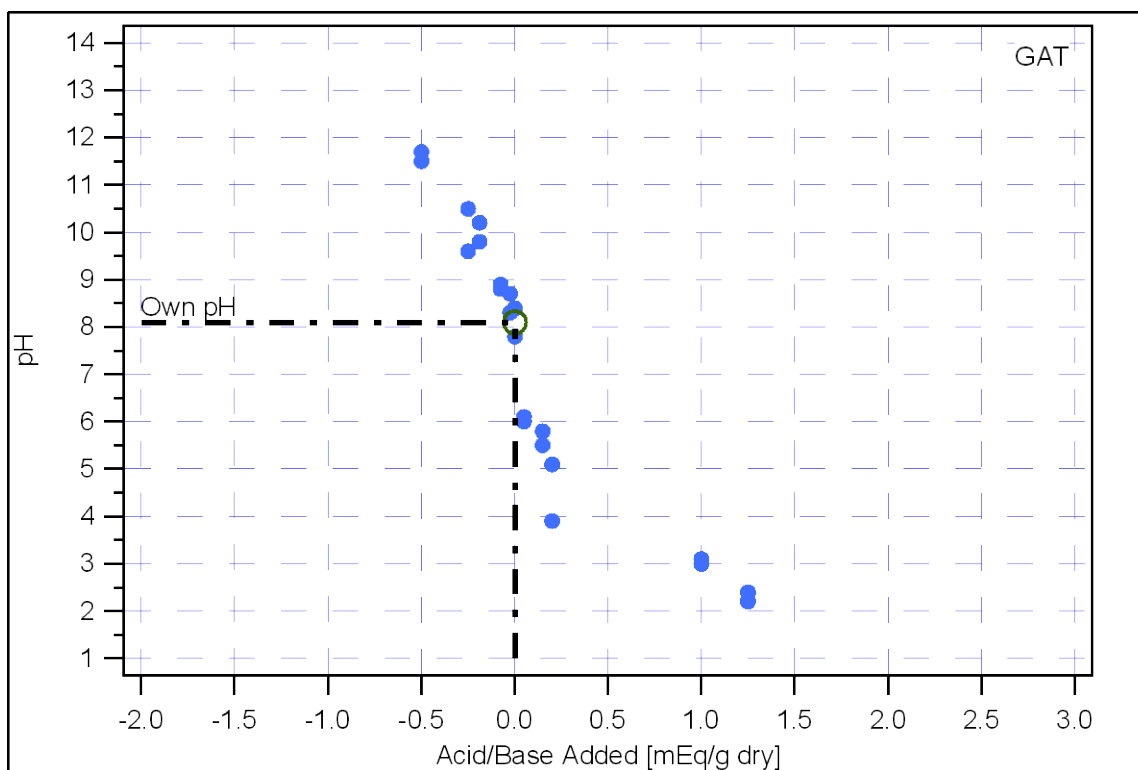
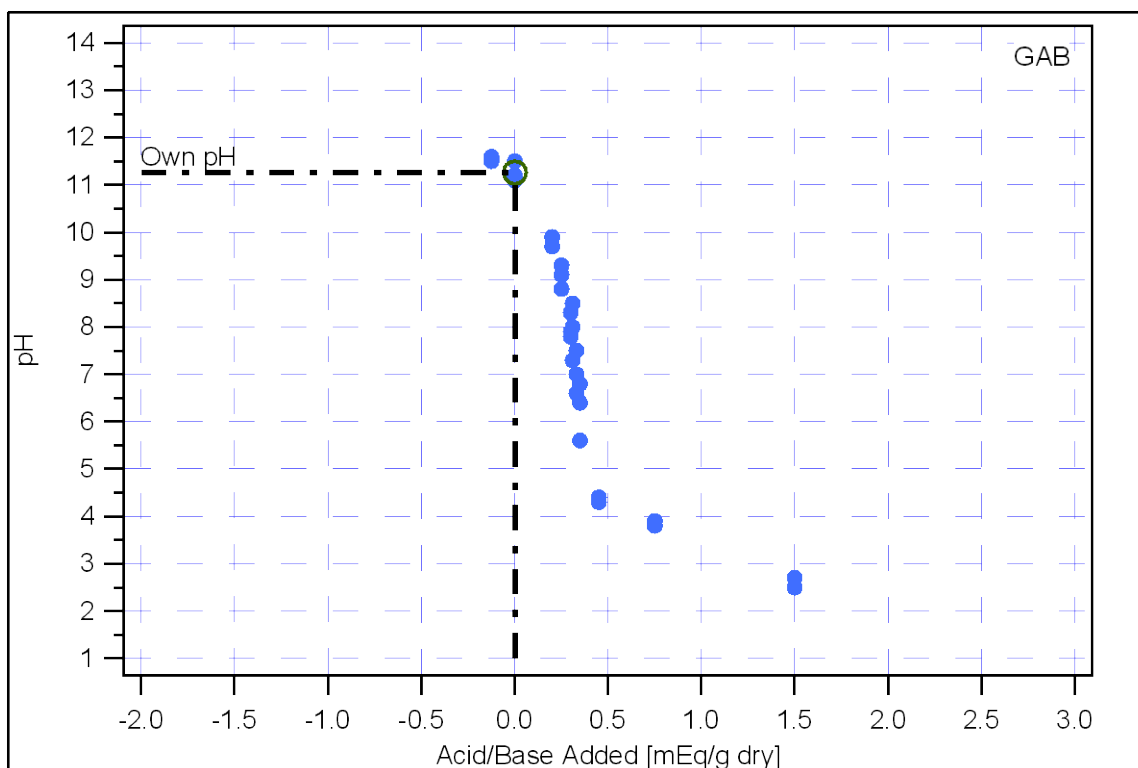
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR-BP.
BCC – mixed fly ash and scrubber sludge (as managed).



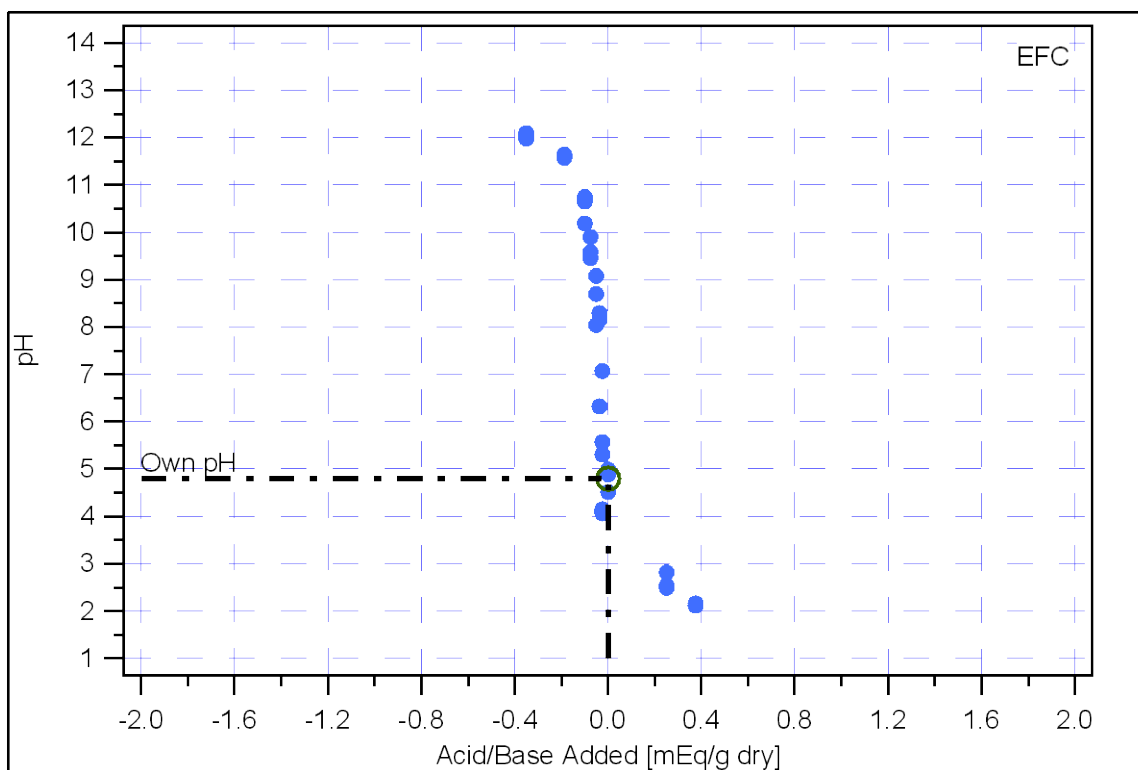
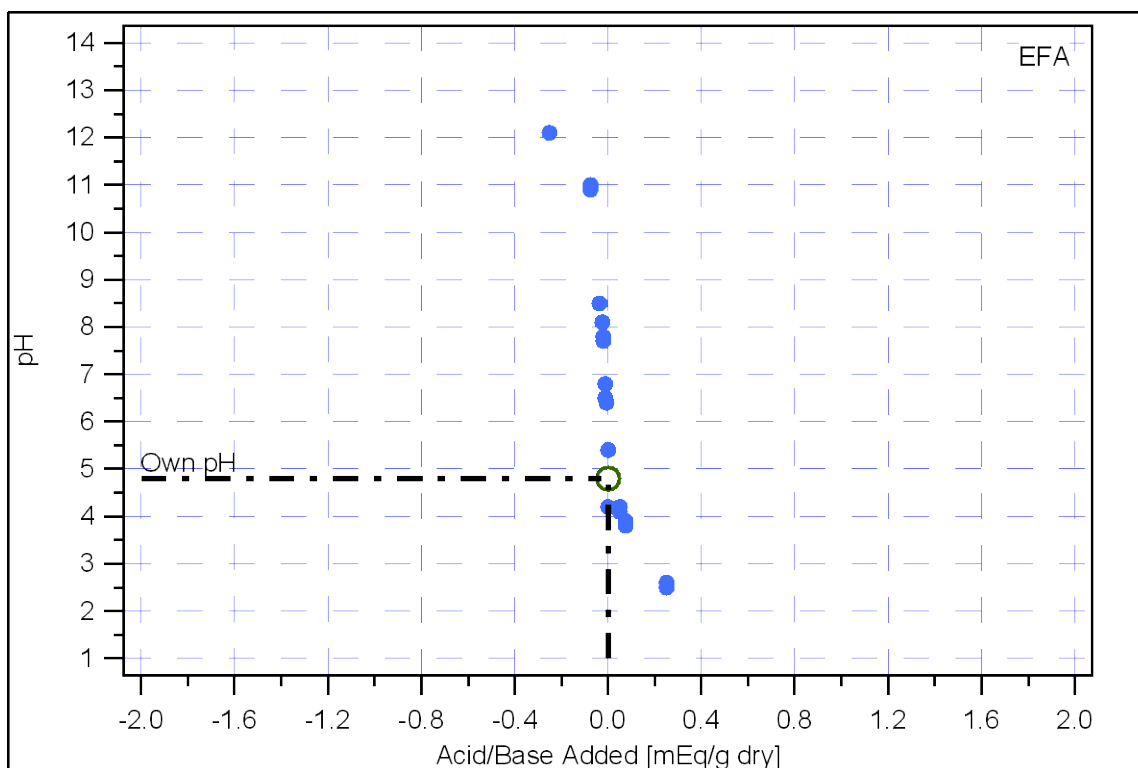
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DFA – fly ash; **DGD** – scrubber sludge.



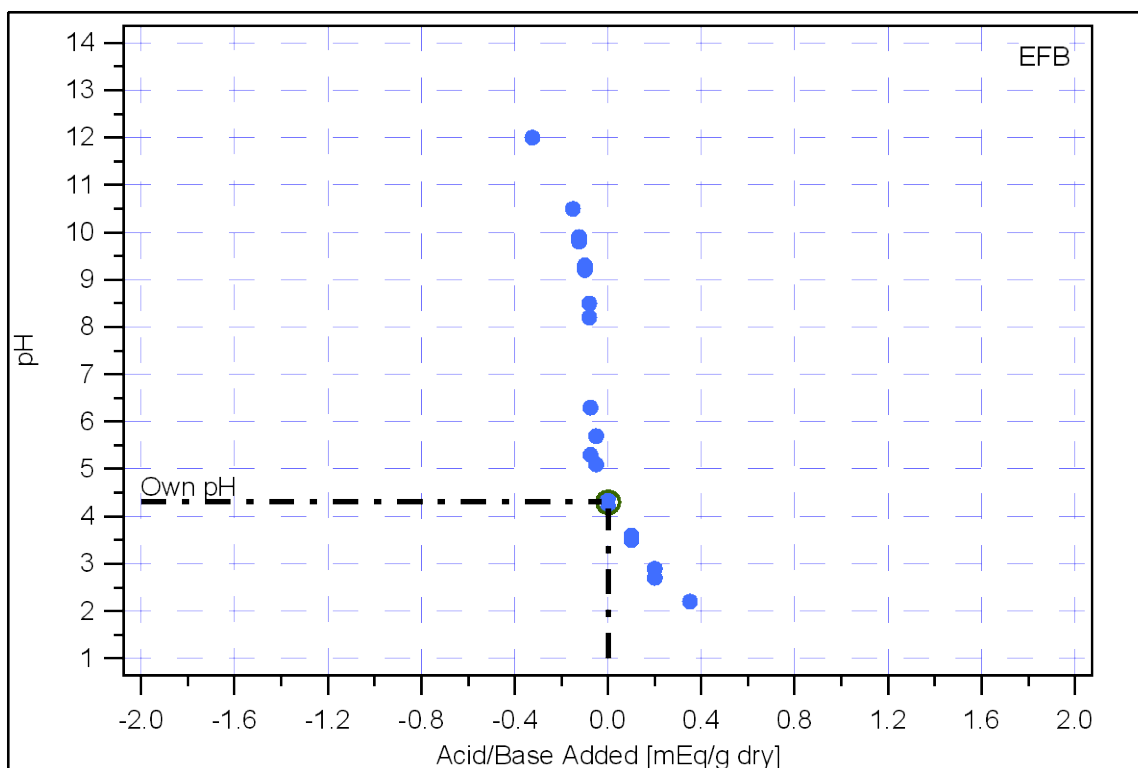
Facility B (Low S East-Bit., CS-ESP, Mg Lime, Natural Oxidation). SCR on.
DCC – mixed fly ash and scrubber sludge (as managed).



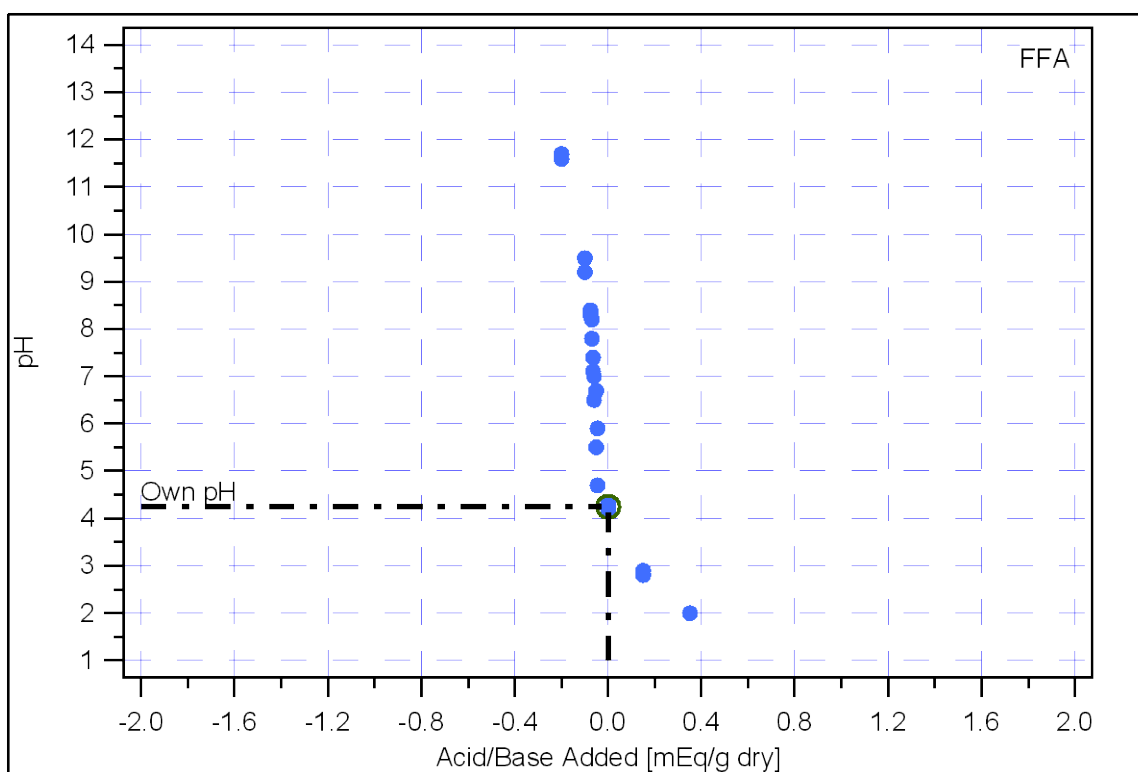
Facility C (Low S East-Bit., HS-ESP w/ COHPAC). **GAB** – fly ash without ACI; **GAT** fly ash with ACI.



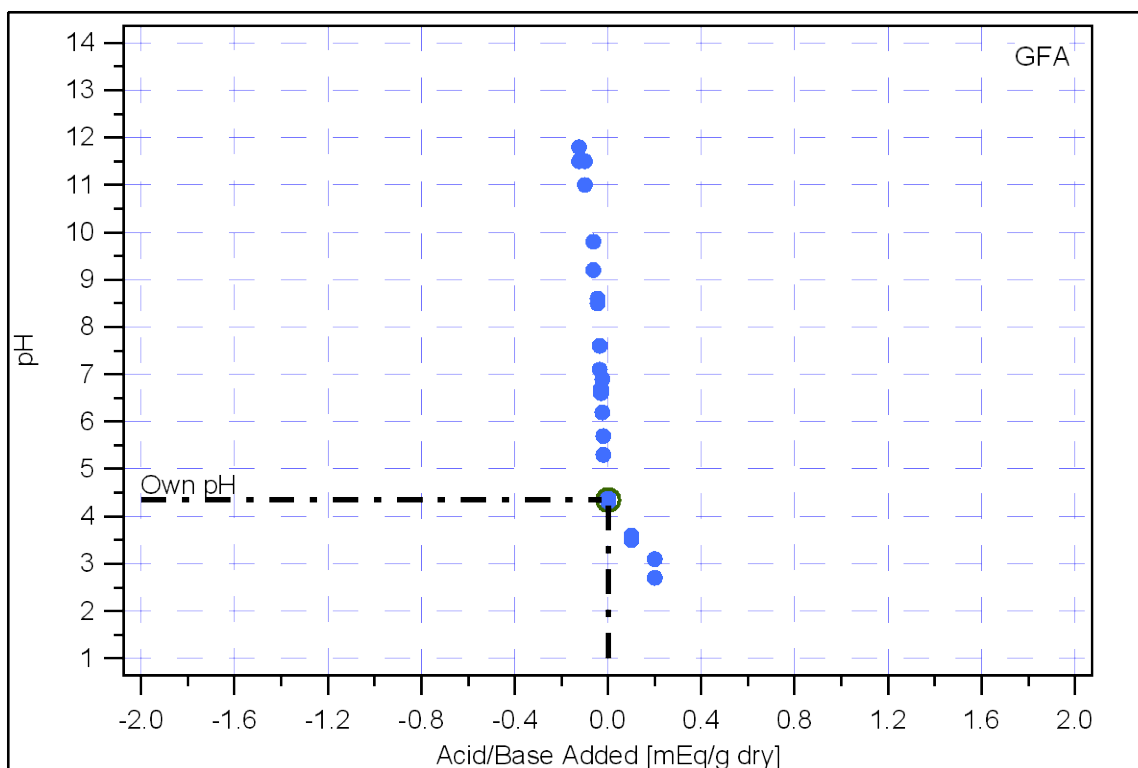
Facility E (Med. S East-Bit.). EFA, EFC – fly ash SCR on.



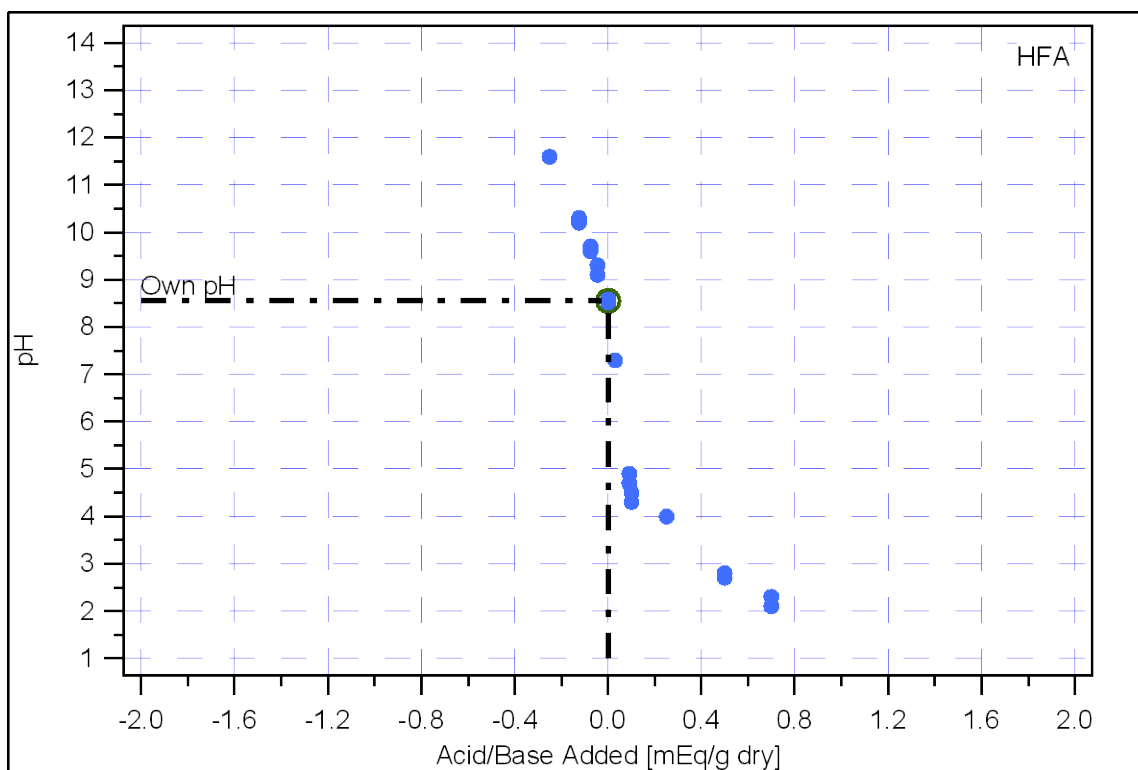
Facility E (Med. S East-Bit.). EFB – fly ash SCR-BP.



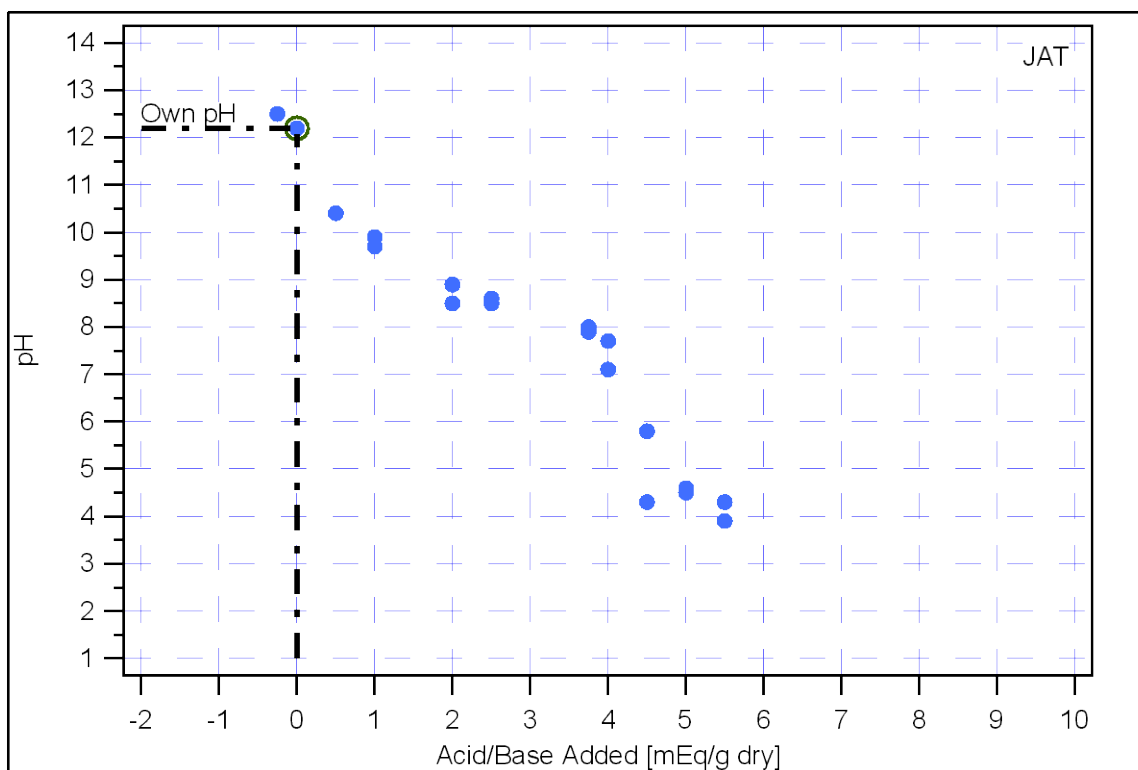
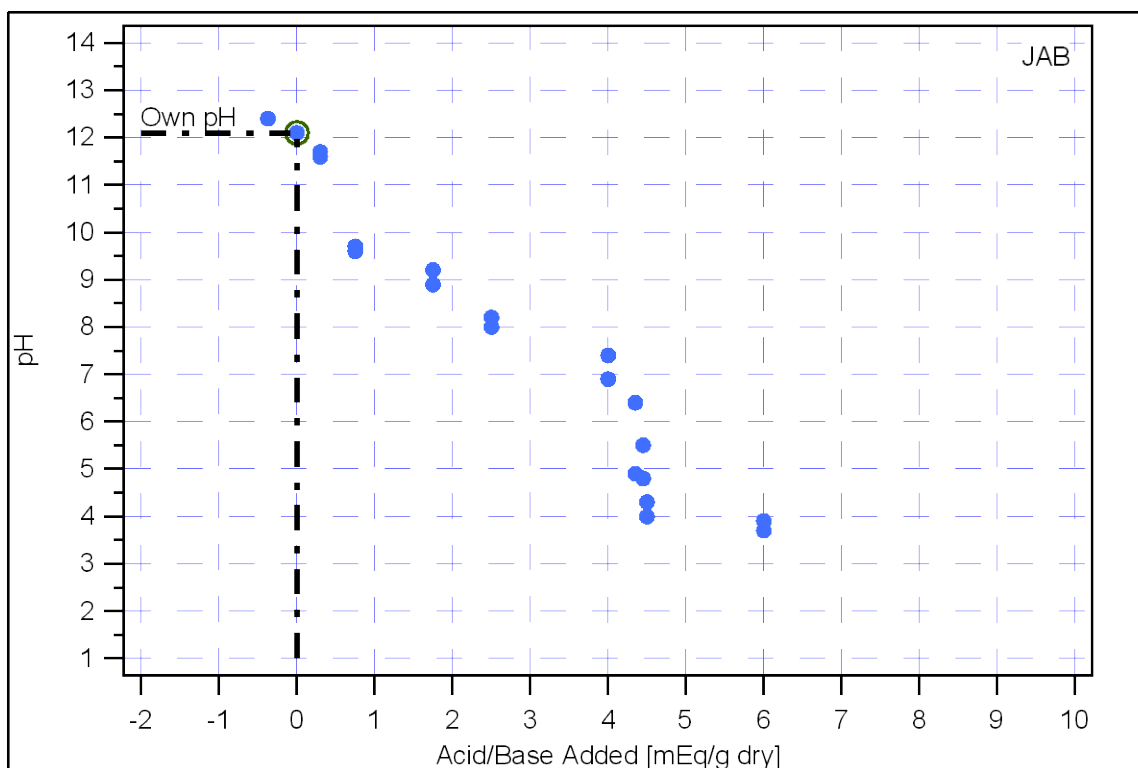
Facility F (Low S East-Bit., CS-ESP). FFA – fly ash.



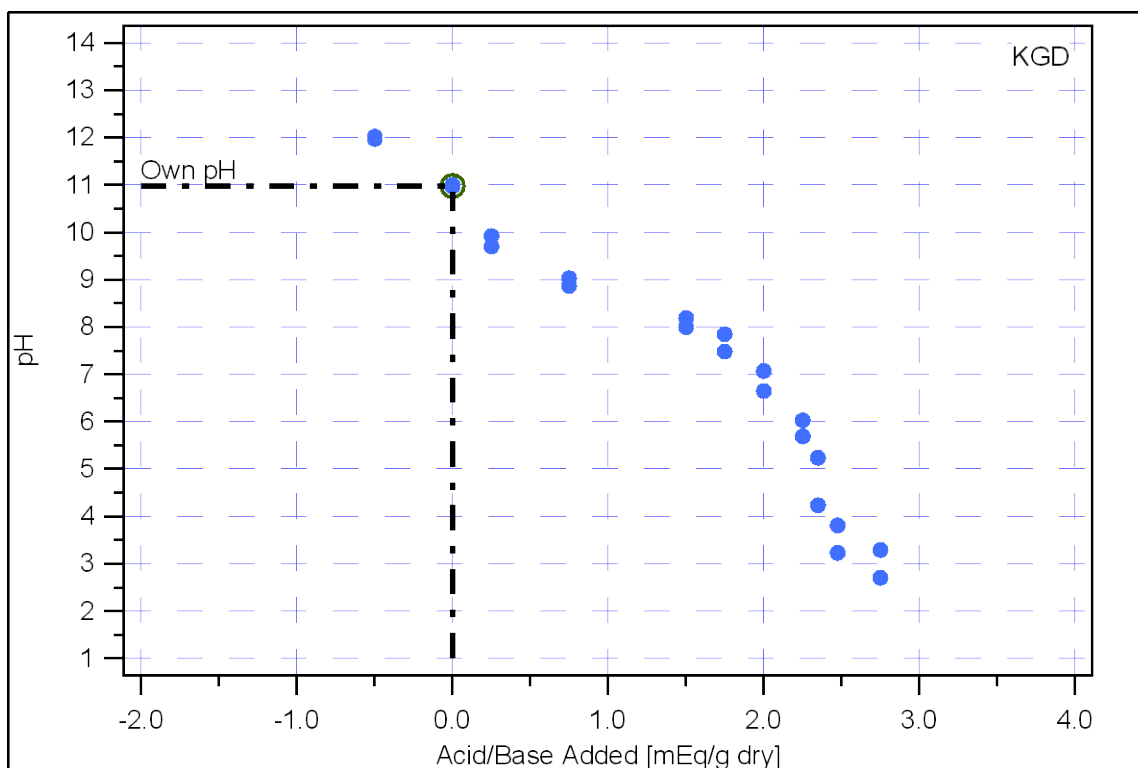
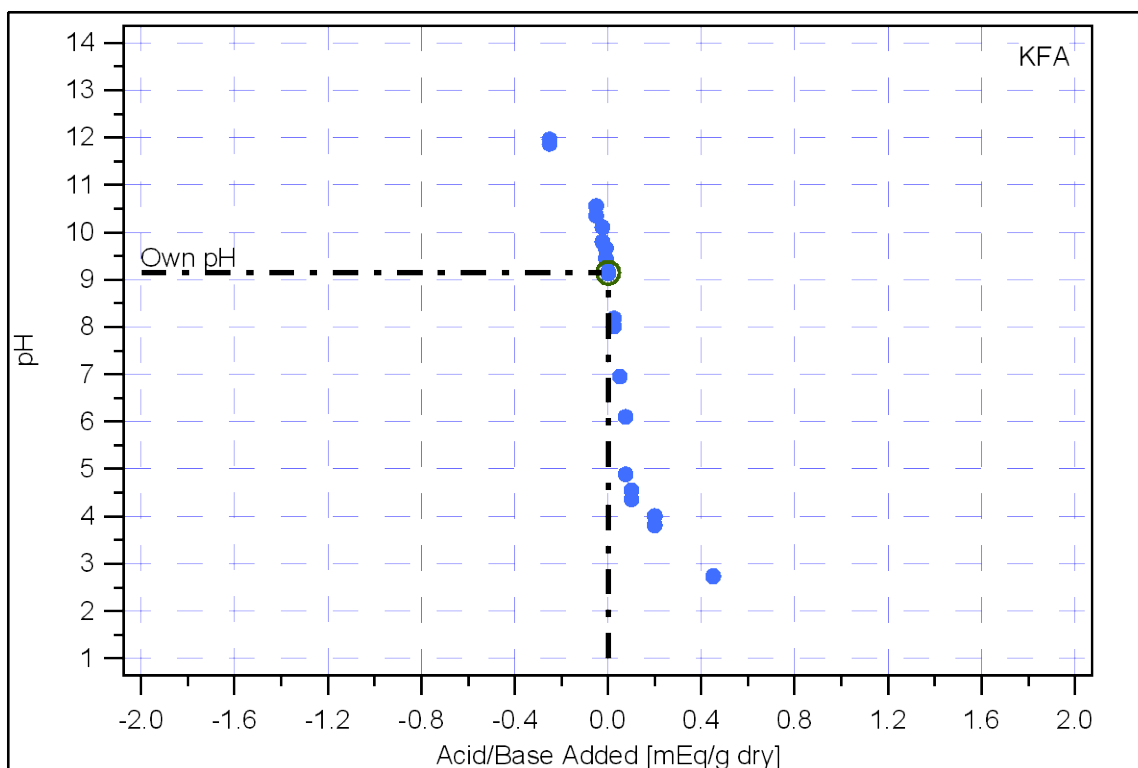
Facility G (Low S East-Bit., SNCR, CS-ESP). **GFA** – fly ash.



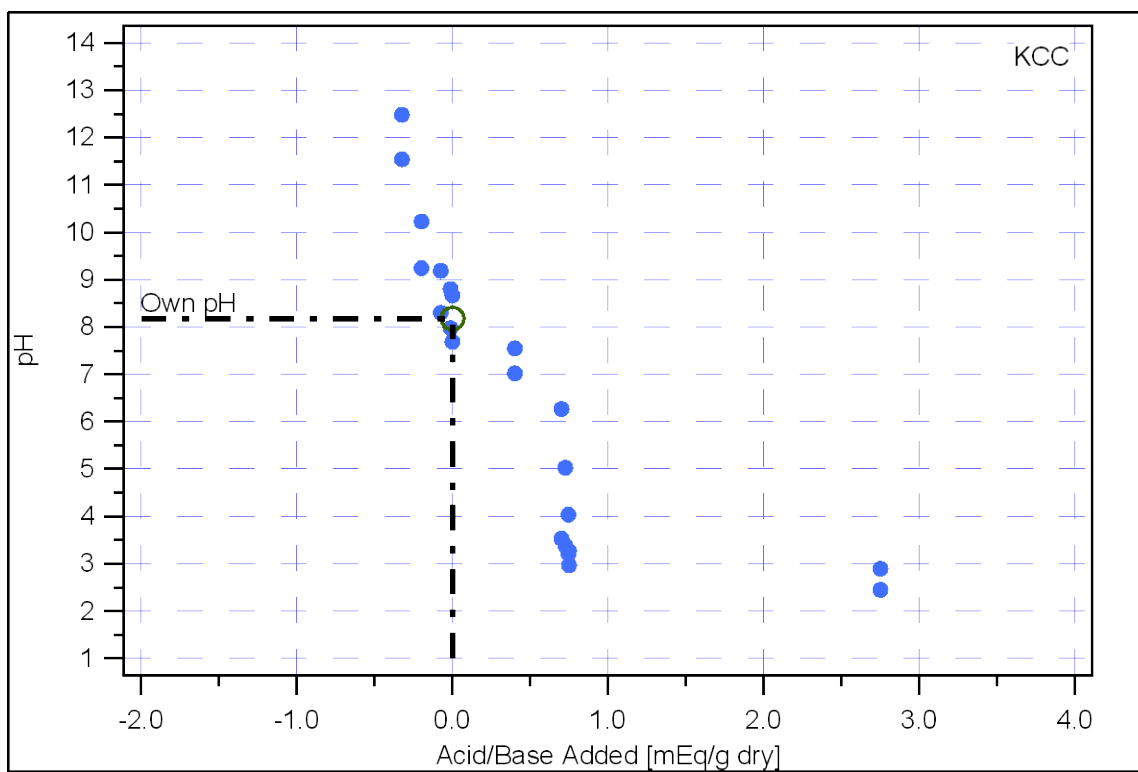
Facility H (High S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **HFA** – fly ash.



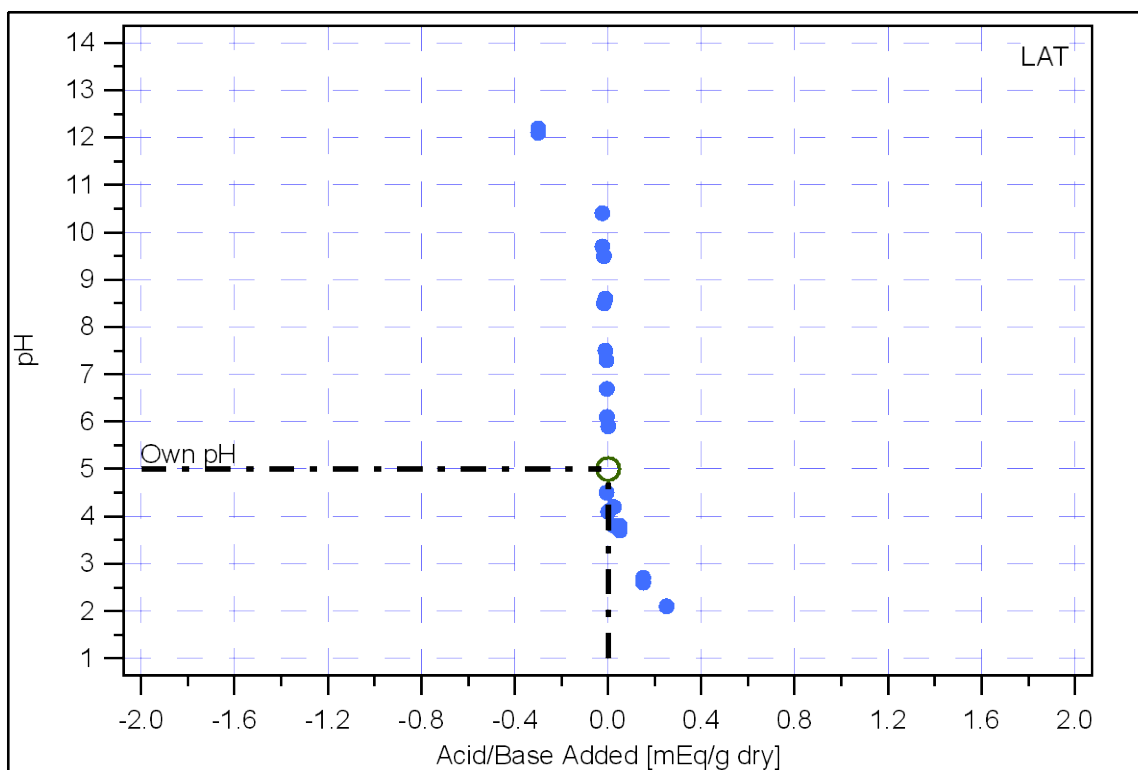
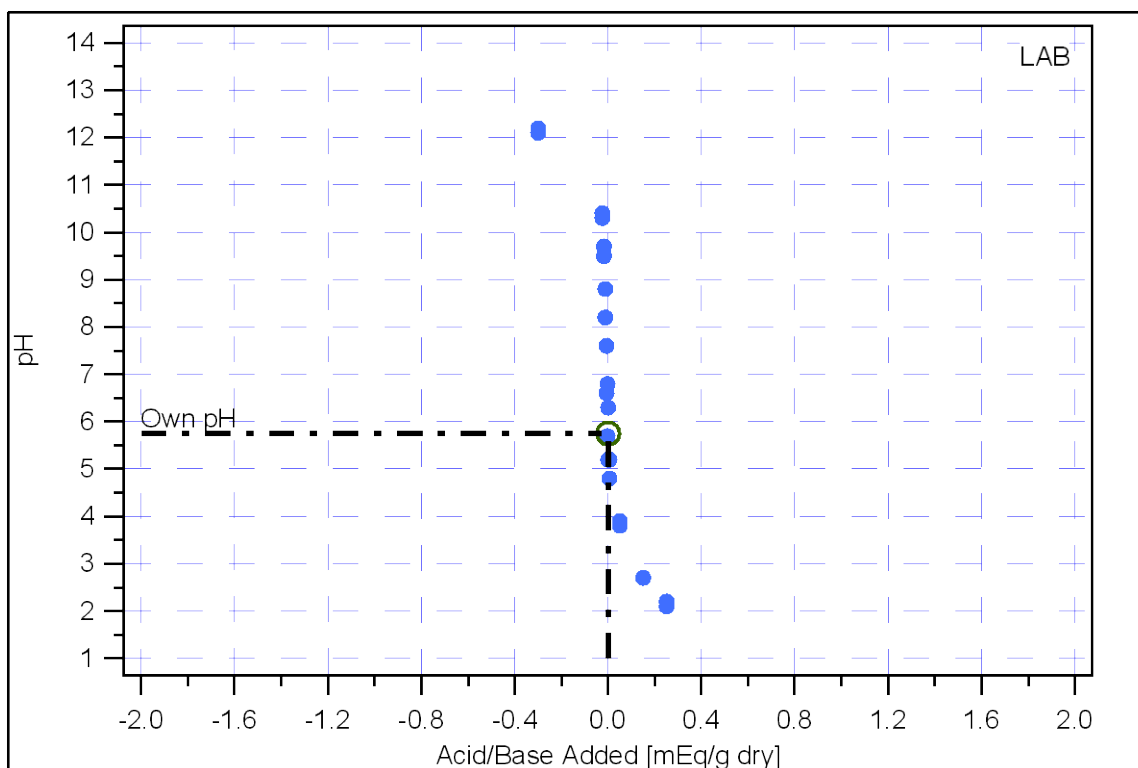
Facility J (PRB/Low S Bit mix., CS-ESP). **JAB** – fly ash without Br-ACI; **JAT** – fly ash with Br-ACI.



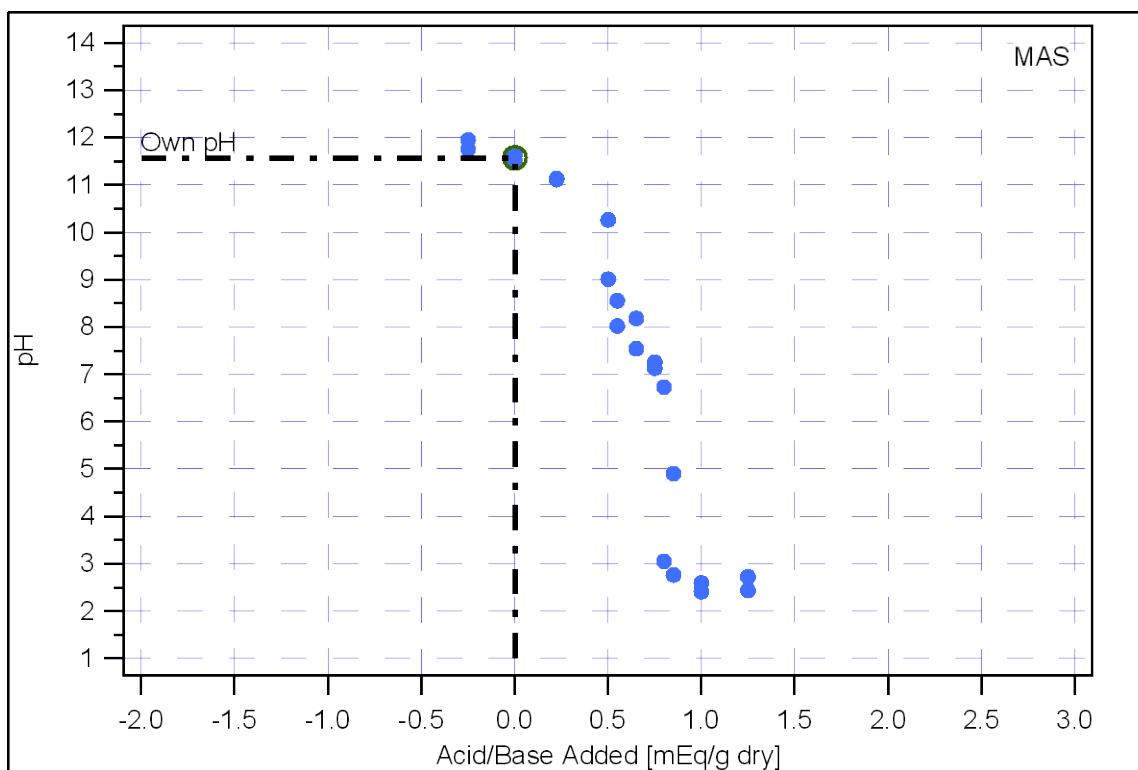
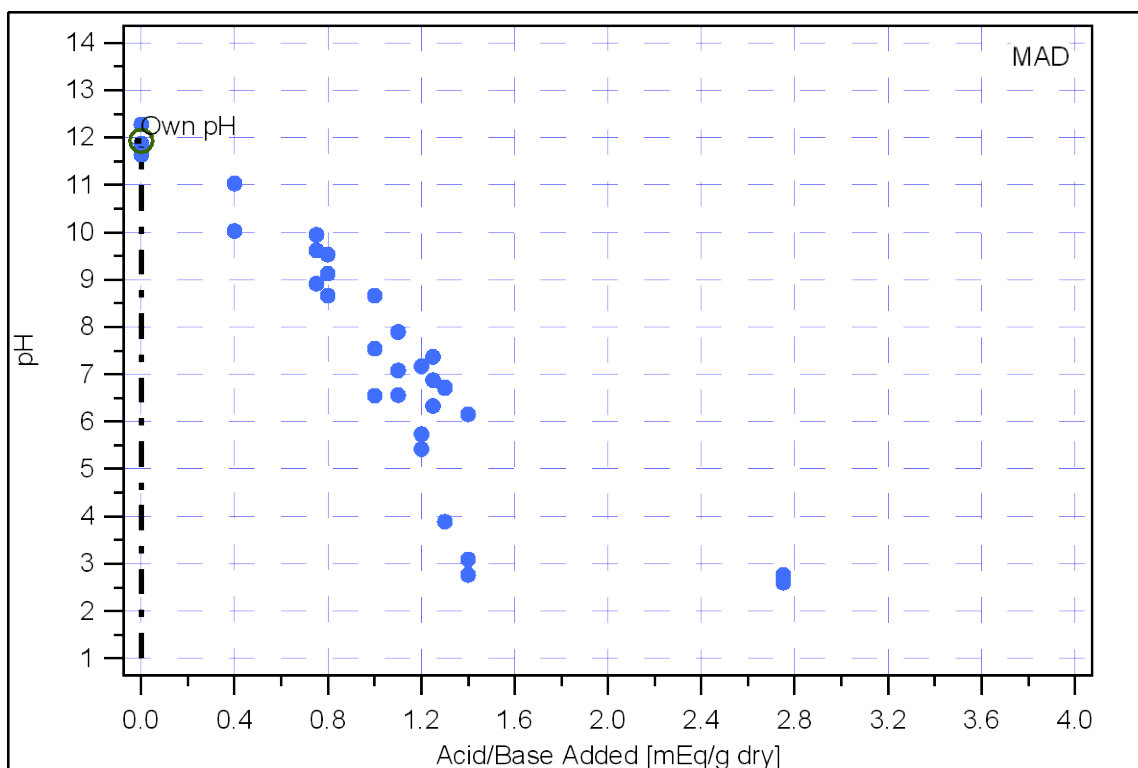
Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KFA – fly ash; **KGD** – scrubber sludge.



Facility K (East-Bit., SCR, CS-ESP, Mg Lime, Natural Oxidation).
KCC – mixed fly ash and scrubber sludge (as managed).



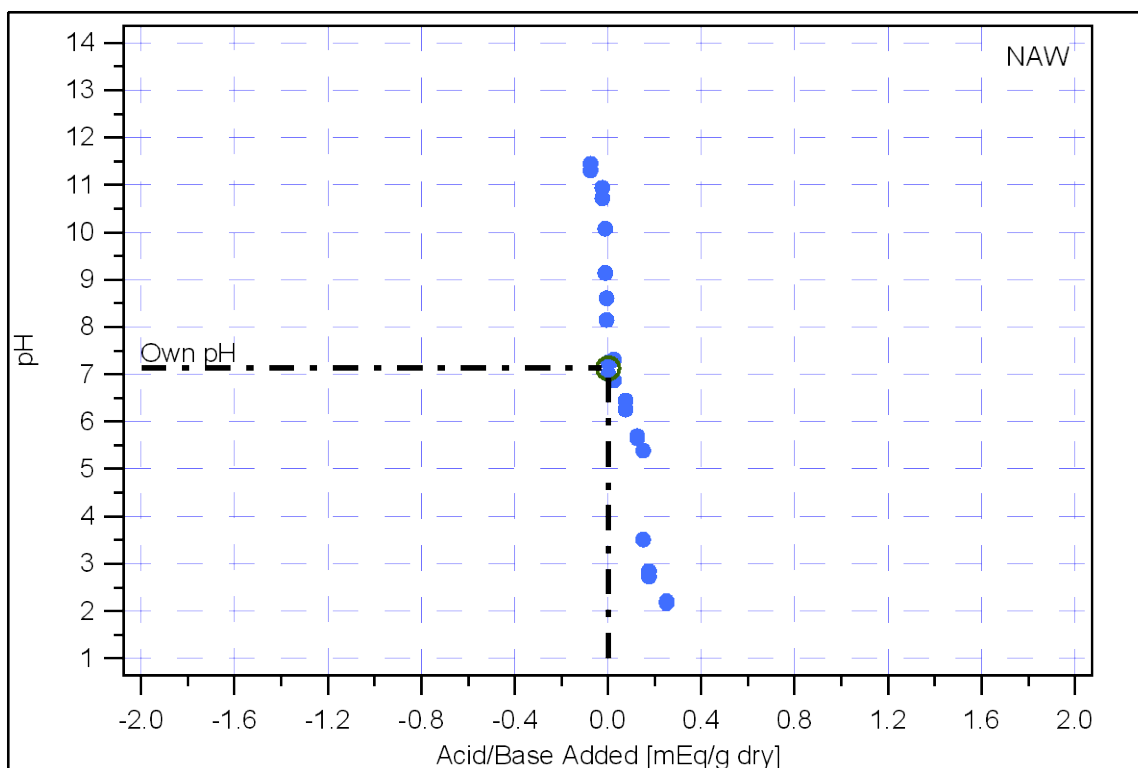
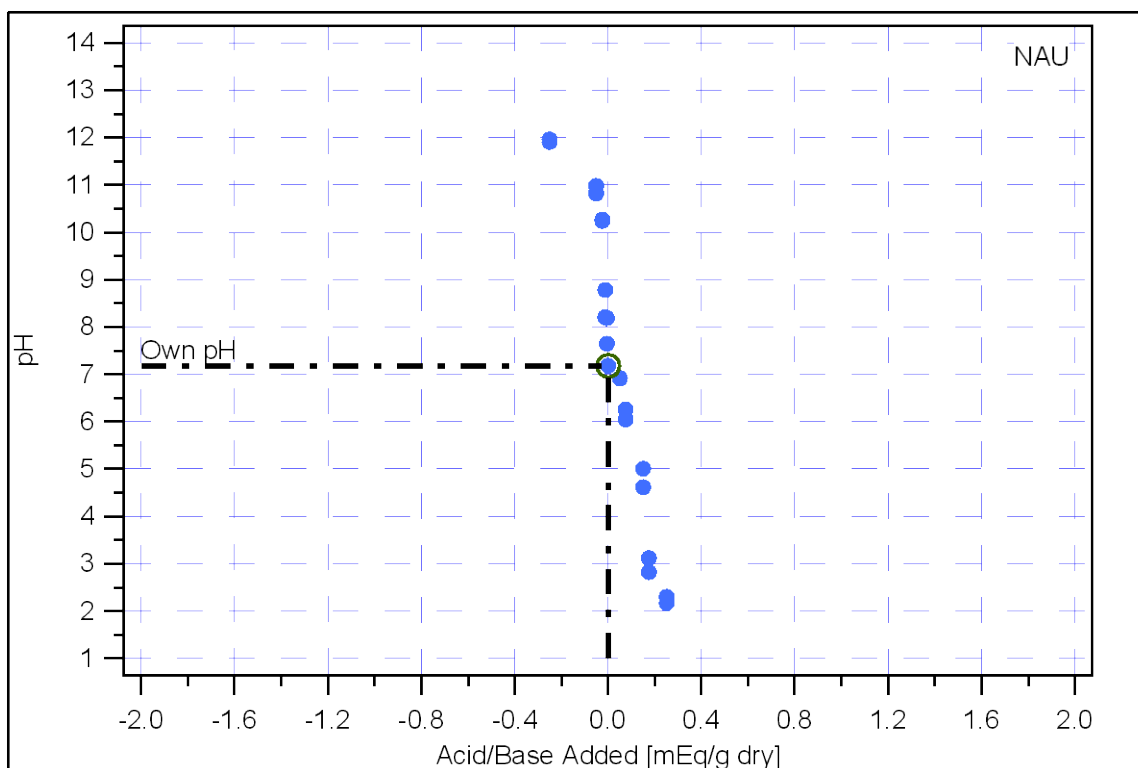
Facility L (Southern Appalachian Low S Bit.; SOFA, HS-ESP).
LAB – fly ash without Br-ACI; **LAT** – fly ash with Br-ACI.



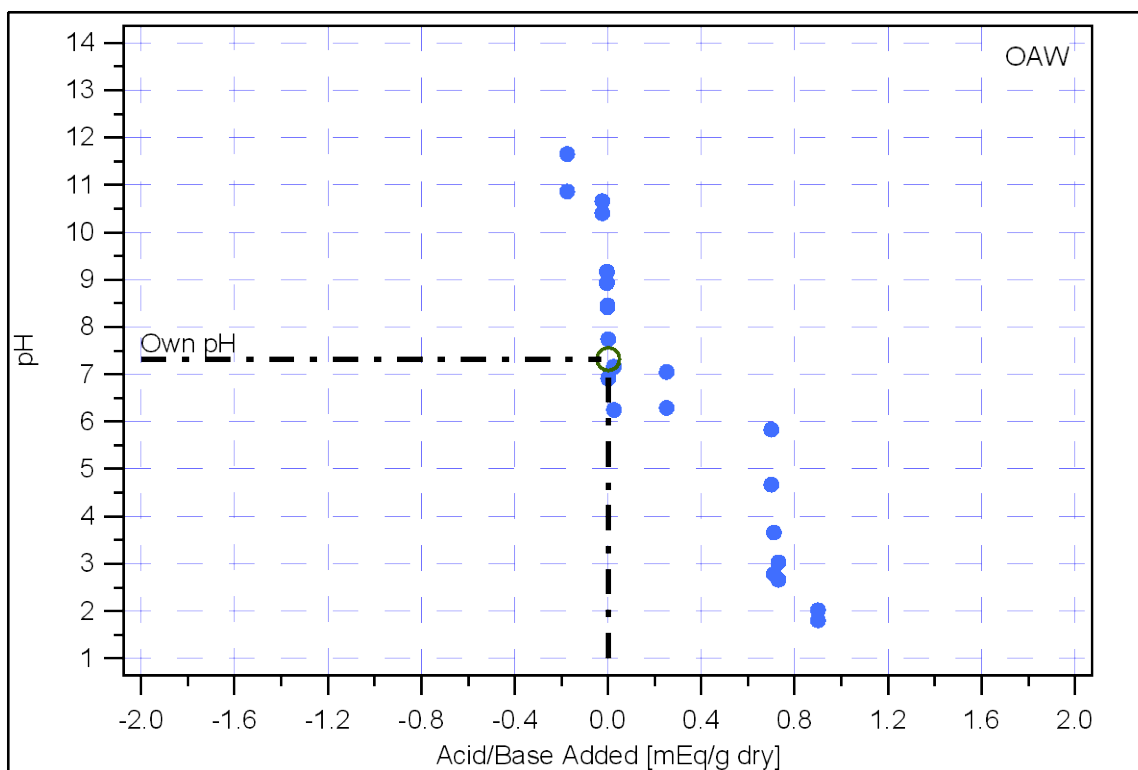
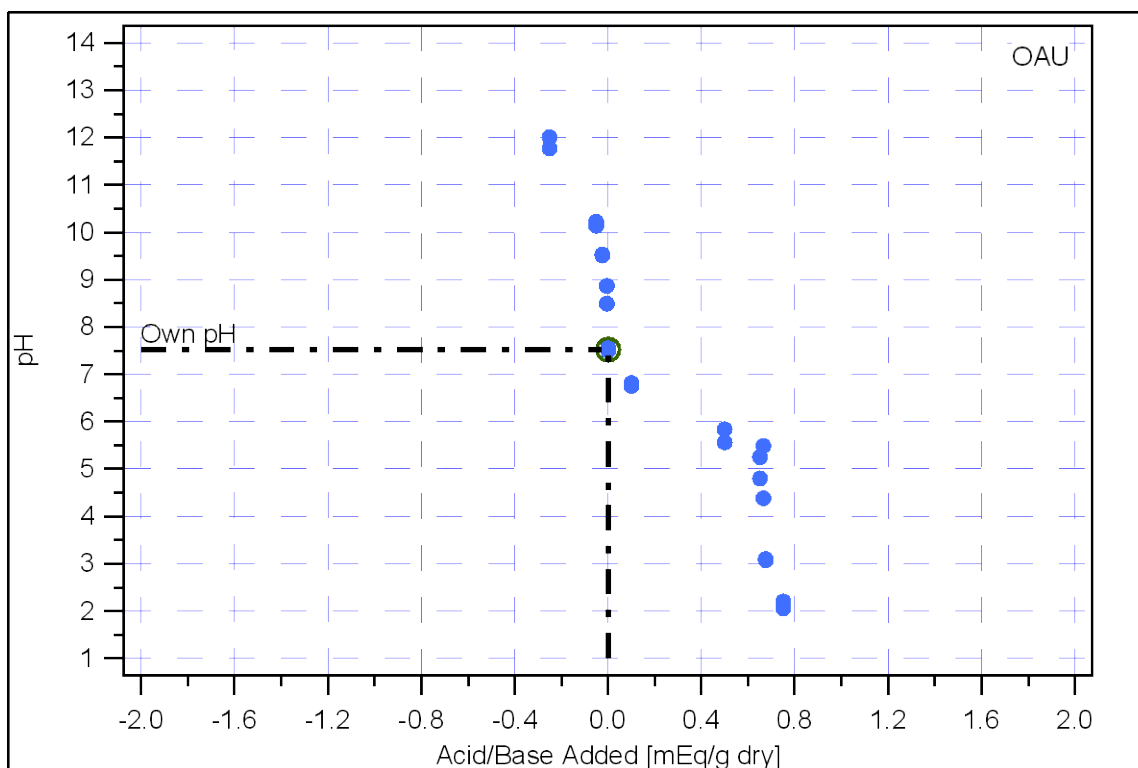
Facility M (Illinois Basin Bit., CS-ESP, Limestone, Inhibited Oxidation).

MAD – SCR-BP; mixed fly ash and scrubber sludge (as managed).

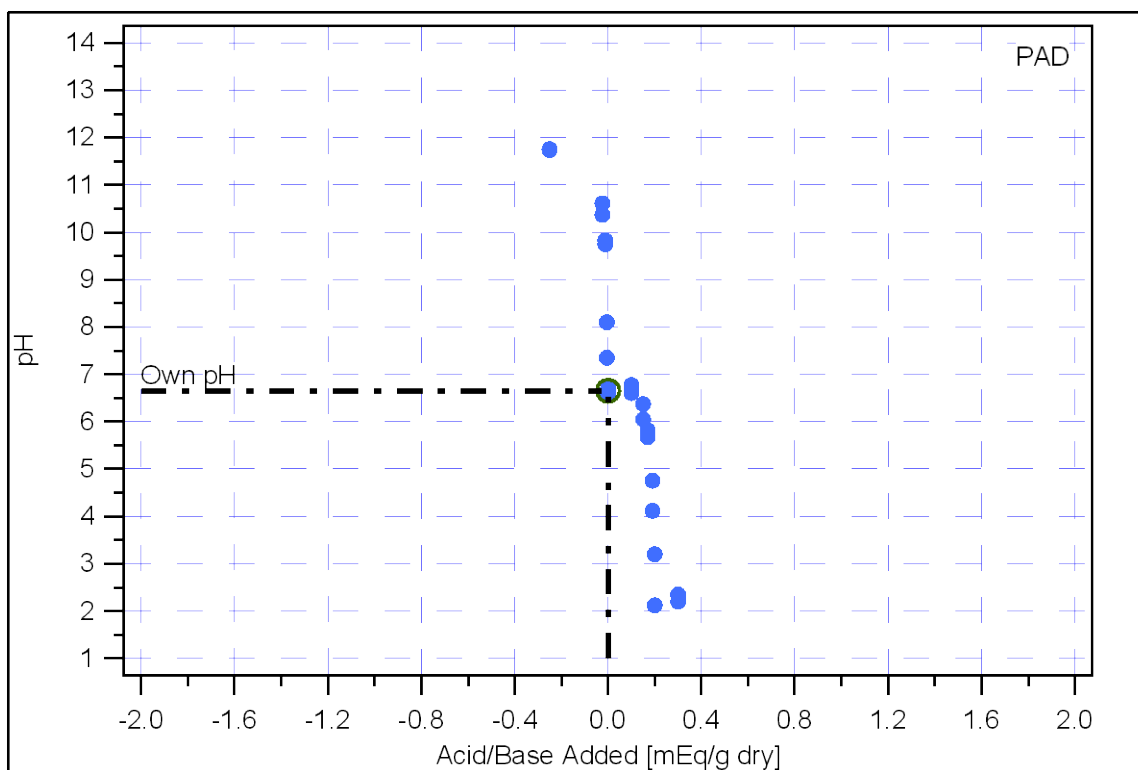
MAS – SCR on; mixed fly ash and scrubber sludge (as managed).



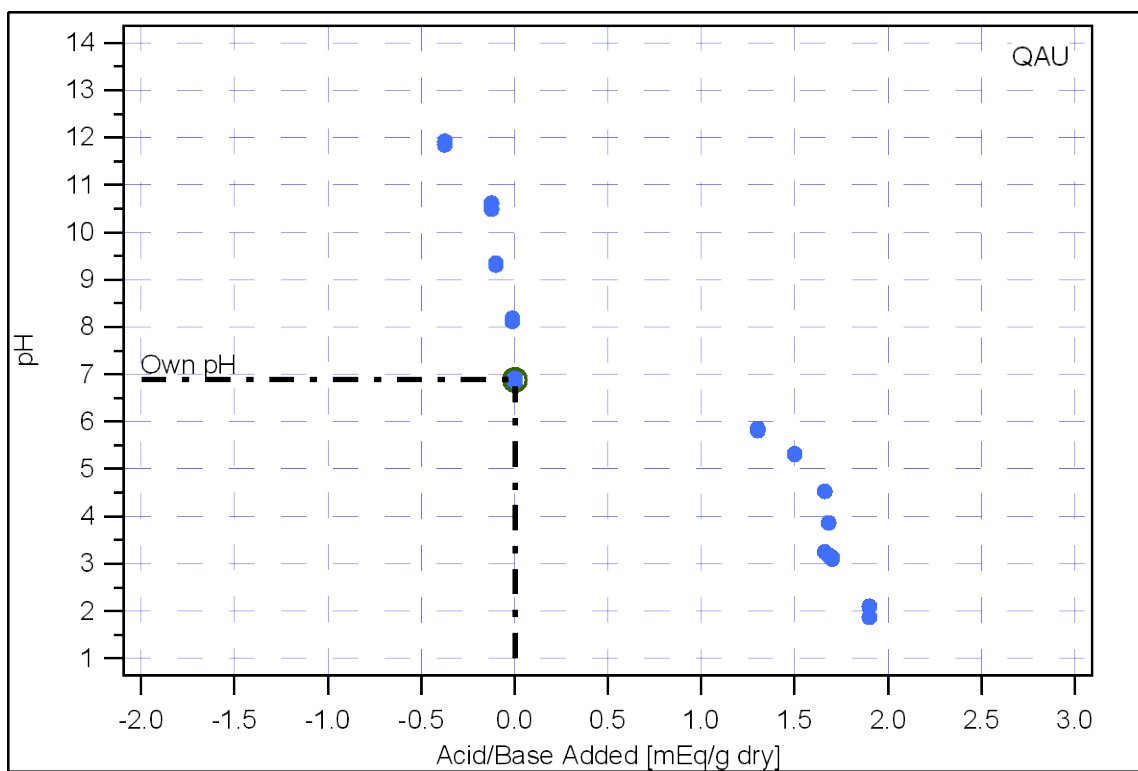
Facility N (High S East-Bit., CS-ESP, Limestone, Forced Oxidation).
NAU – unwashed gypsum; **NAW** – washed gypsum.



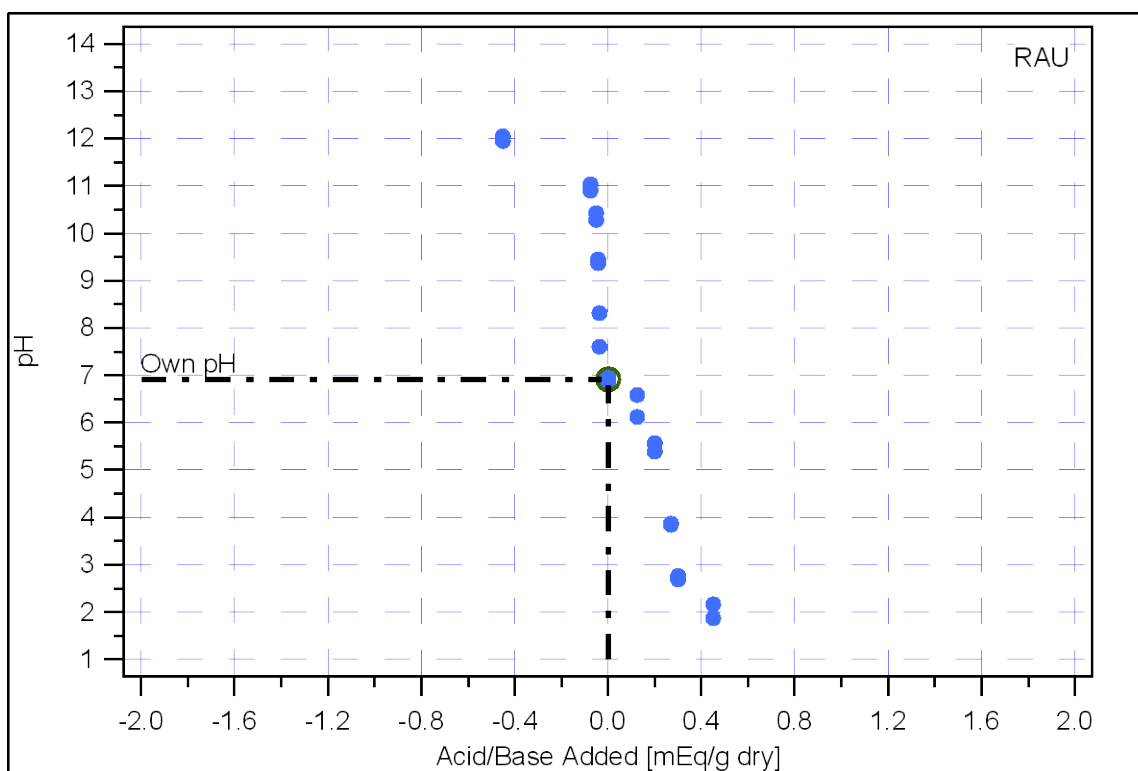
Facility O (Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
OAU – unwashed gypsum; **OAW** – washed gypsum.



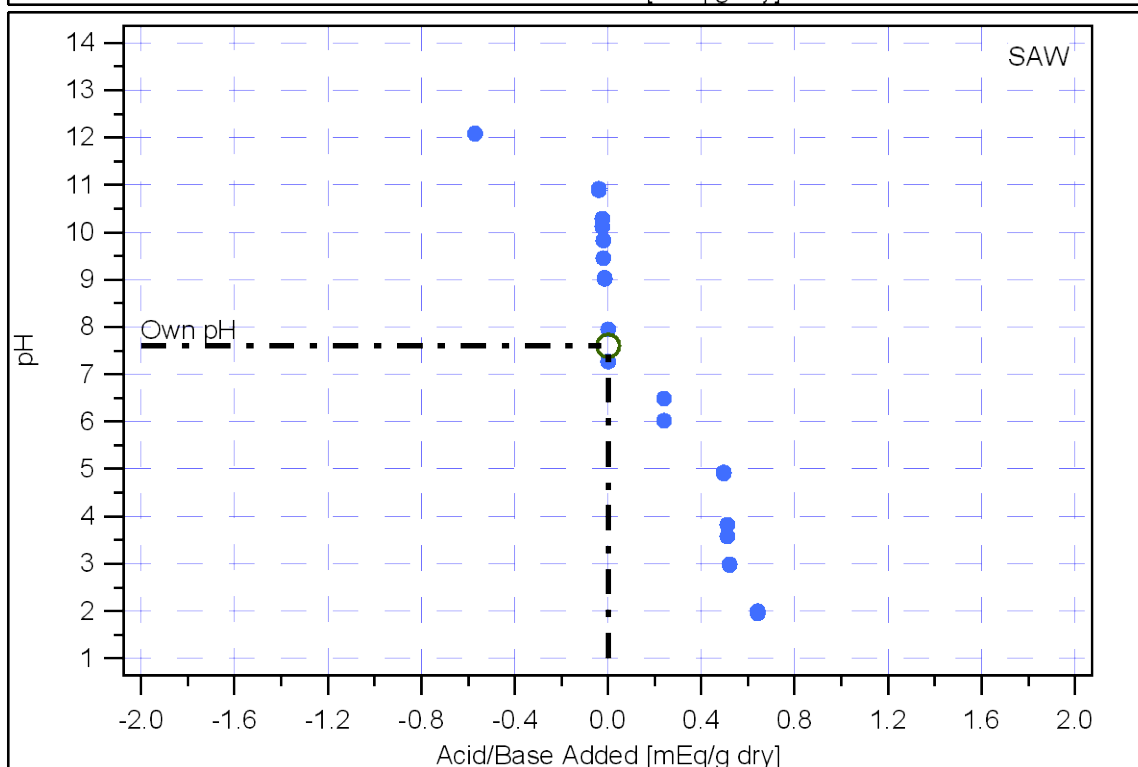
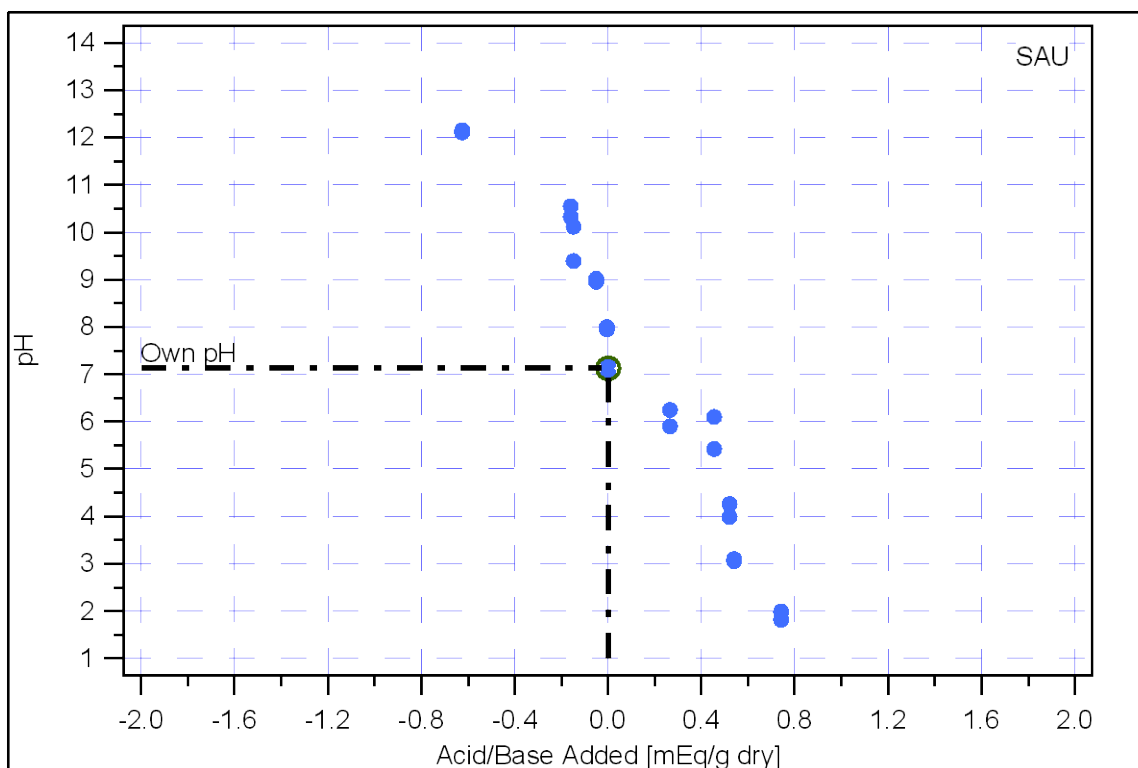
Facility P (Med. S East-Bit., SCR&SNCR, CS-ESP, Limestone, Forced Ox.). **PAD** – unwashed gyp.



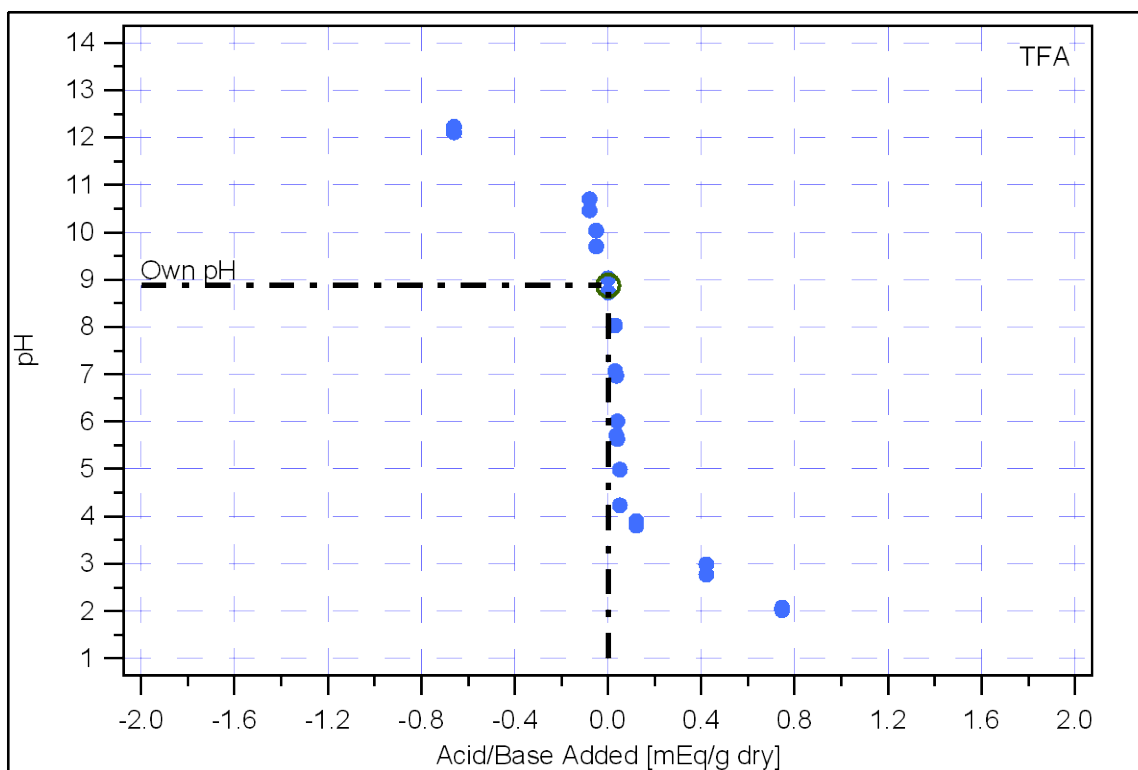
Facility Q (PRB, HS-ESP, Limestone, Forced Oxidation). **QAU** – unwashed gypsum.



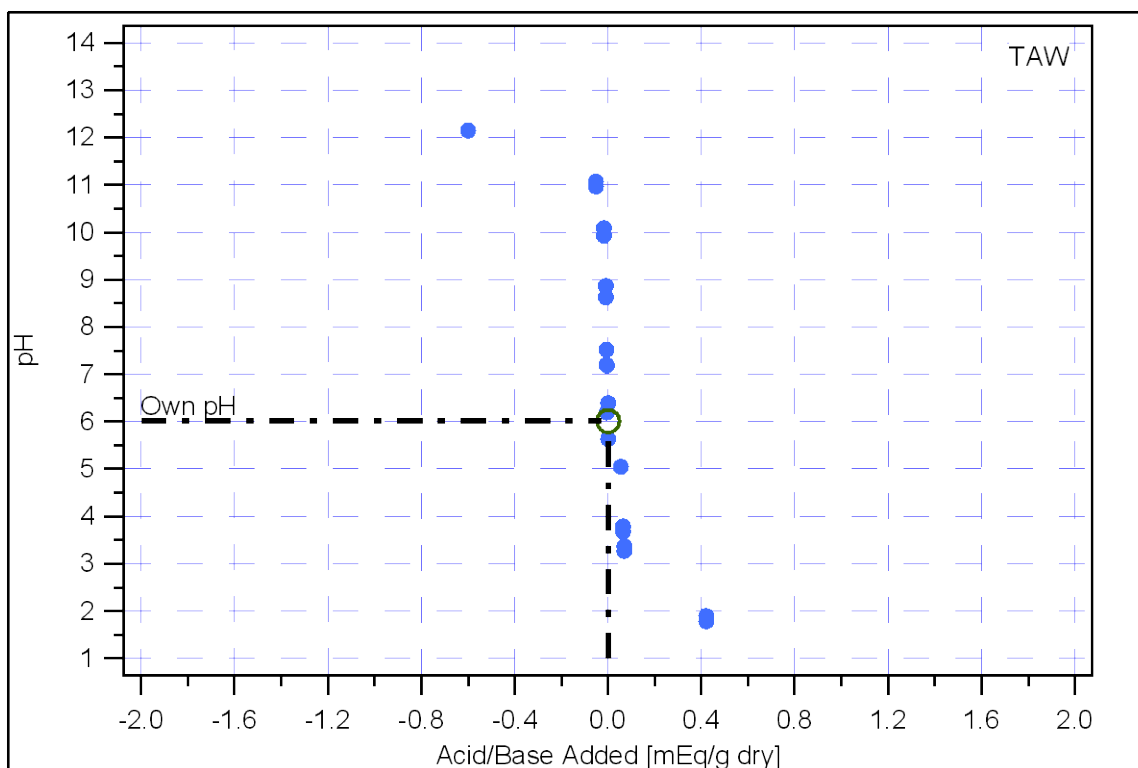
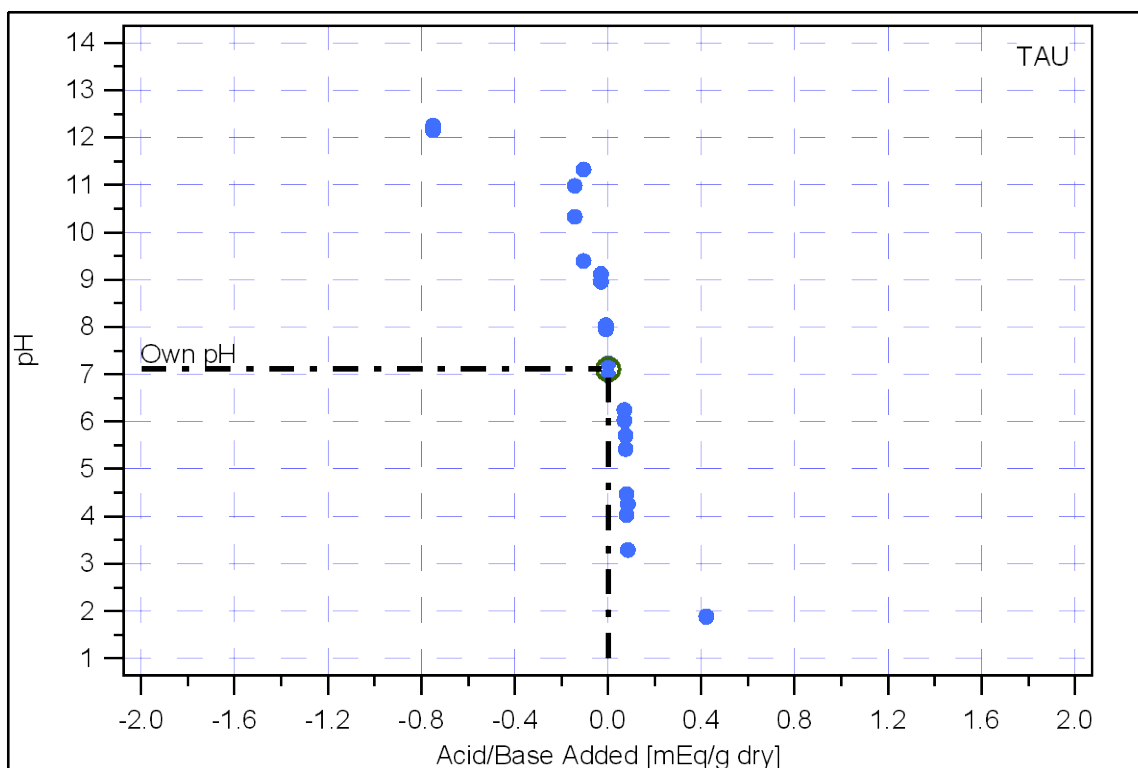
Facility R (PRB, CS-ESP, Limestone, Forced Oxidation). **RAU** – unwashed gypsum.



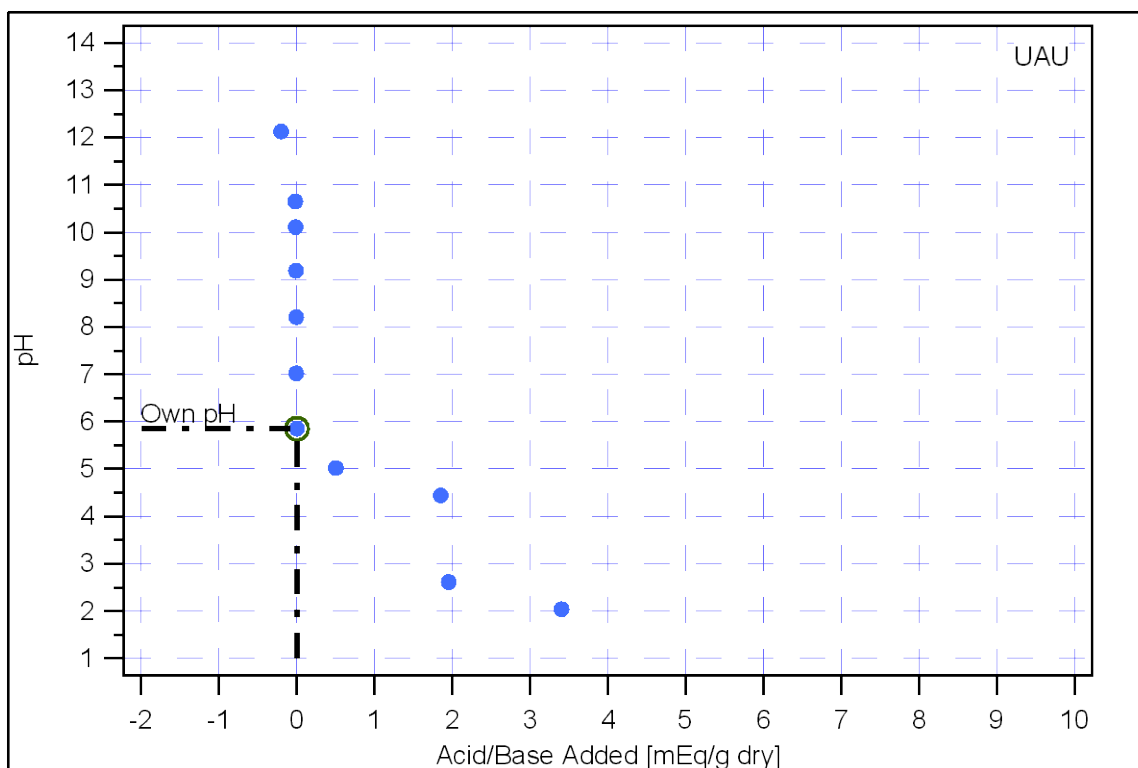
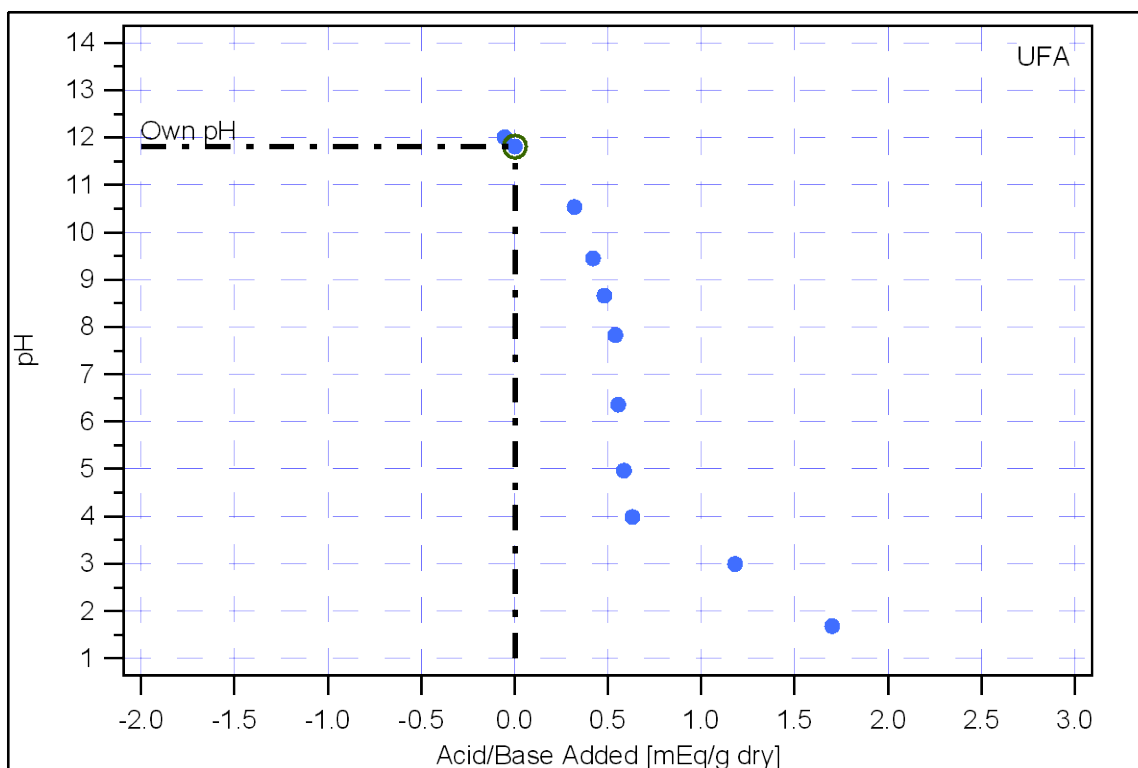
Facility S (Illinois Basin High S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
SAU – unwashed gypsum; **SAW** – washed gypsum.



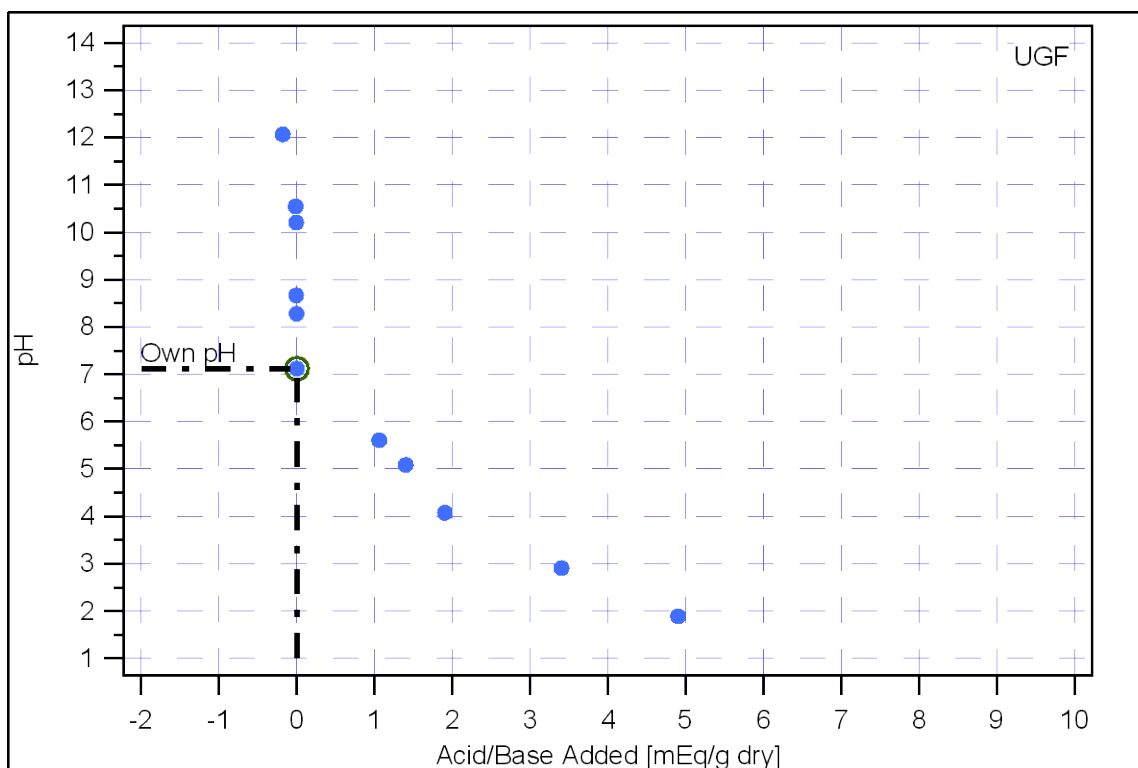
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TFA – fly ash.



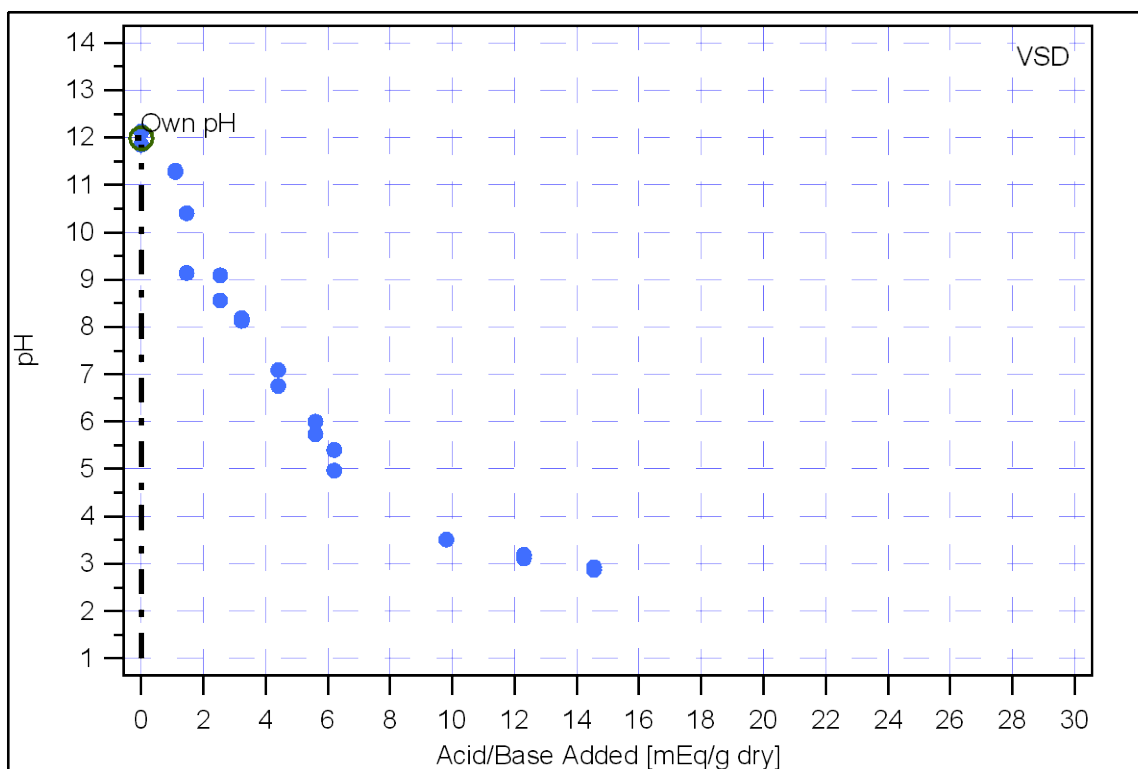
Facility T (Med. S East-Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
TAU – unwashed gypsum; **TAW** – washed gypsum.



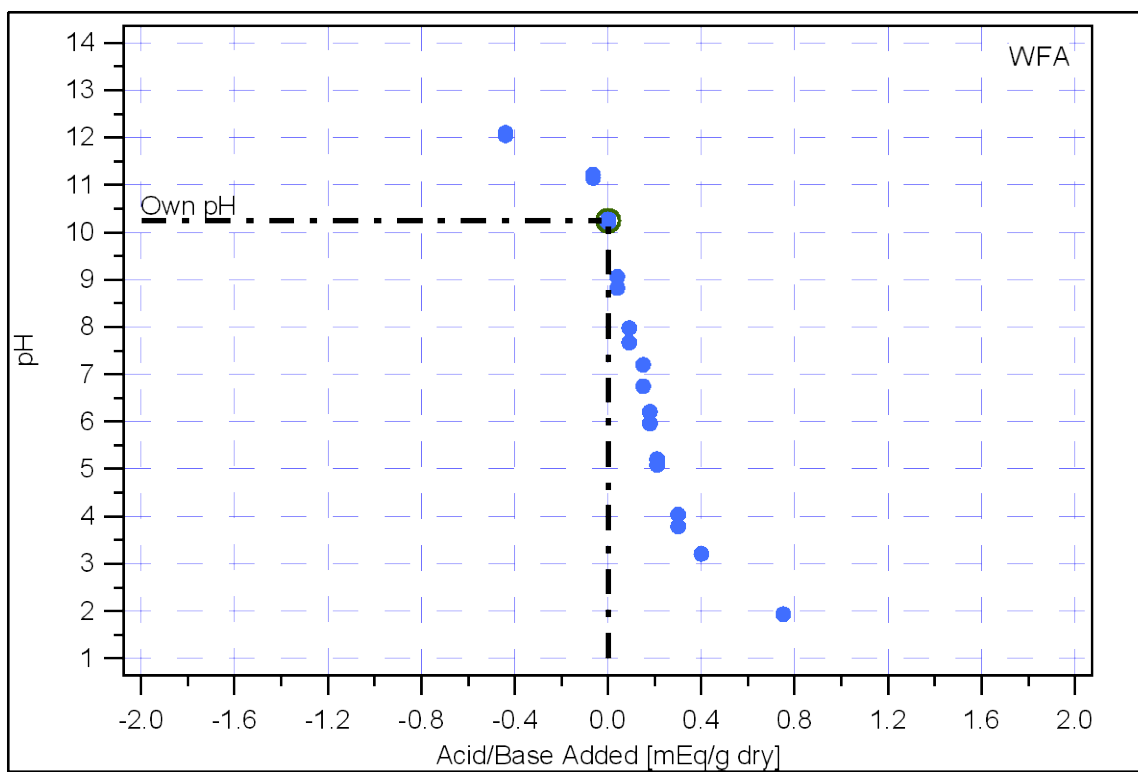
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation).
UFA – fly ash; **UAU** – unwashed gypsum.



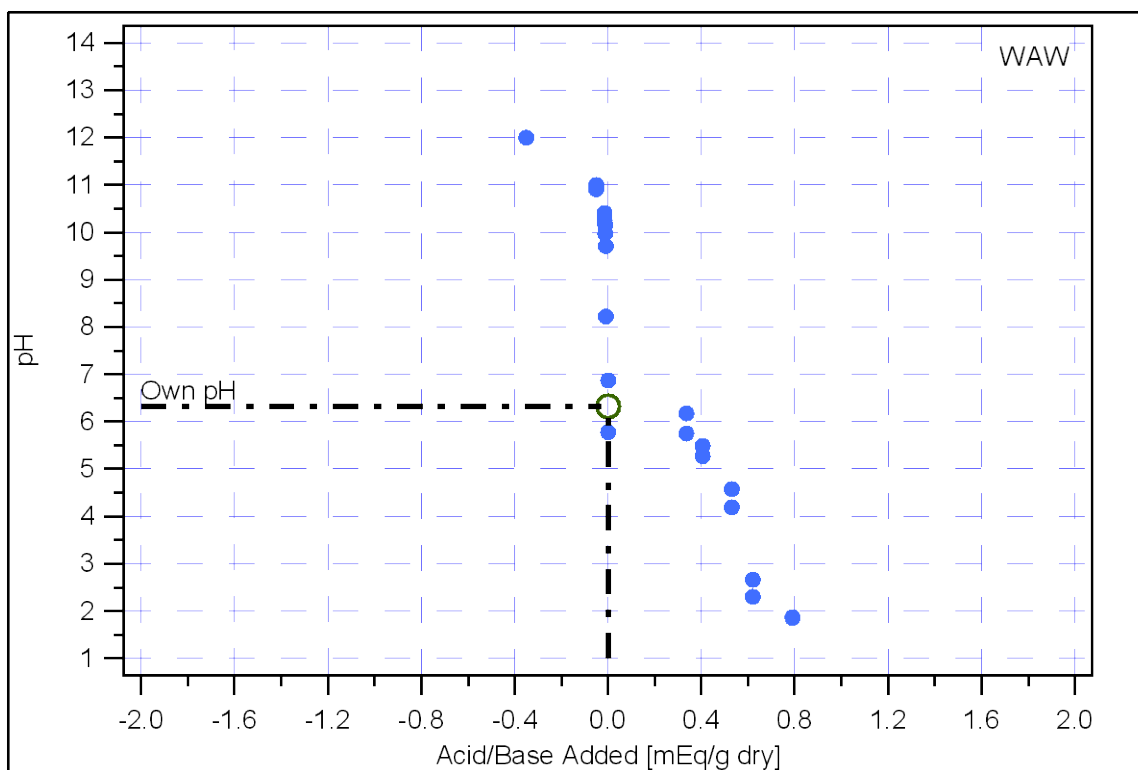
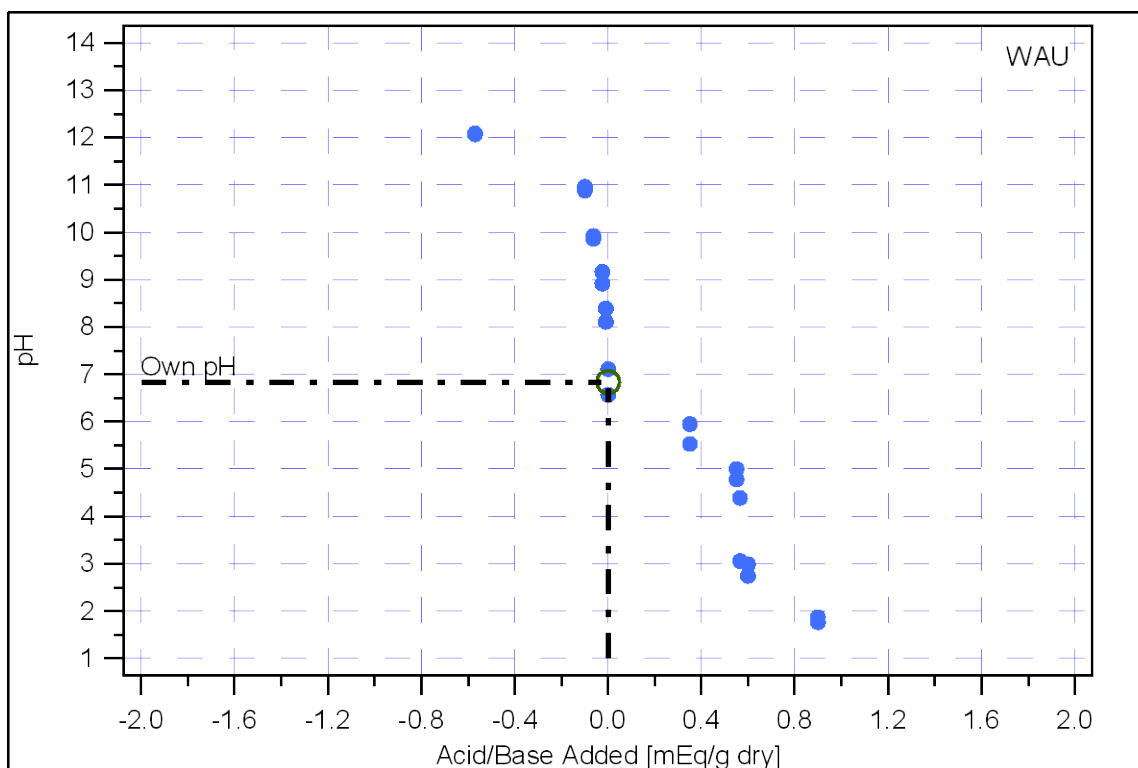
Facility U (Southern Appalachian Low S Bit., SCR, CS-ESP, Limestone, Forced Oxidation). **UGF** – gypsum/flyash.



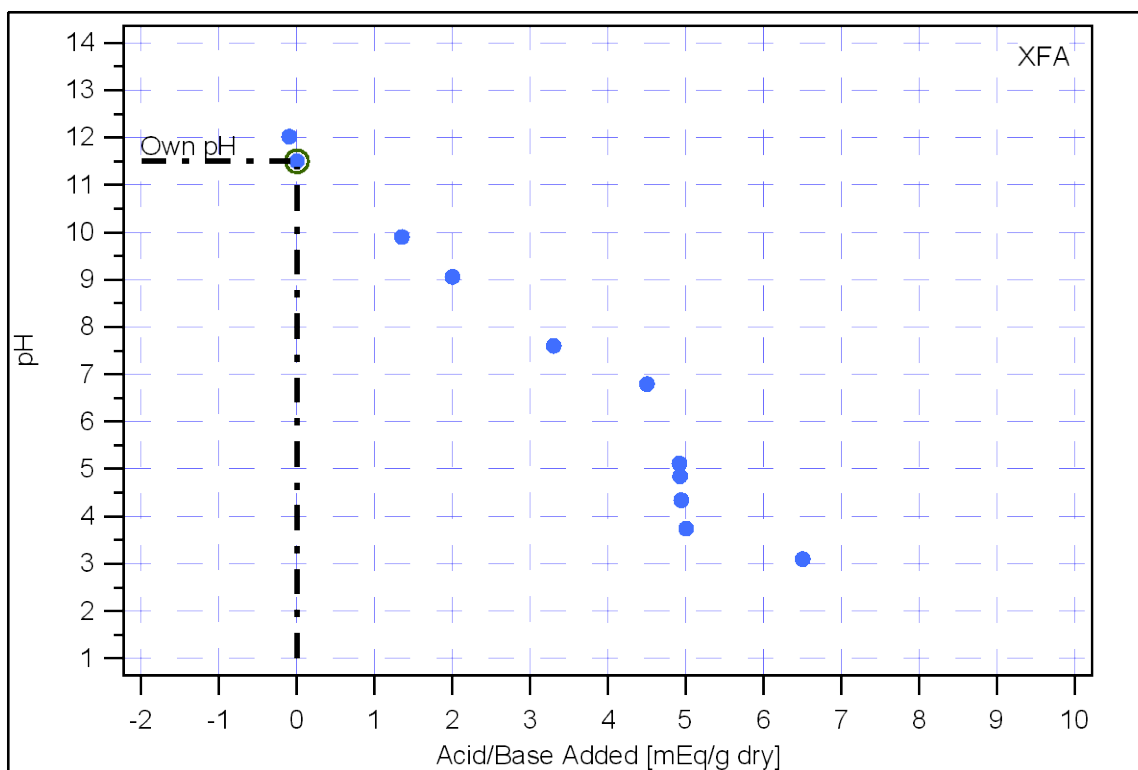
Facility V (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime). **VSD** – spray dryer ash.



Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WFA** – fly ash.

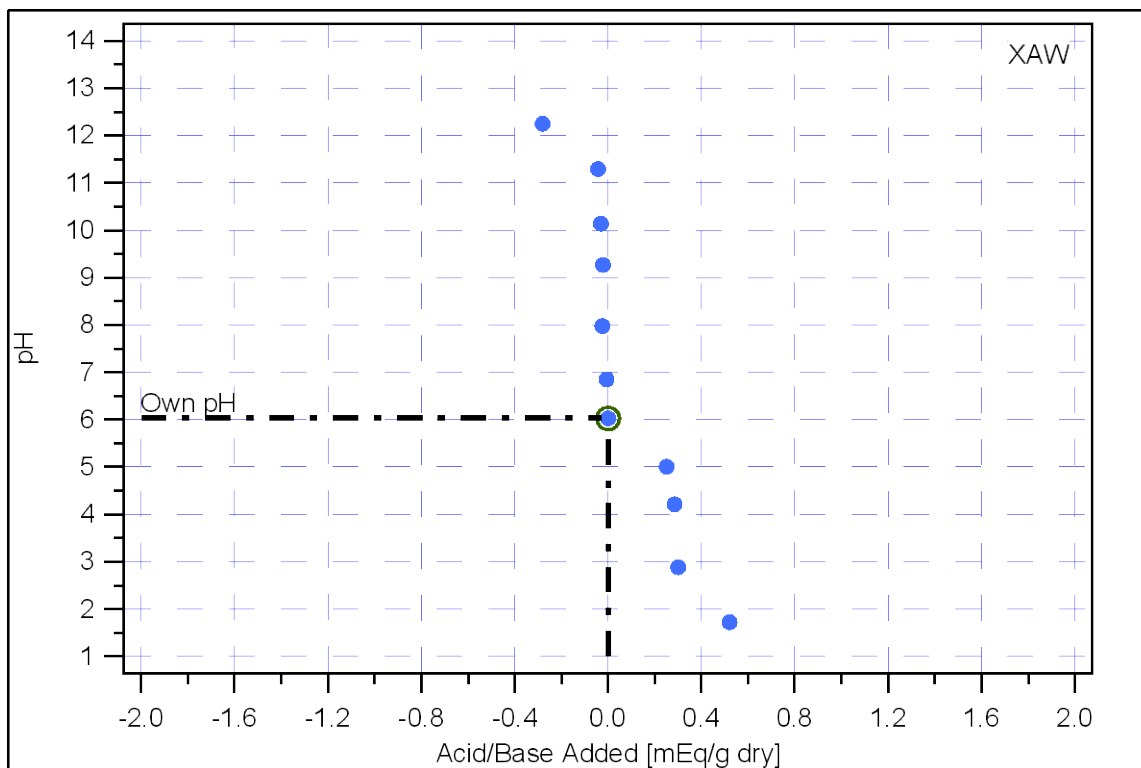
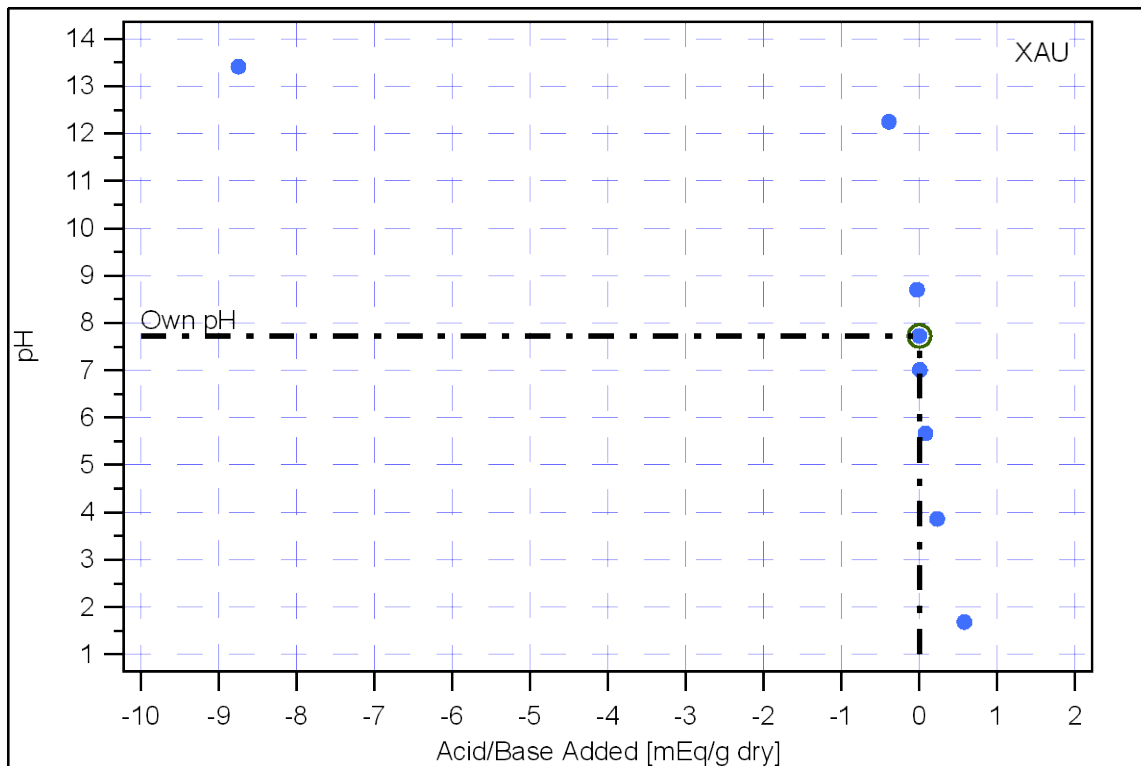


Facility W (Med. S East-Bit., SCR-BP, CS-ESP, Limestone, Forced Oxidation, Duct Sorbent Inj.-Troana). **WAU** – unwashed gypsum; **WAW** – washed gypsum.

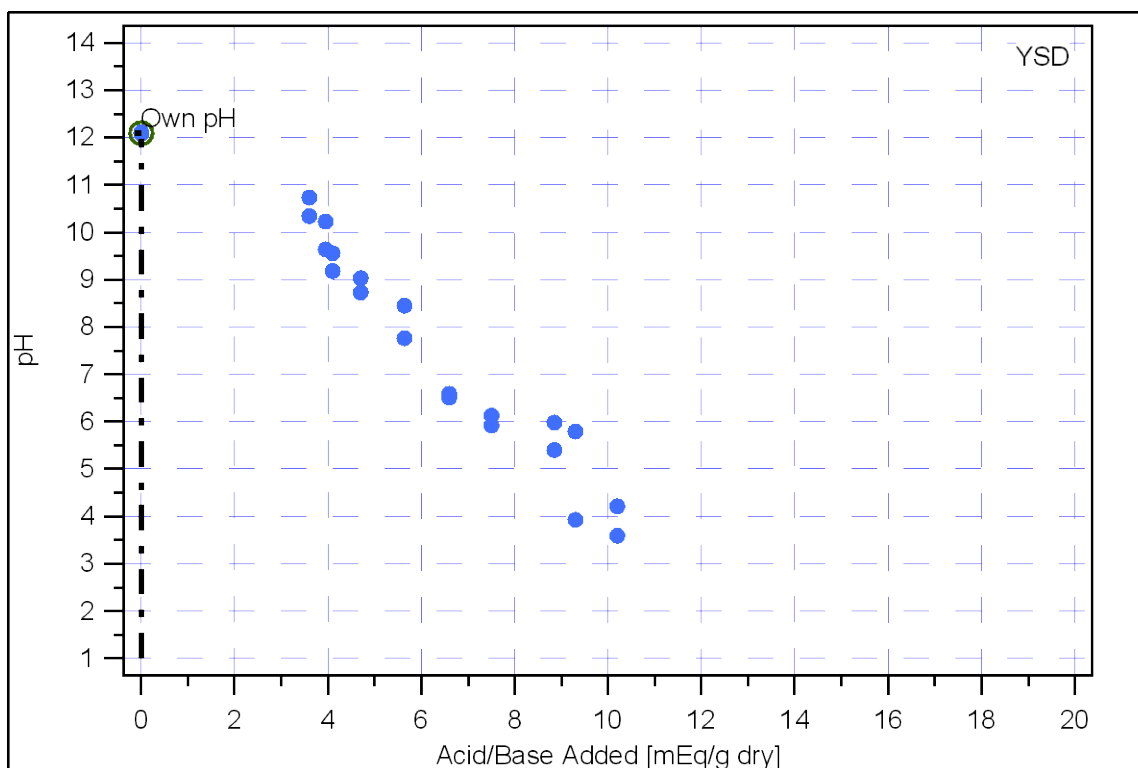


Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).

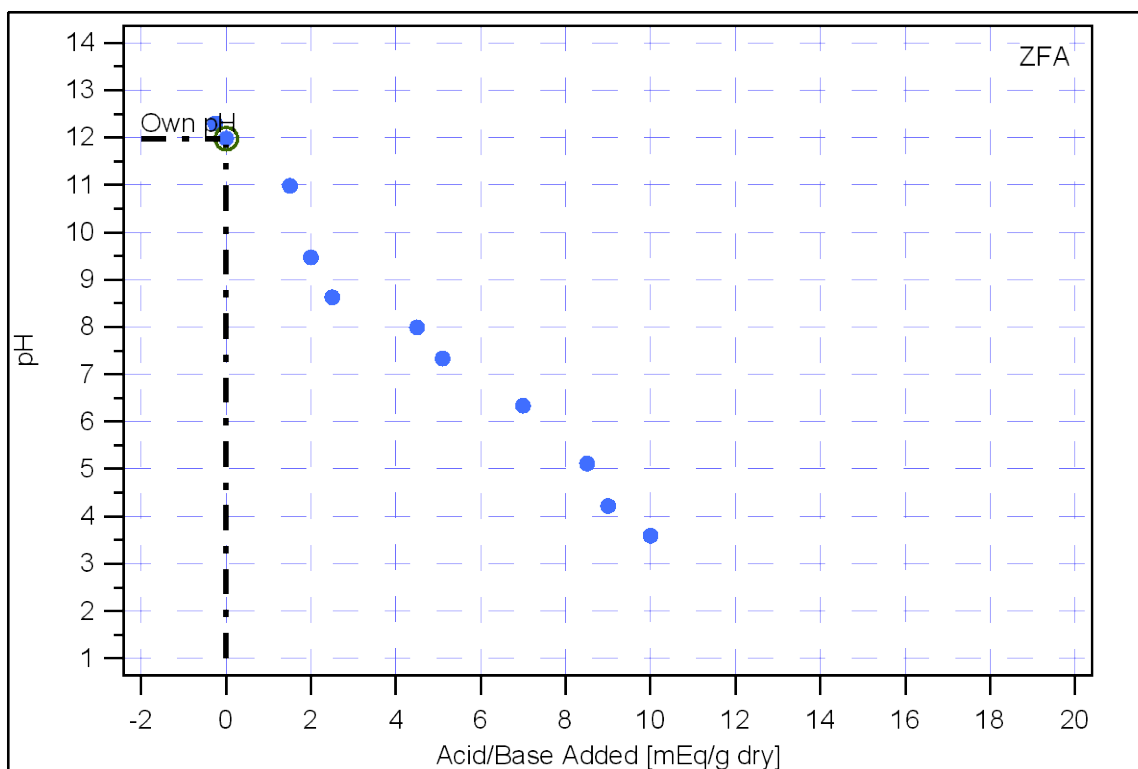
XFA – fly ash.



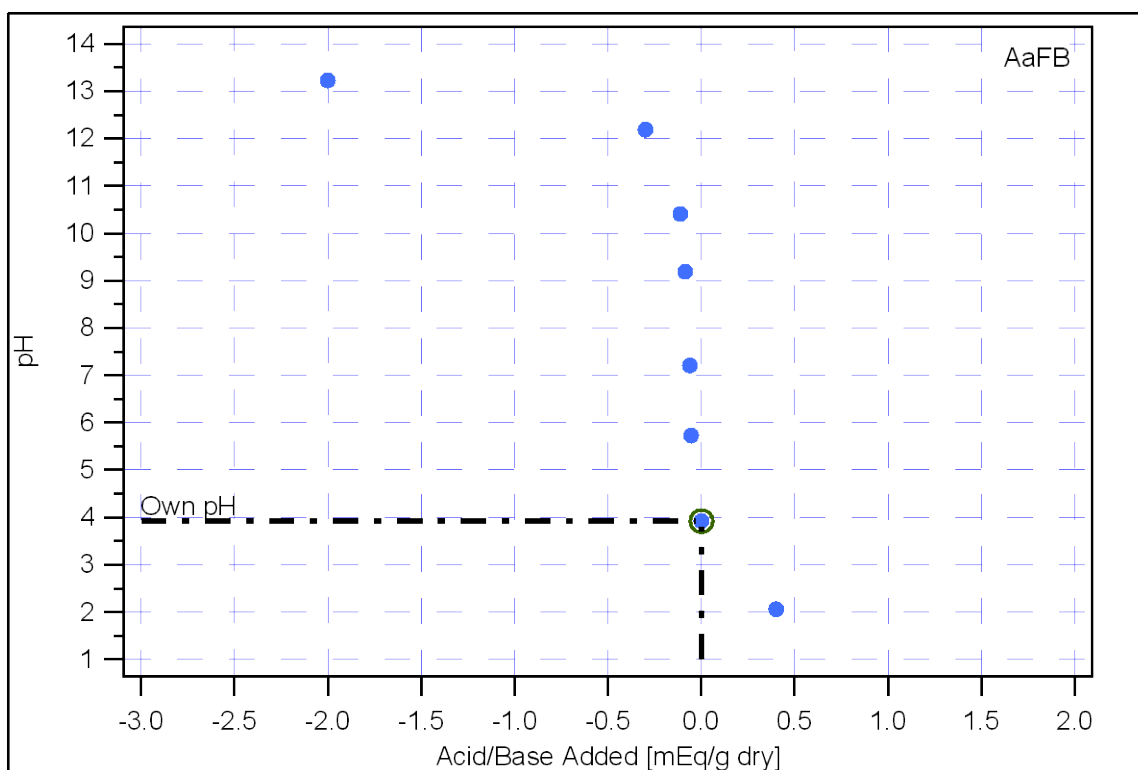
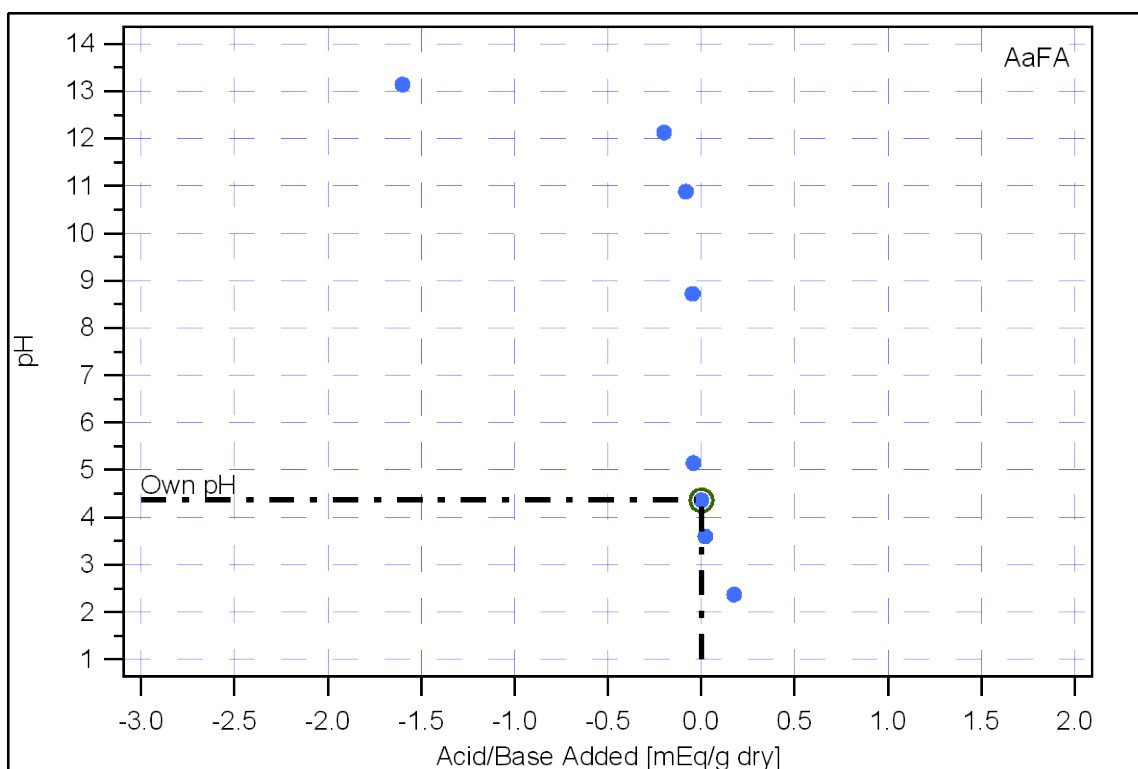
Facility X (PRB, SCR, CS-ESP, Limestone, Forced Oxidation).
XAU – unwashed gypsum; **XAW** – washed gypsum.



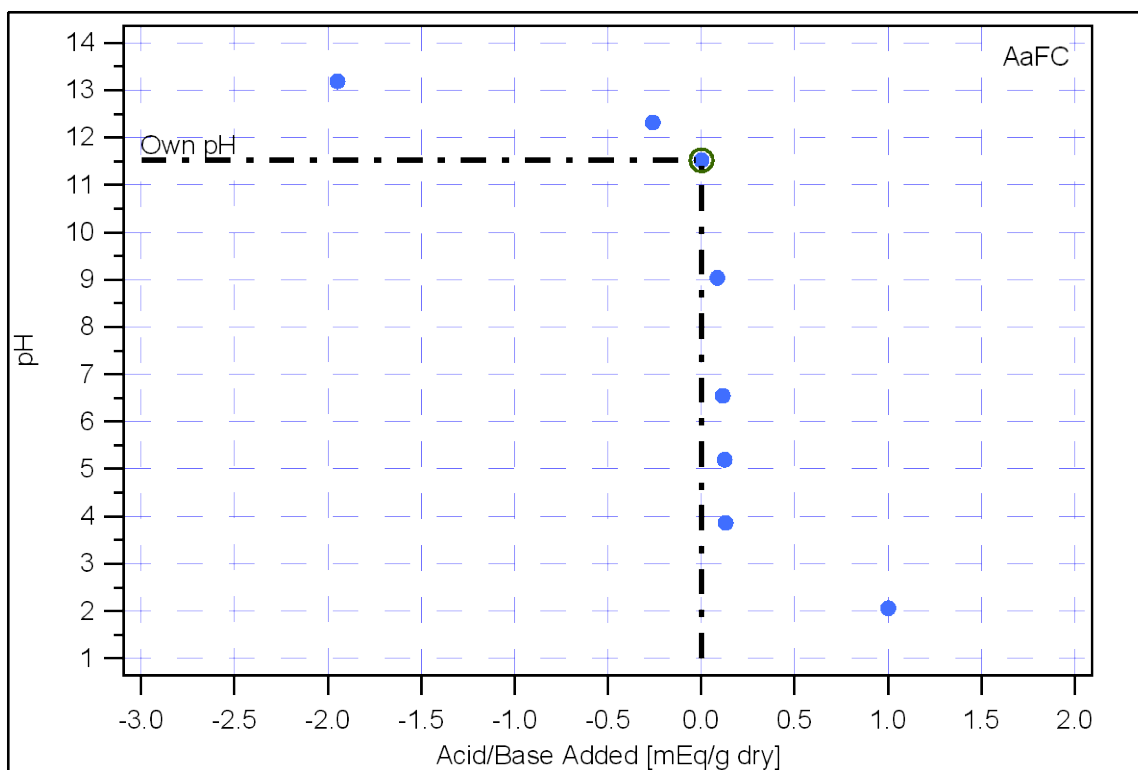
Facility Y (PRB, SCR, Fabric F., Spray Dryer, Slaked Lime, Natural Oxidation). **YSD** – spray dryer ash.



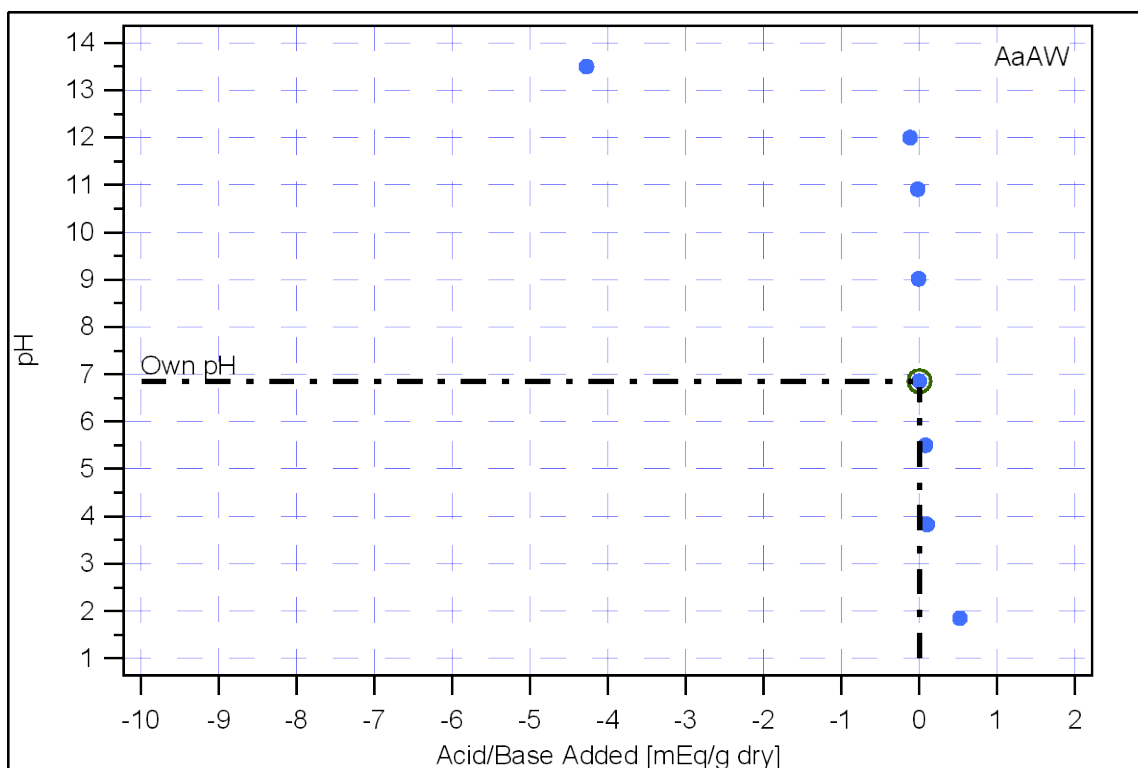
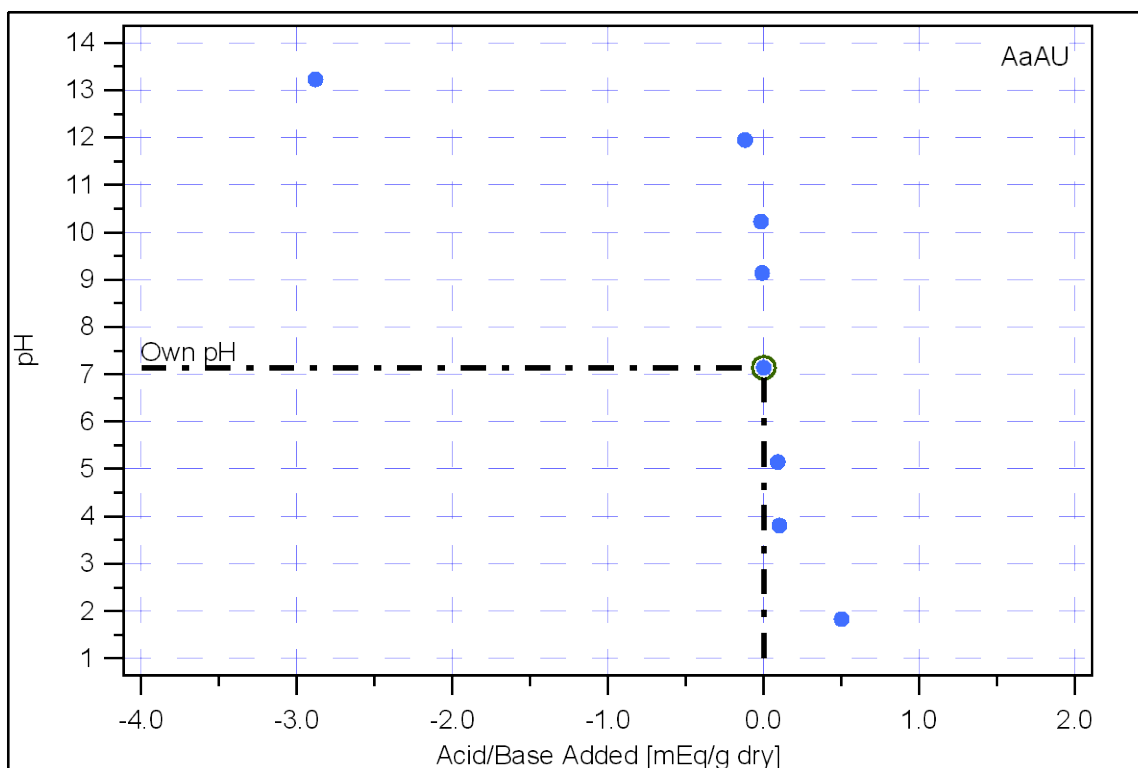
Facility Z (PRB, CS-ESP). **ZFA** – fly ash.



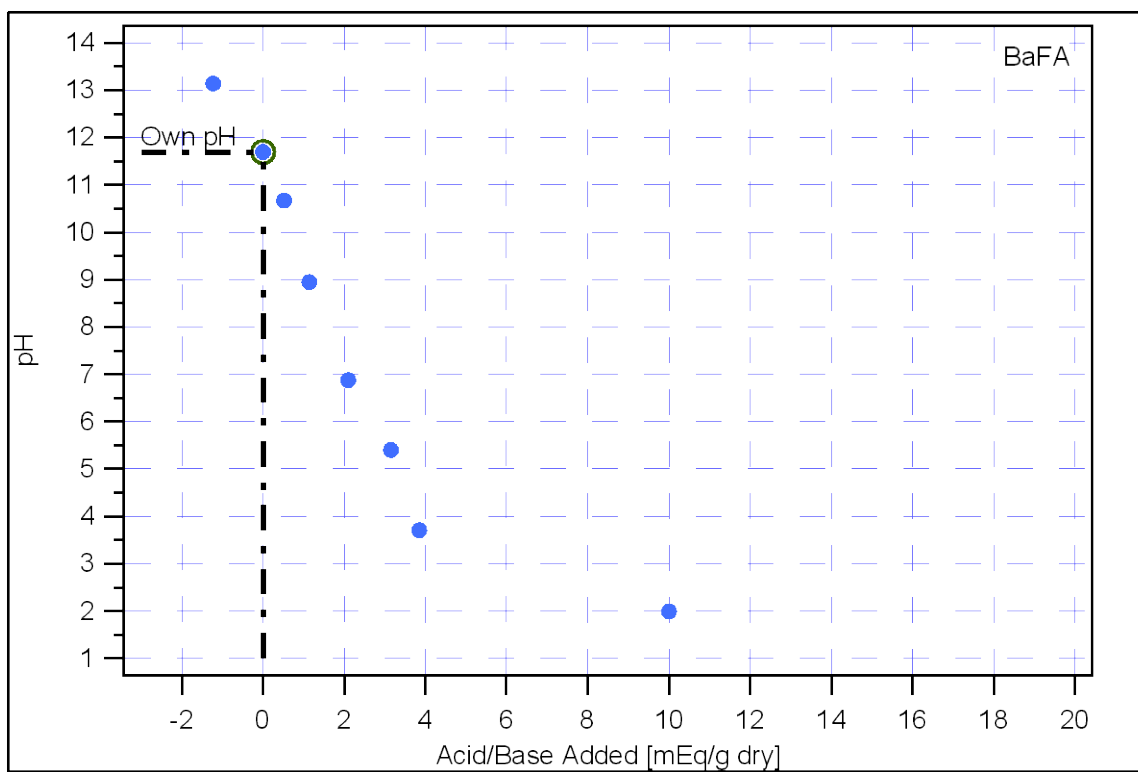
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFA, AaFB – fly ash (CS-ESP).



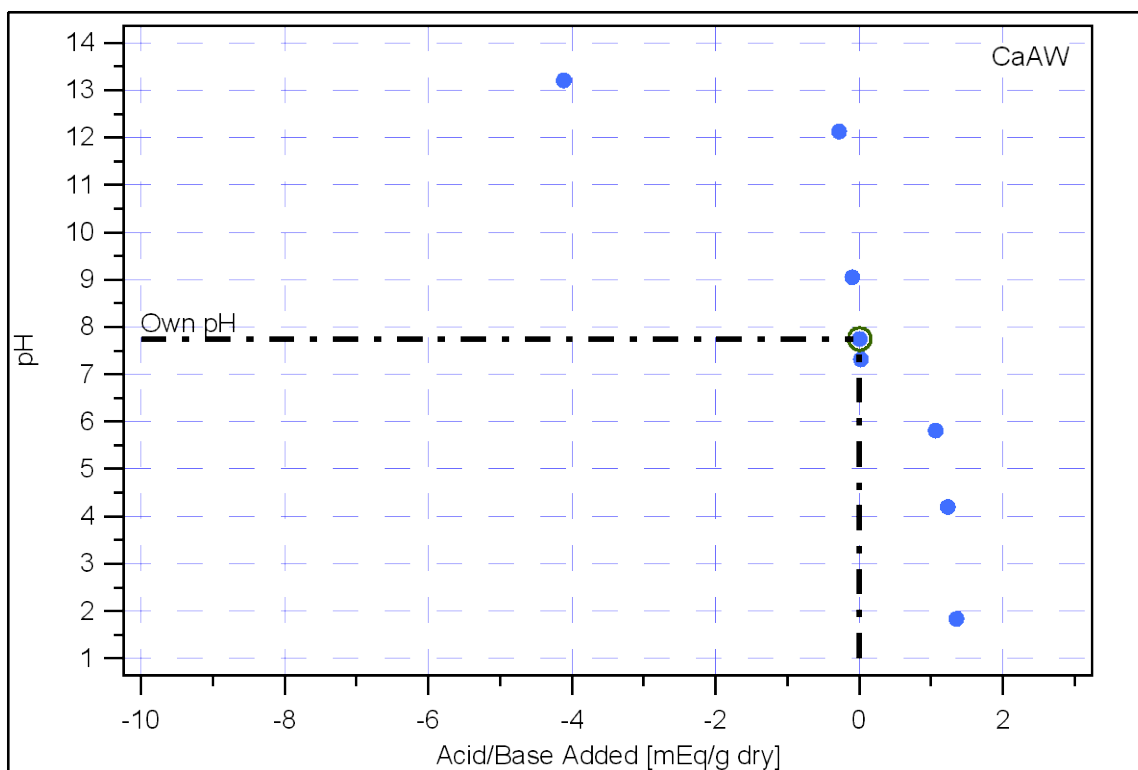
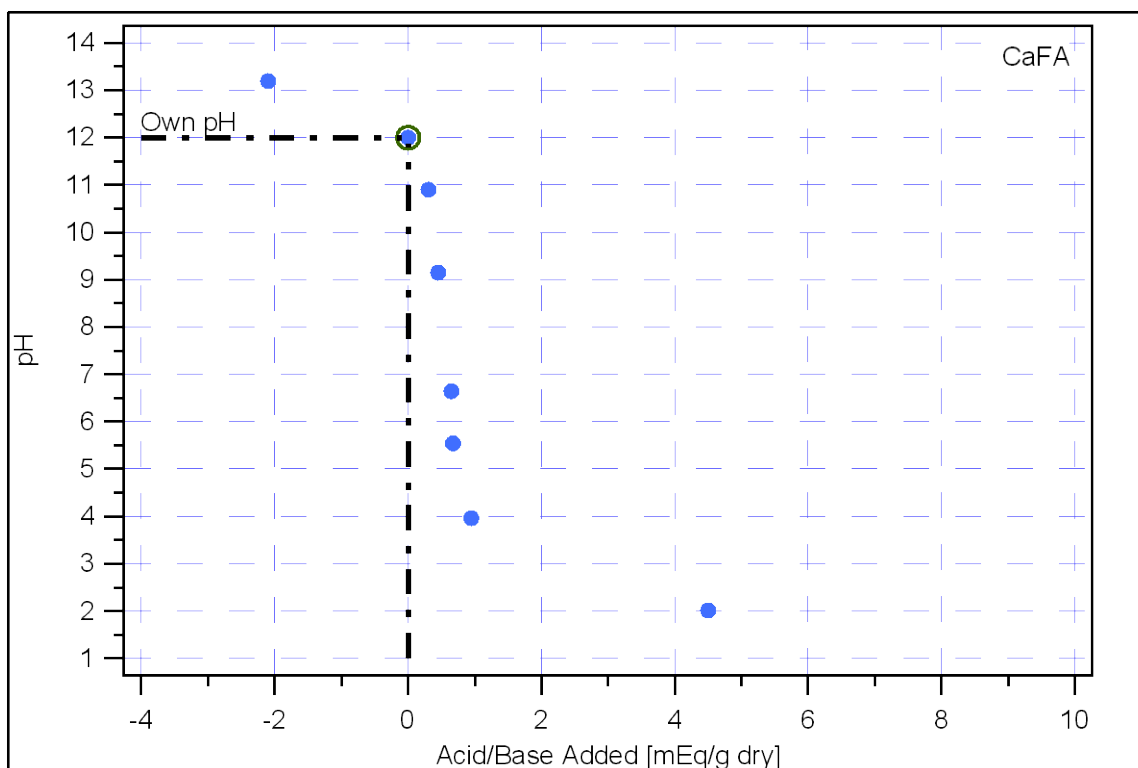
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaFC – fly ash (HS-ESP).



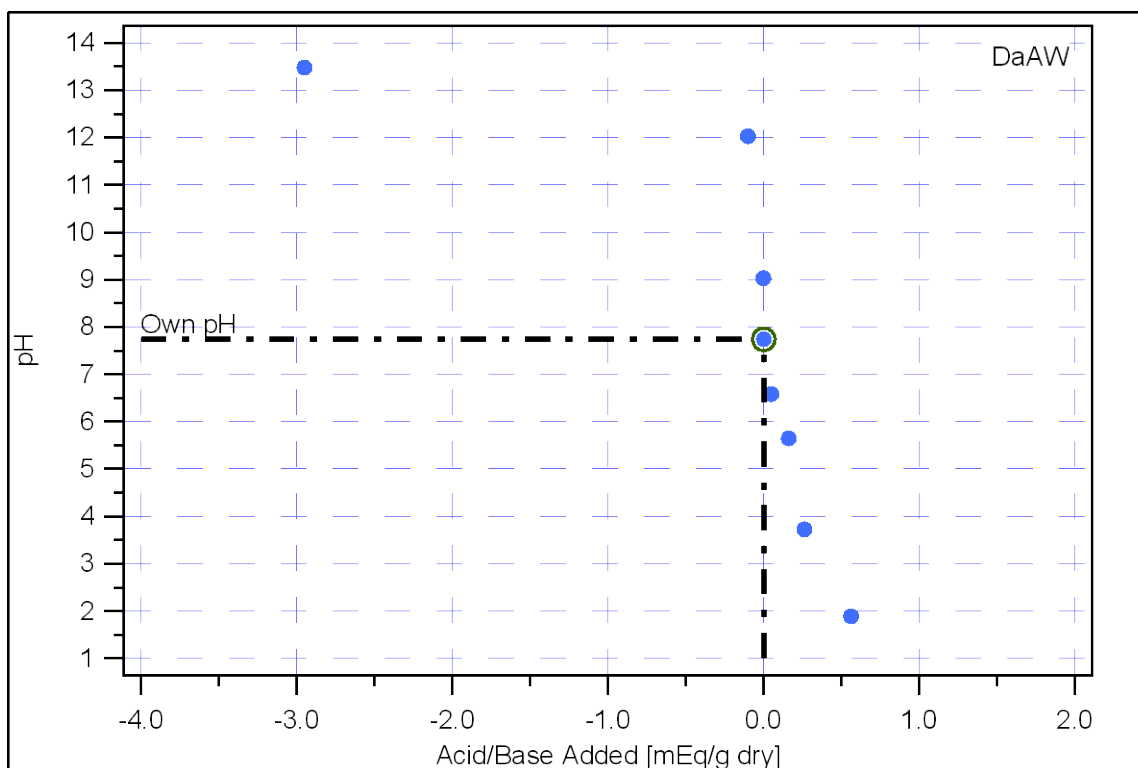
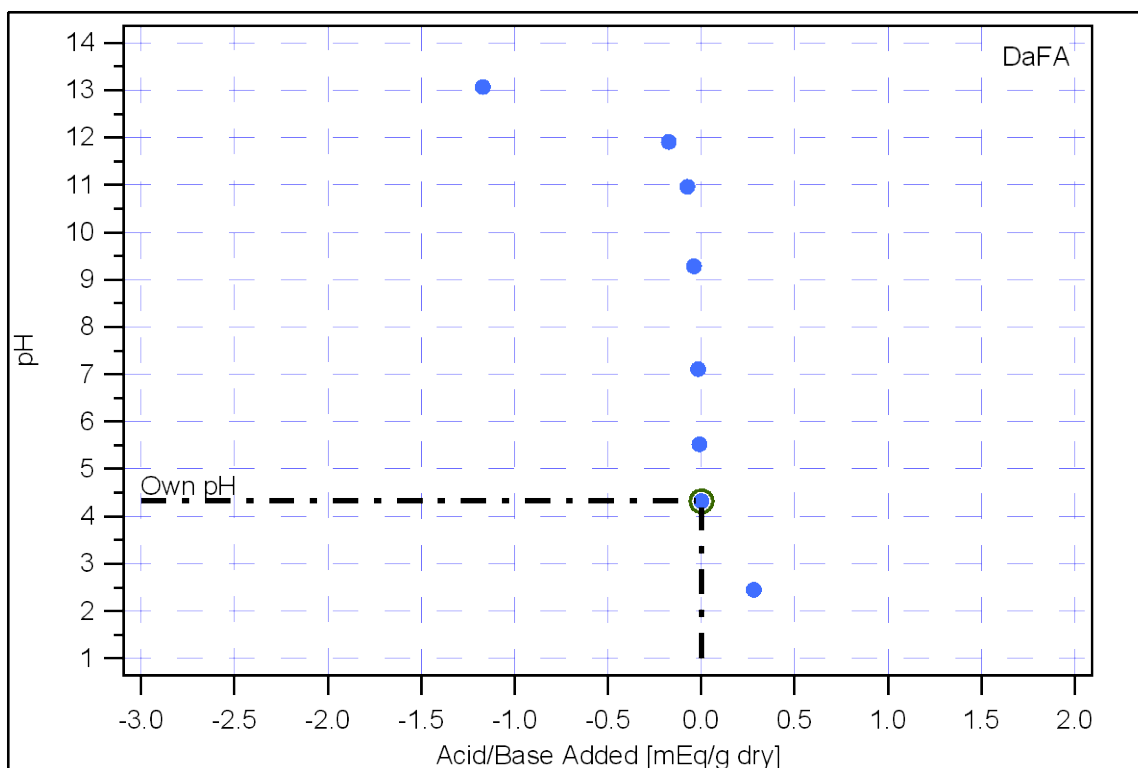
Facility Aa (Med. S East-Bit., SCR, ESP, Limestone, Forced Oxidation).
AaAU – unwashed gypsum; **AaAW** – washed gypsum.



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

Fly Ash without Hg Sorbent Injection	H-1
Fly Ash without and with Hg Sorbent Injection Pairs	H-3
Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	H-3
Filter Cake	H-3

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO ₃ Control	Solid Phase Cr (VI)	Eluate Total Eluate Cr (VI)				Eluate Total Eluate Cr (VI)			
							pH	Cr	Conc.	Eluate Cr (VI)	pH	Cr	Conc.	Eluate Cr (VI)
						%		mg/L	mg/L	%		mg/L	mg/L	%

Fly Ash without Hg Sorbent Injection

Bituminous, Low S

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 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

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 Ca	CaFA	CS ESP	None	None	Duct Sorbent inj. - Troana	16.5	NA	NA	NA	NA	NA	NA	NA	NA
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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
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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
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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
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Filter Cake

Bituminous, Med S

Facility T	TFC	CS ESP	None	None	None	0.7	NA	NA	NA	NA	NA	NA	NA	NA
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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)

St. Clair	JAB	CS ESP	None	None	None	12.10	1072	1080	101
						12.35	1062	1130	106

Lignite (Class C)

Facility Ba	BaFA	CS ESP w/ COHPAC	Ammonia Inj.	PAC	None	NA	NA	NA	NA
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Spray dryer with Fabric Filter (fly ash and FGD collected together)

Sub-bituminous

Facility V	VSD	Fabric F.	SCR	None	None	NA	NA	NA	NA
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Filter Cake

Bituminous, Med S

Facility T	TFC	CS ESP	None	None	None	NA	NA	NA	NA
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NA - not analyzed

Appendix I

Summary of Statistics (Min/Max/Own pH Values)

Fly Ash - Bituminous	I-1
Fly Ash - Sub-bituminous	I-1
Fly Ash - with and without ACI	I-8
Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	I-8
Gypsum, Unwashed and Washed	I-15
Scrubber Sludge	I-15
Blended CCRs	I-15

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						TI					
	Se max Val	Se min Val	Se ownpHVal	Se pH at Max	Se pH at Min	Se ownph	TI max Val	TI min Val	TI ownpHVal	TI pH at Max	TI pH at Min	TI 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

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						TI					
	Se max Val	Se min Val	Se ownpHVal	Se pH at Max	Se pH at Min	Se ownph	TI max Val	TI min Val	TI ownpHVal	TI pH at Max	TI pH at Min	TI 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 (DaAU)	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						TI					
	Se max Val	Se min Val	Se ownpHVal	Se pH at Max	Se pH at Min	Se ownph	TI max Val	TI min Val	TI ownpHVal	TI pH at Max	TI pH at Min	TI 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)

<u>Aluminum</u>	<u>J-1</u>
<u>Arsenic</u>	<u>J-1</u>
<u>Boron</u>	<u>J-1</u>
<u>Barium</u>	<u>J-1</u>
<u>Cadmium</u>	<u>J-2</u>
<u>Cobalt</u>	<u>J-2</u>
<u>Chromium</u>	<u>J-2</u>
<u>Mercury</u>	<u>J-2</u>
<u>Molybdenum</u>	<u>J-3</u>
<u>Lead</u>	<u>J-3</u>
<u>Antimony</u>	<u>J-3</u>
<u>Selenium</u>	<u>J-3</u>
<u>Thallium</u>	<u>J-4</u>

Max Eluate Concentrations for $5.4 \leq \text{pH} \leq 12.4$ [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

Max Eluate Concentrations for $5.4 \leq \text{pH} \leq 12.4$ [$\mu\text{g/L}$]						Eluate Concentrations at Own pH [$\mu\text{g/L}$]				
TI	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

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	L-1
Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study	L-12
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Fly Ash without Hg Sorbent Injection	L-23
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Fly Ash without and with Hg Sorbent Injection Pairs	L-25
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Spray Dryer with Fabric Filter (Fly Ash and FGD collected together)	L-26
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Gypsum, Unwashed and Washed	L-27
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Scrubber Sludge	L-29
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Mixed Fly Ash and Scrubber Sludge (blended CCRs)	L-30
Minimum attenuation factor needed for the maximum eluate concentration (5.4 ≤pH≤12.4) to be reduced to less than the MCL for Mixed Fly Ash and Gypsum (blended CCRs)	L-31
Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Fly Ash without Hg Sorbent Injection	L-32
Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Fly Ash without and with Hg Sorbent Injection Pairs	L-34

Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Spray Dryer with Fabric Filter (Fly Ash and FGD collected together) L-35

Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Gypsum, Unwashed and Washed L-36

Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Scrubber Sludge L-38

Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Mixed Fly Ash and Scrubber Sludge (blended CCRs) L-39

Minimum attenuation factor needed for the own eluate concentration to be reduced to less than the MCL for Mixed Fly Ash and Gypsum (blended CCRs) L-40

Individual COPCs

Minimum attenuation factor needed for the **maximum eluate concentration** ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

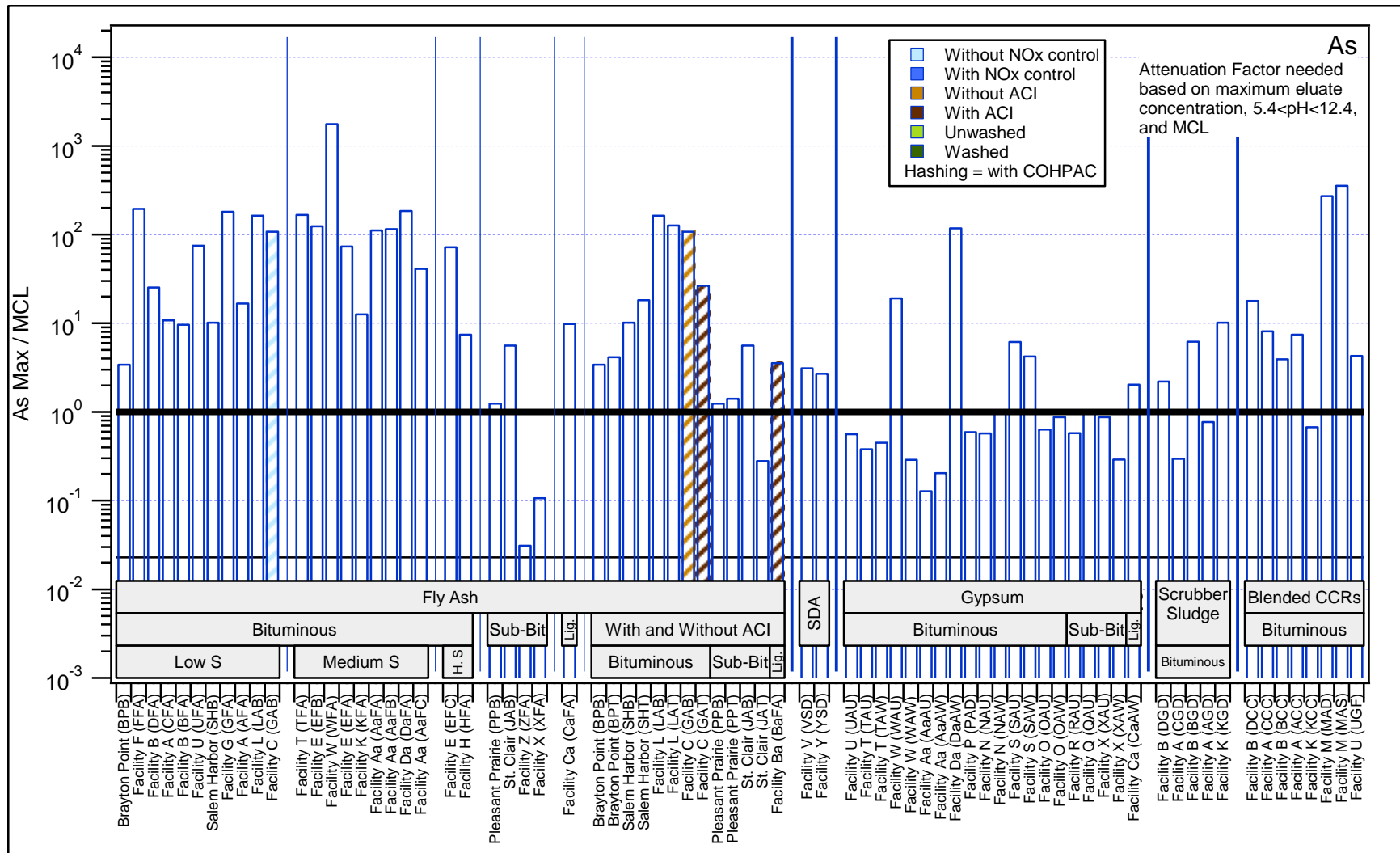


Figure L-1. Arsenic - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

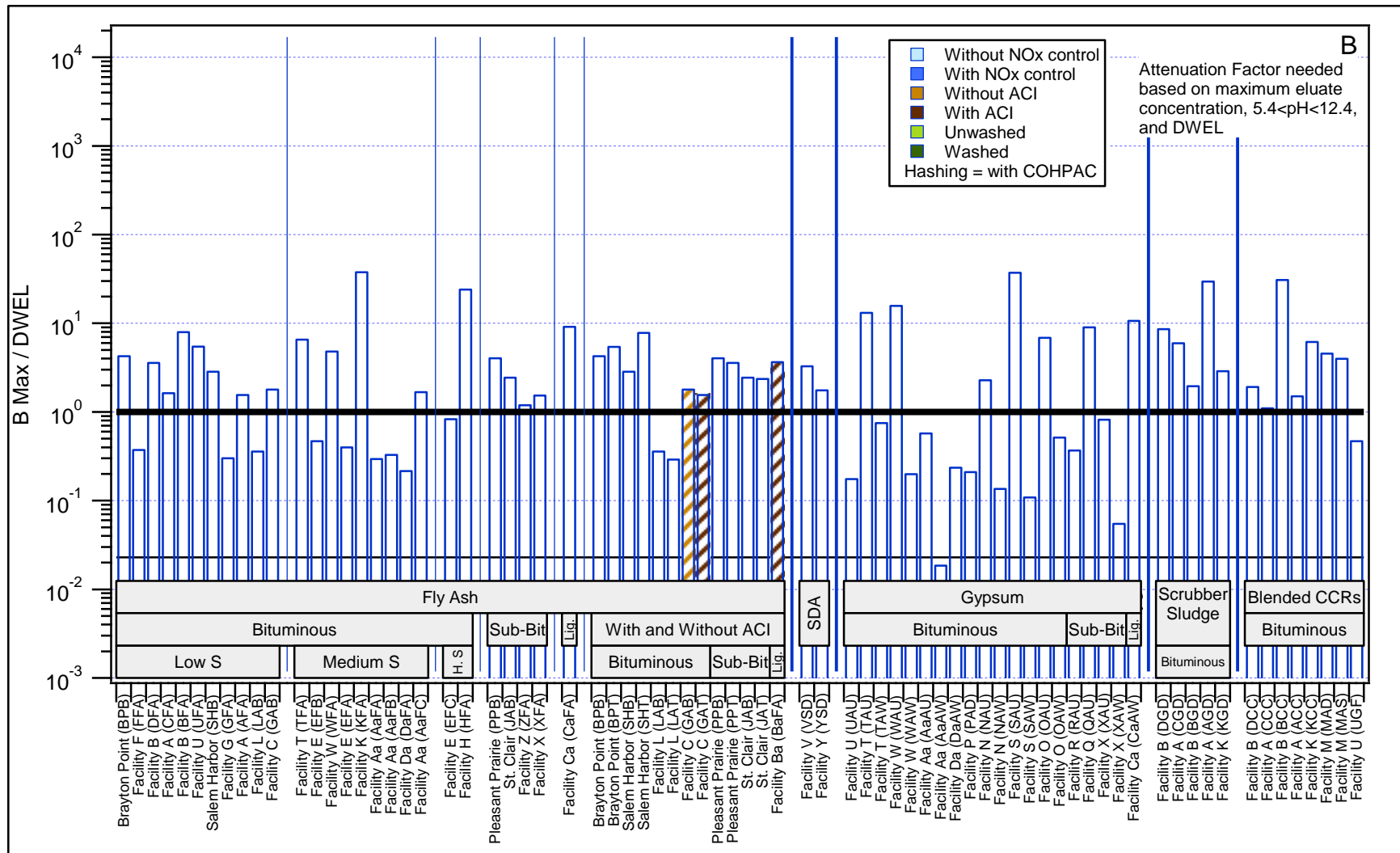


Figure L-2. Boron - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the DWEL for each CCR evaluated in this study.

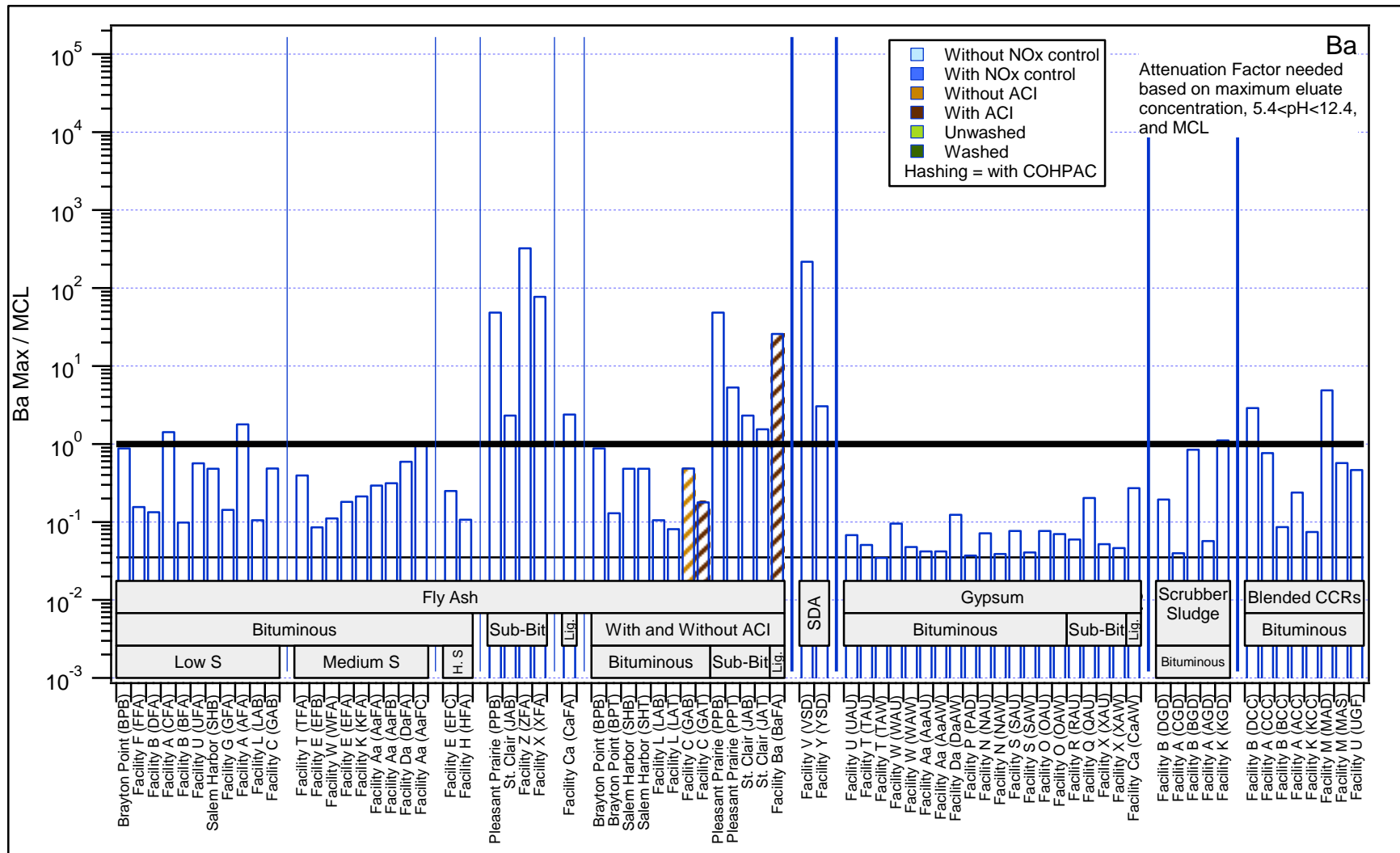


Figure L-3. Barium - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

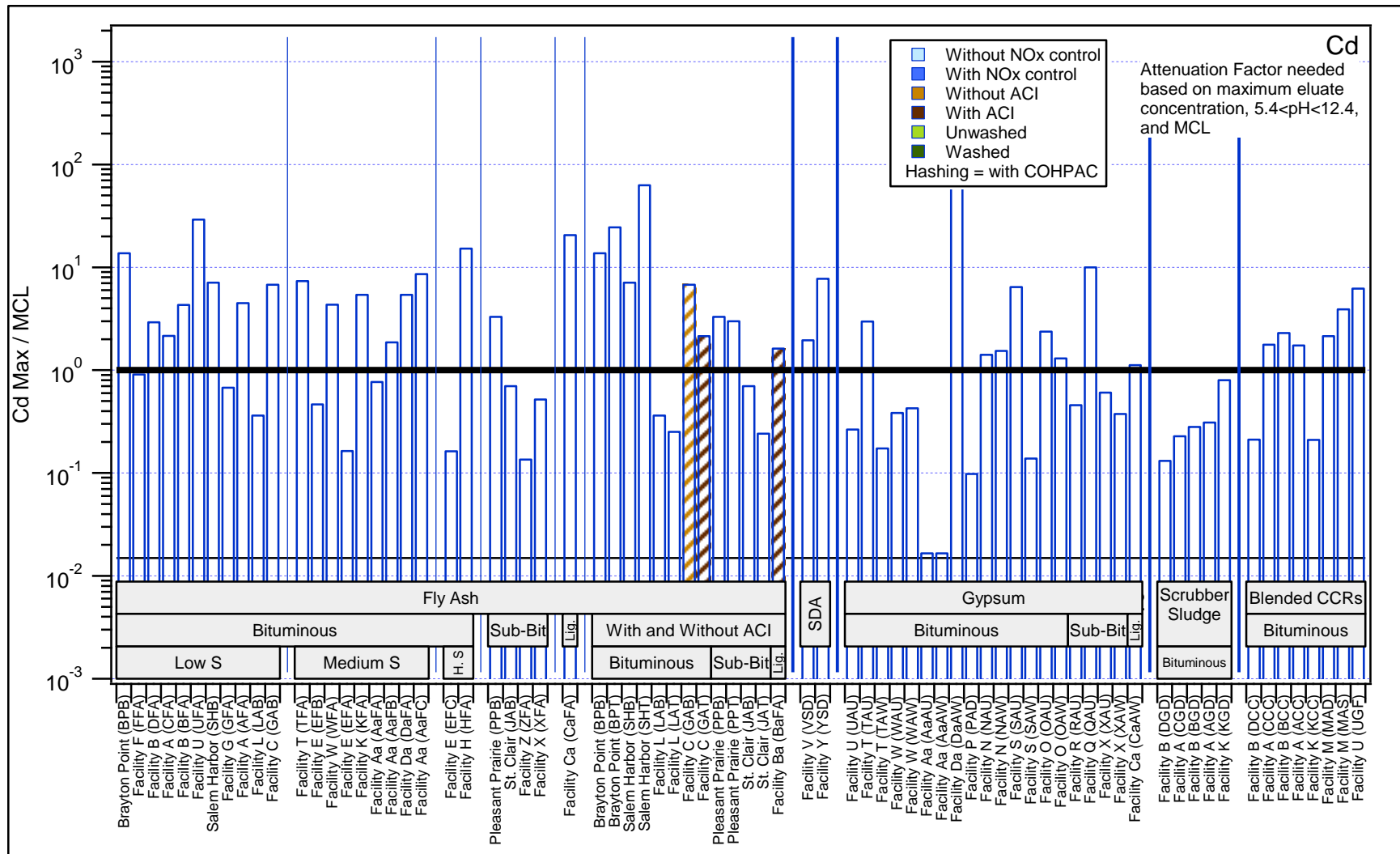


Figure L-4. Cadmium - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

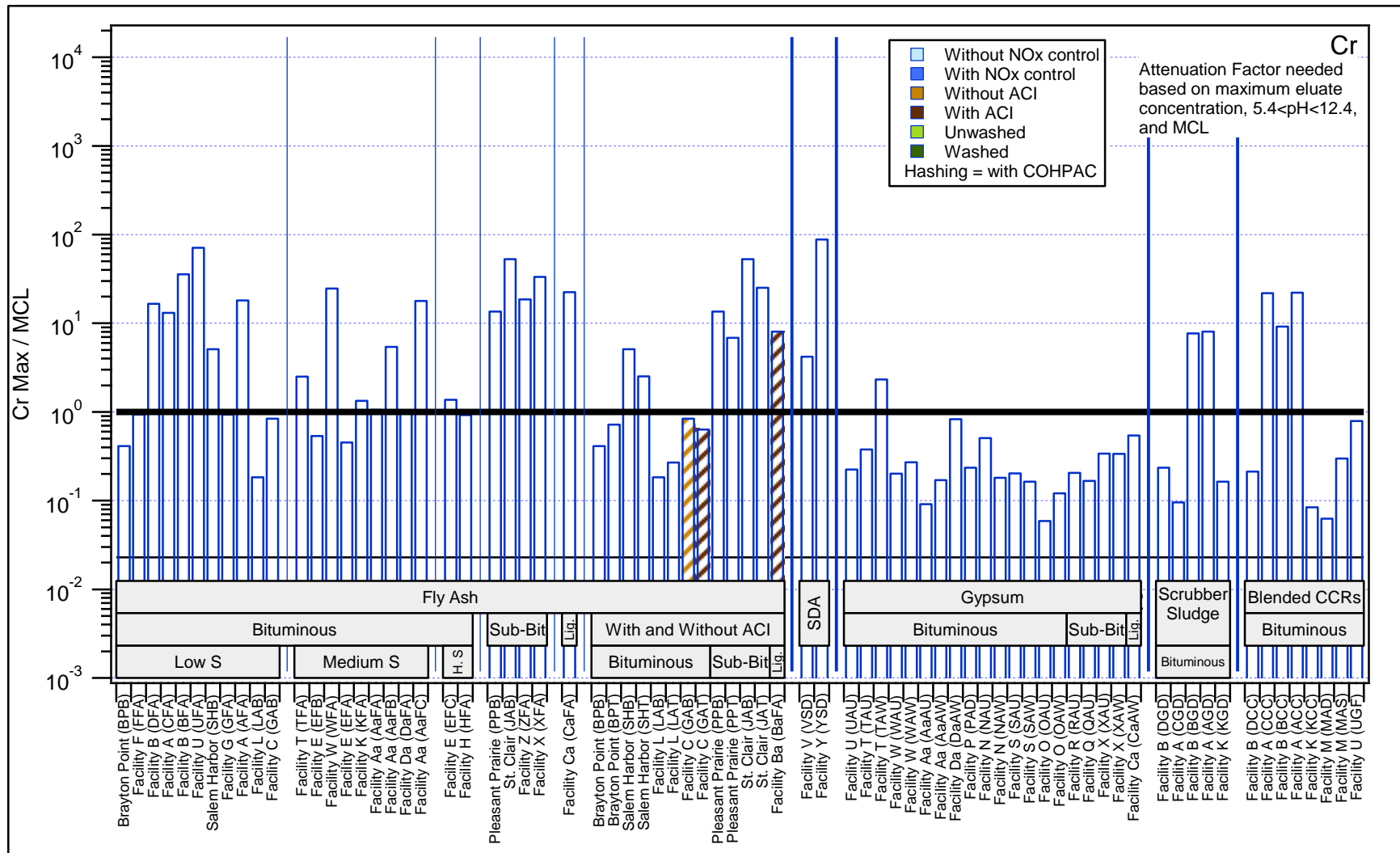


Figure L-5. Chromium - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

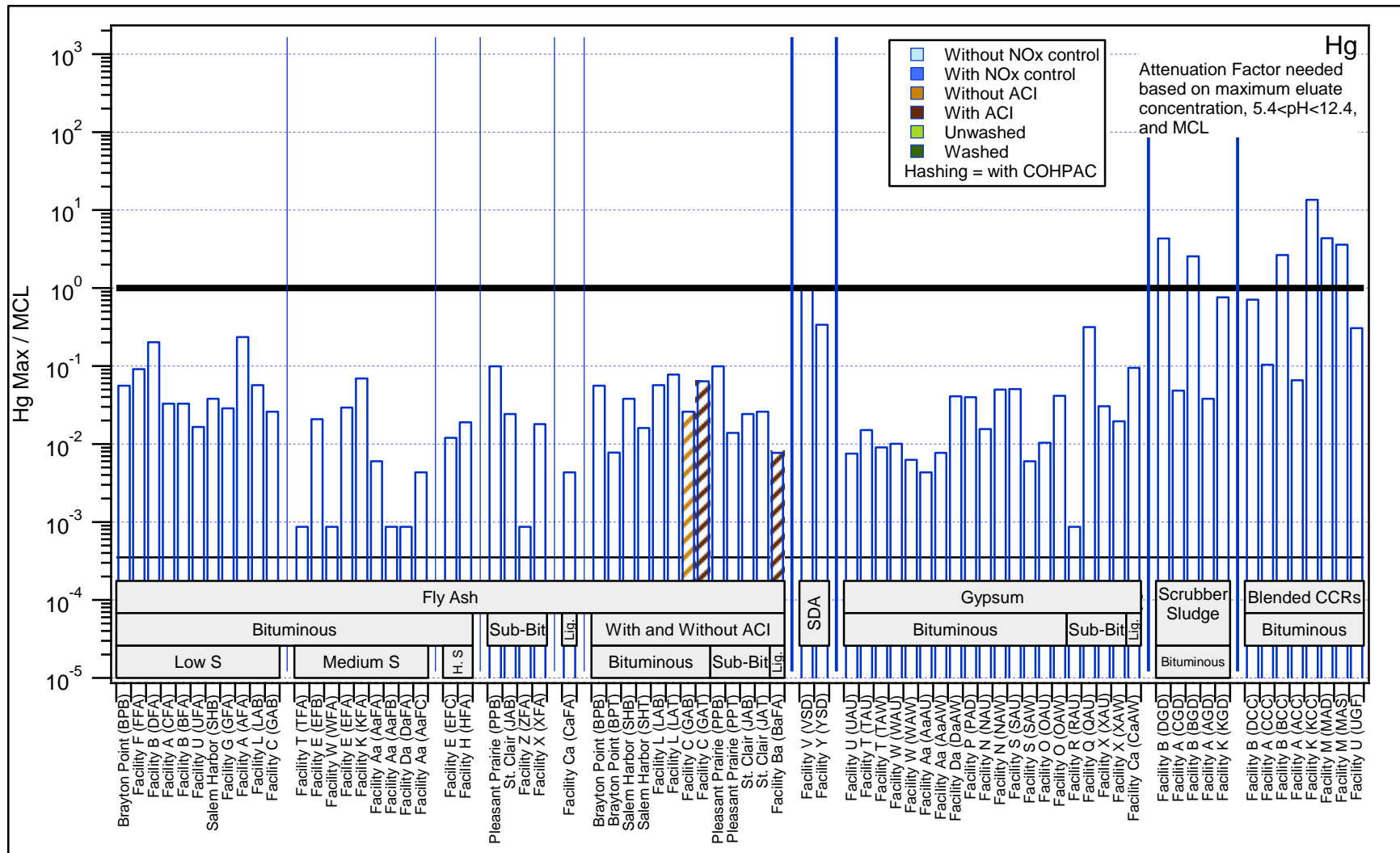


Figure L-6. Mercury - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

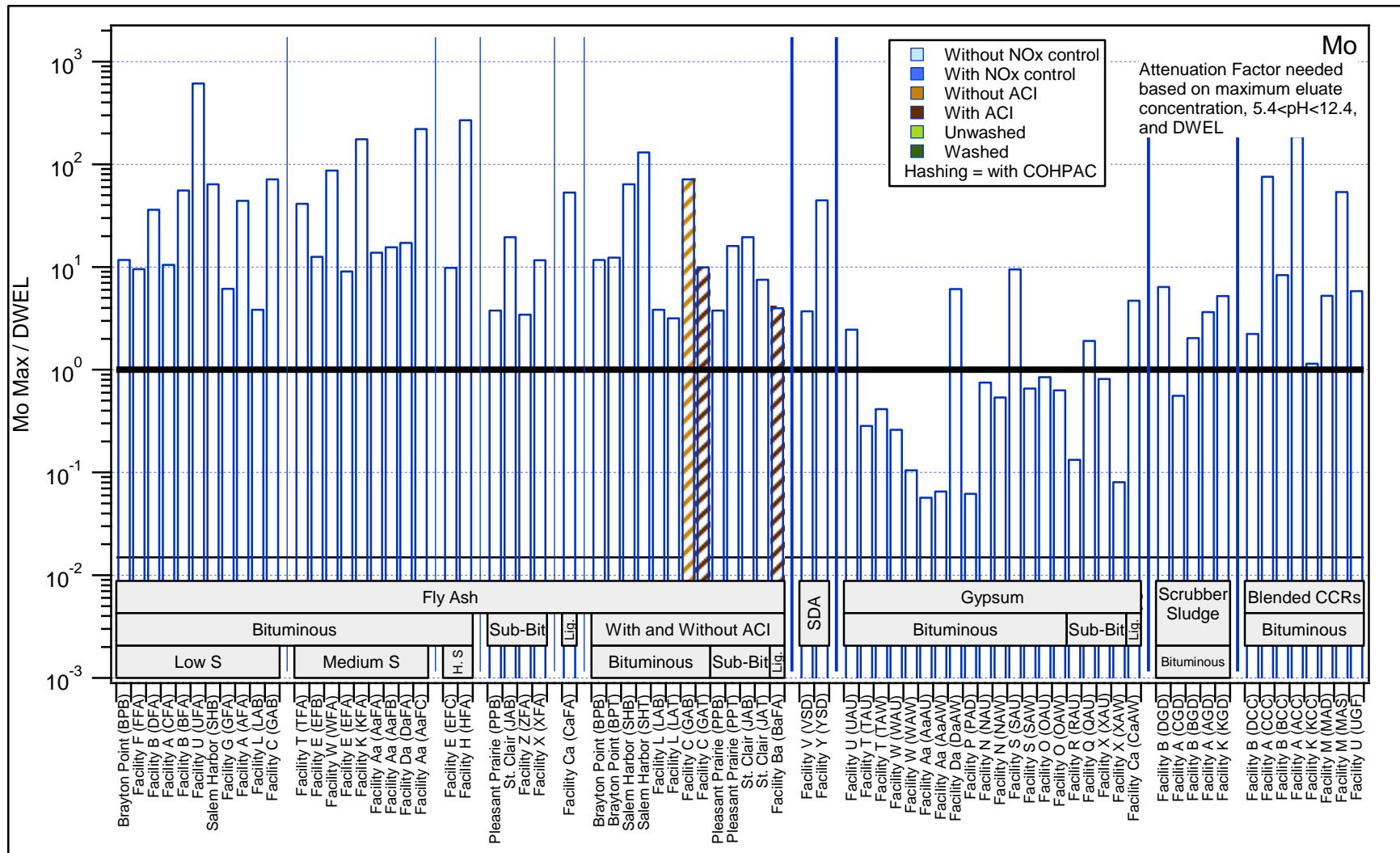


Figure L-7. Molybdenum - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the DWEL for each CCR evaluated in this study.

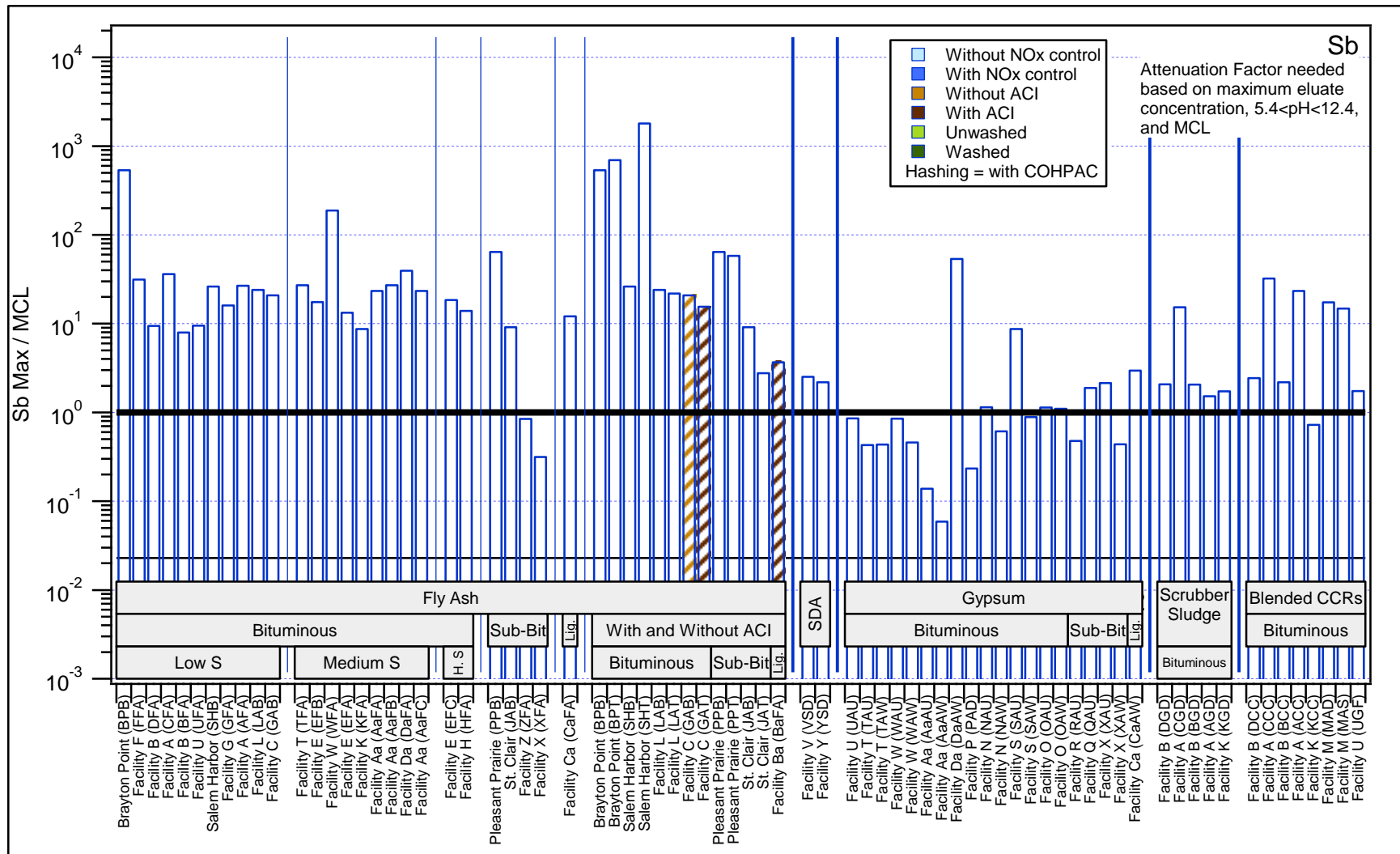


Figure L-8. Antimony - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

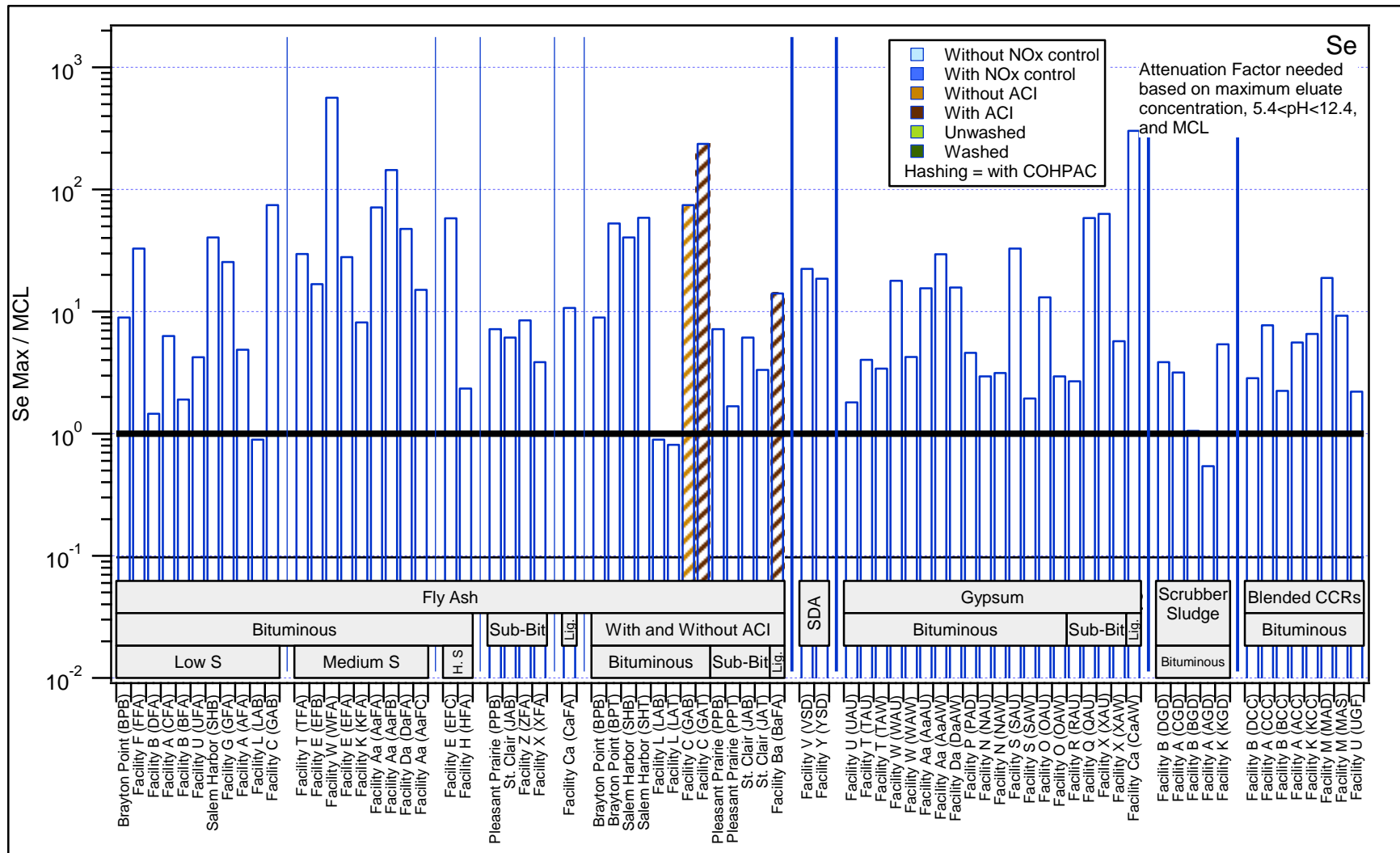


Figure L-9. Selenium - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

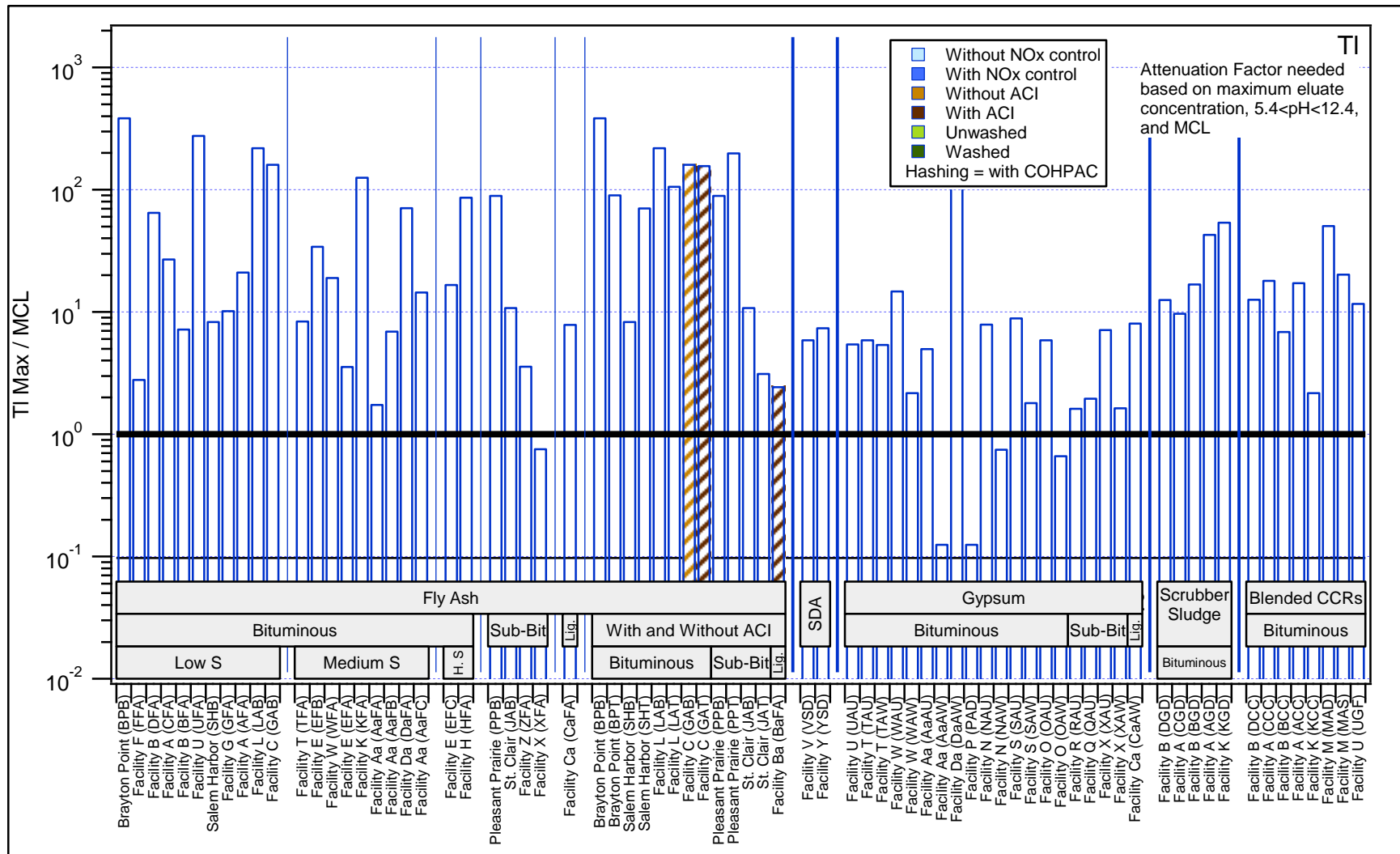


Figure L-10. Thallium - Minimum attenuation factor needed for the maximum eluate concentration ($5.4 \leq \text{pH} \leq 12.4$) to be reduced to less than the MCL for each CCR evaluated in this study.

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.

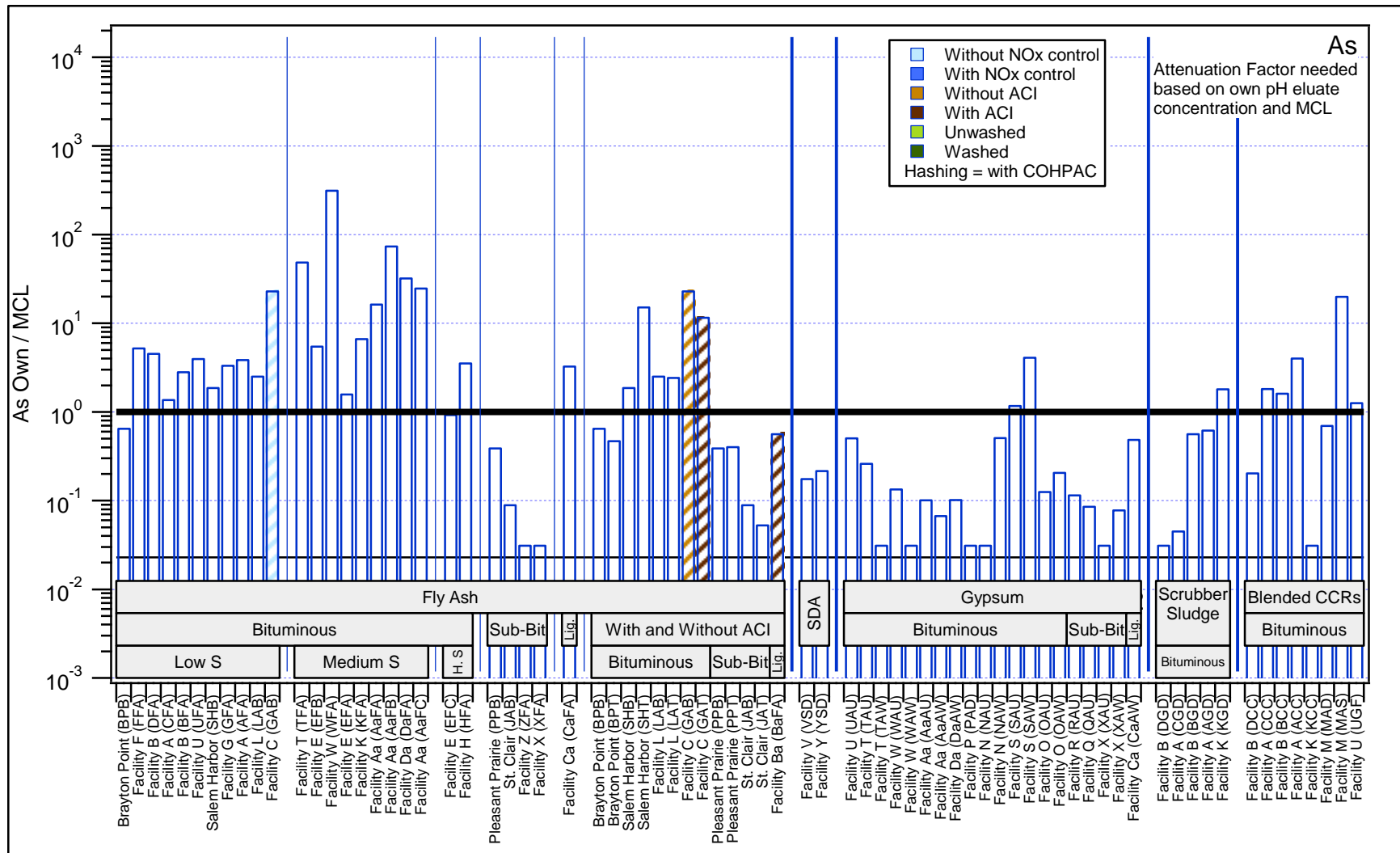


Figure L-11. Arsenic - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

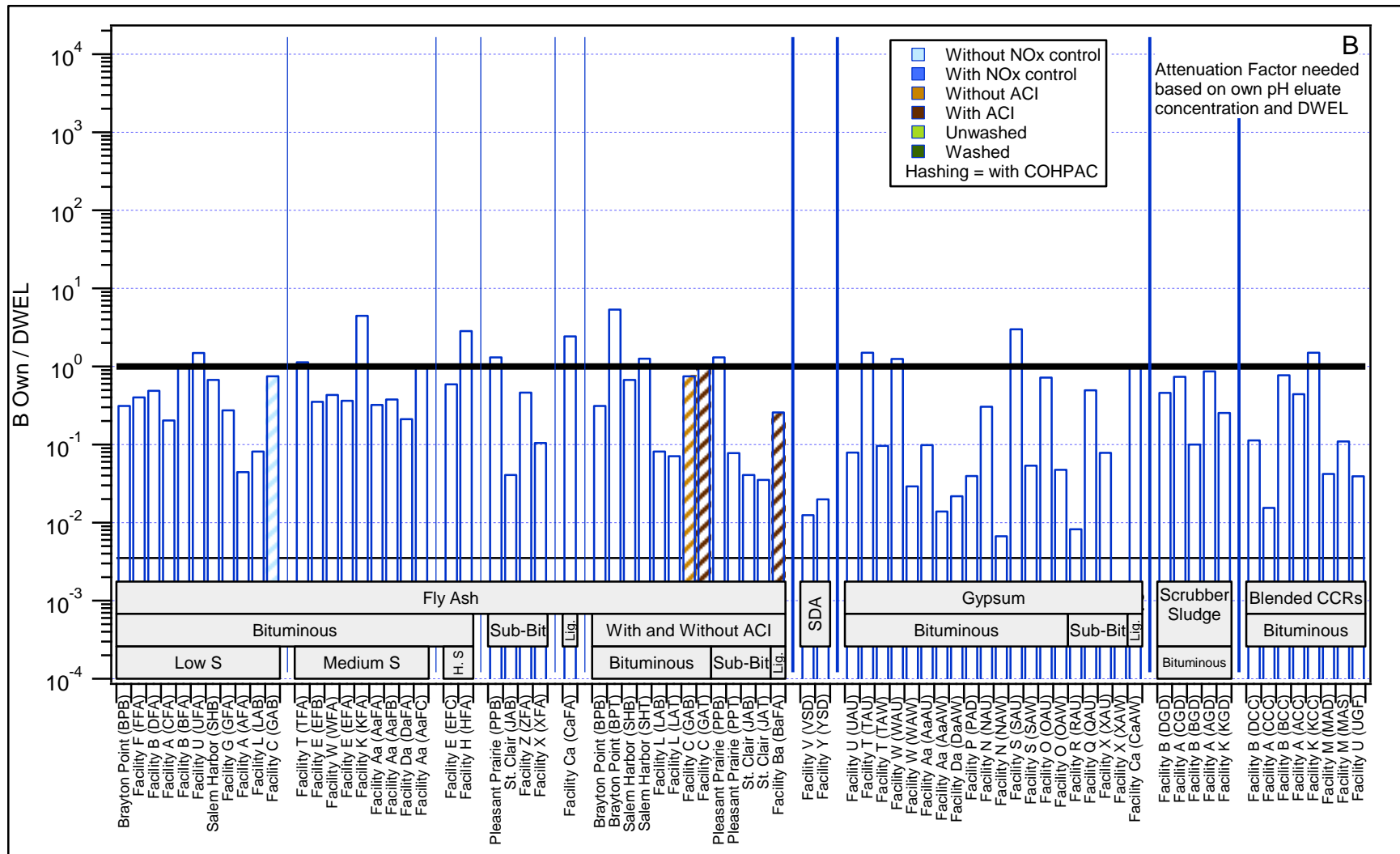


Figure L-12. Boron - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the DWEL for each CCR evaluated in this study.

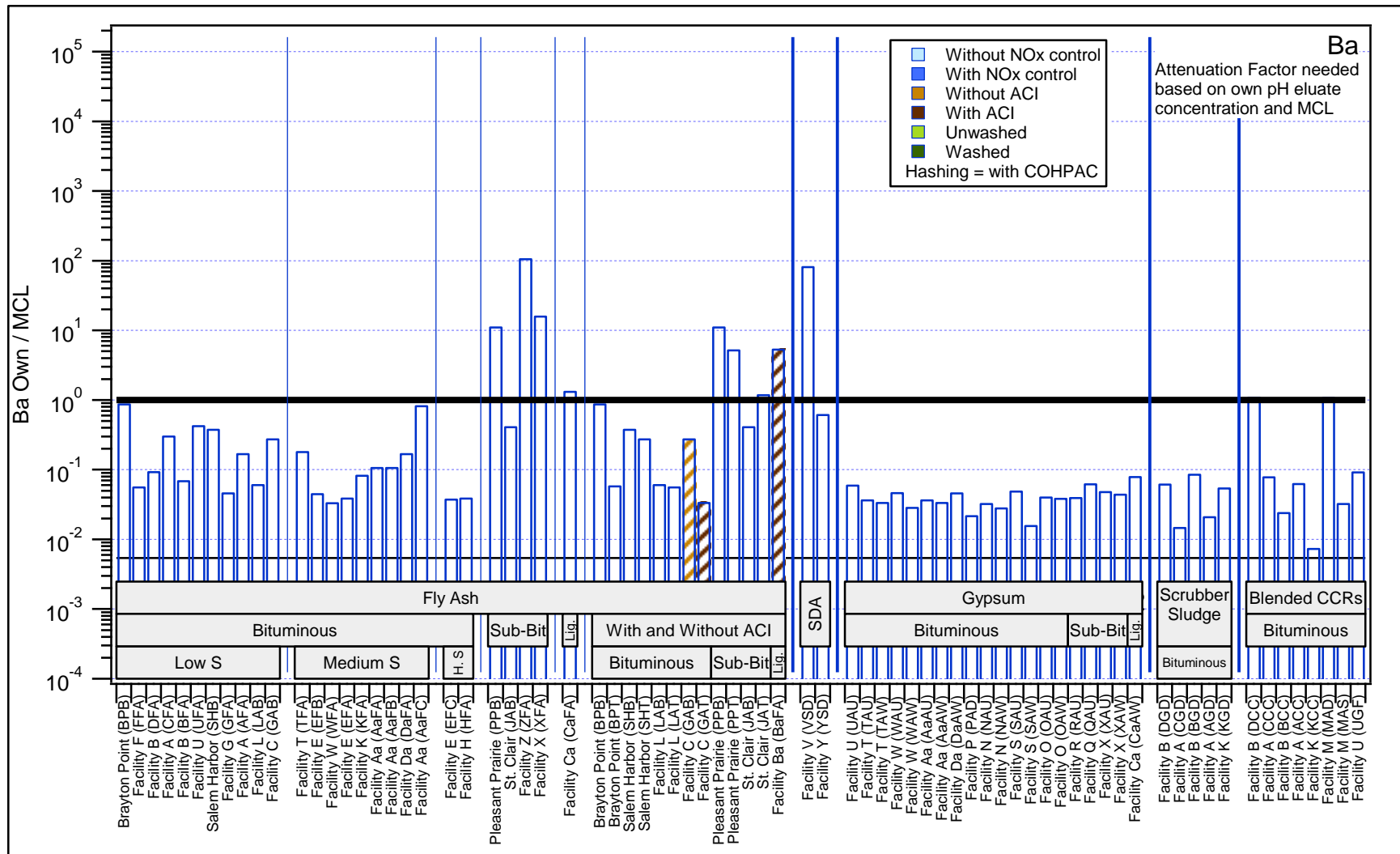


Figure L-13. Barium - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

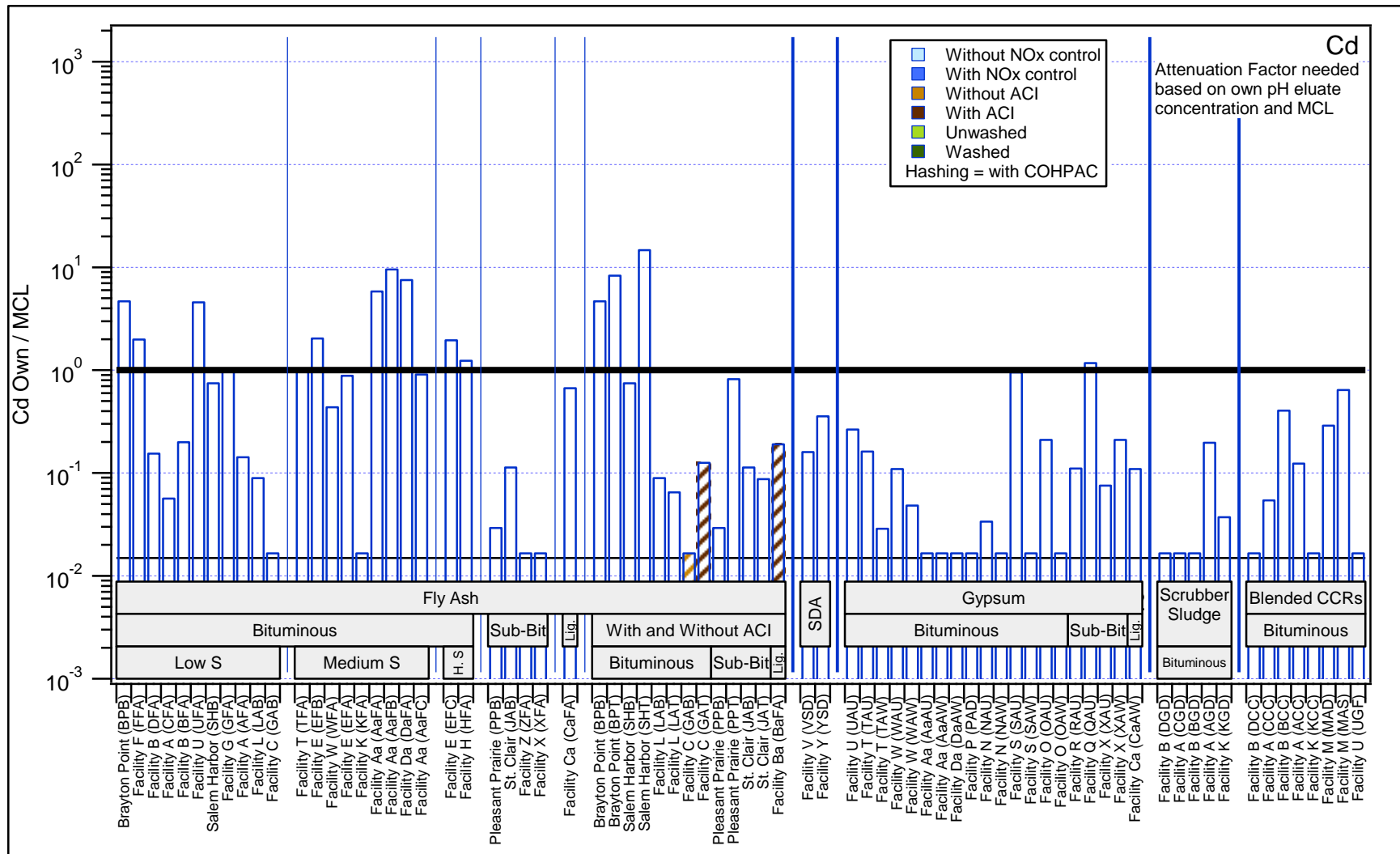


Figure L-14. Cadmium - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

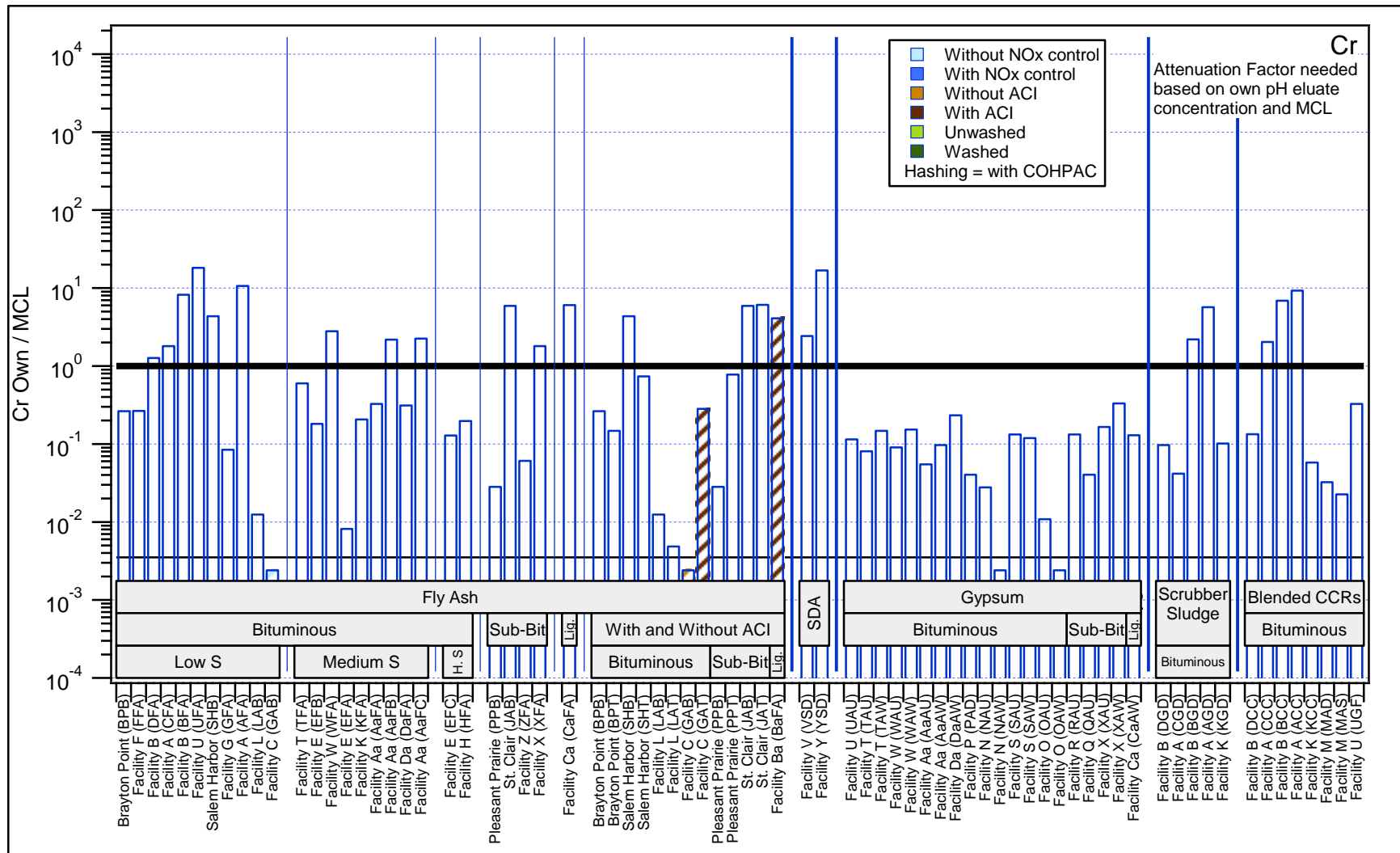


Figure L-15. Chromium - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

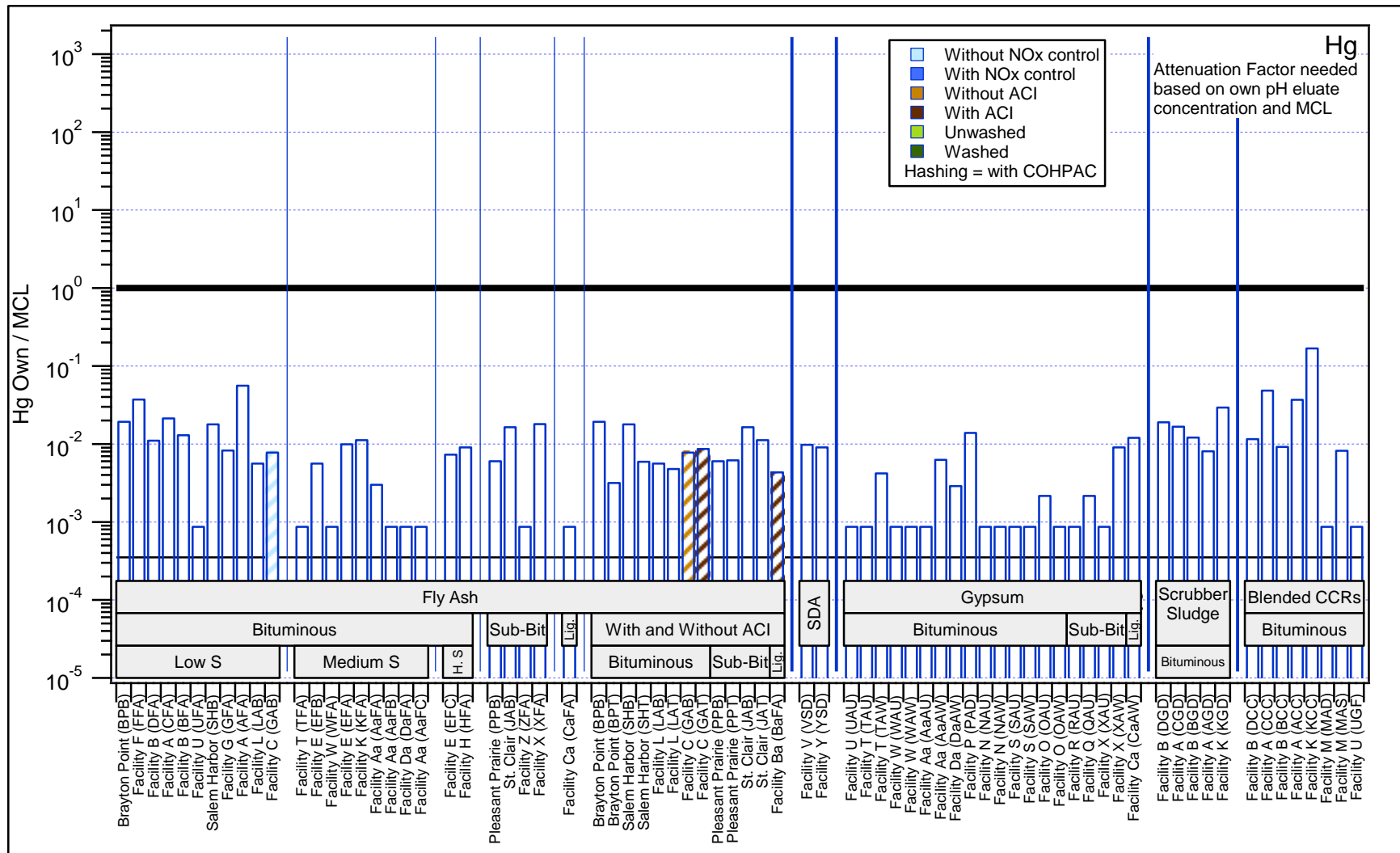


Figure L-16. Mercury - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

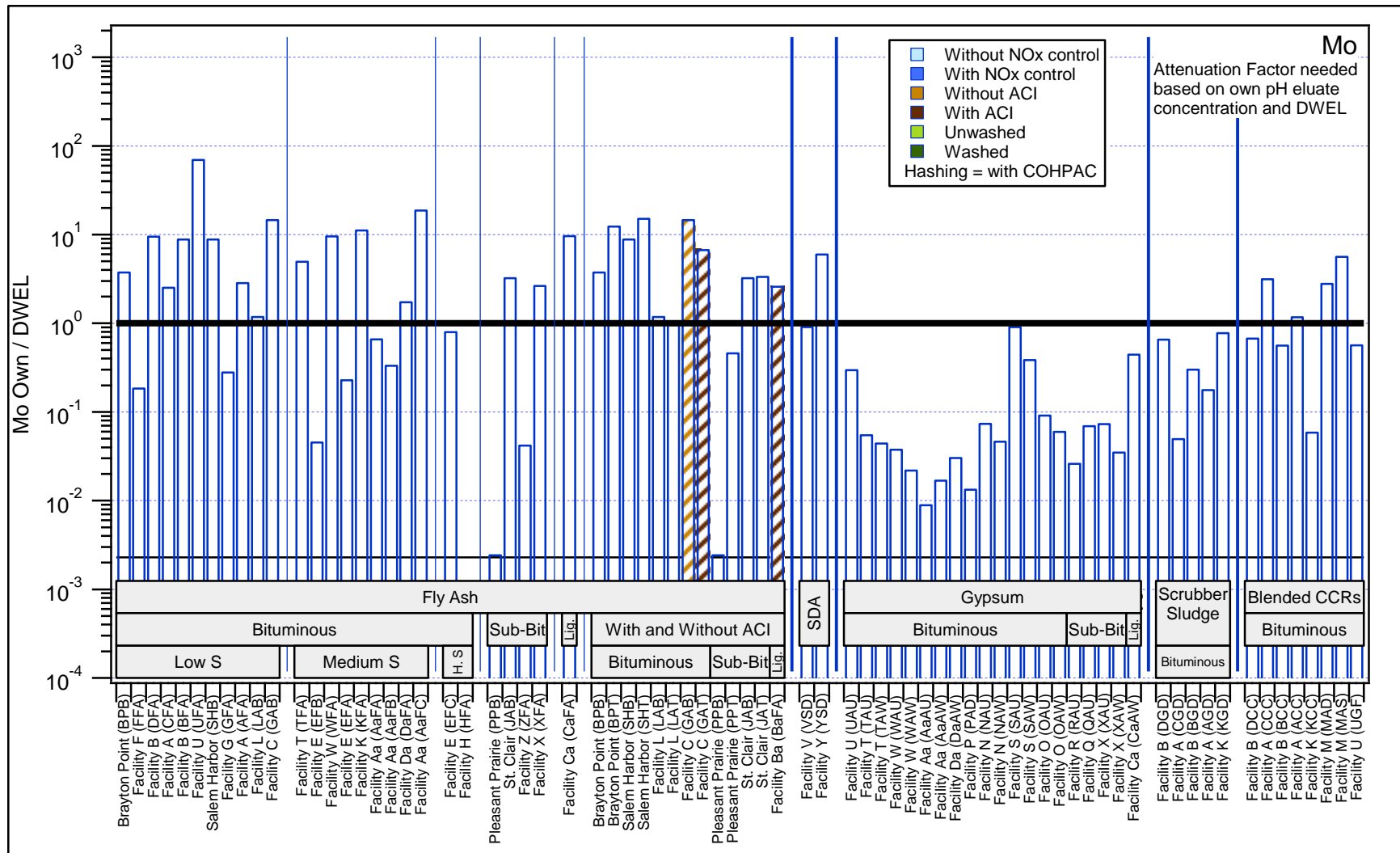


Figure L-17. Molybdenum - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the DWEL for each CCR evaluated in this study.

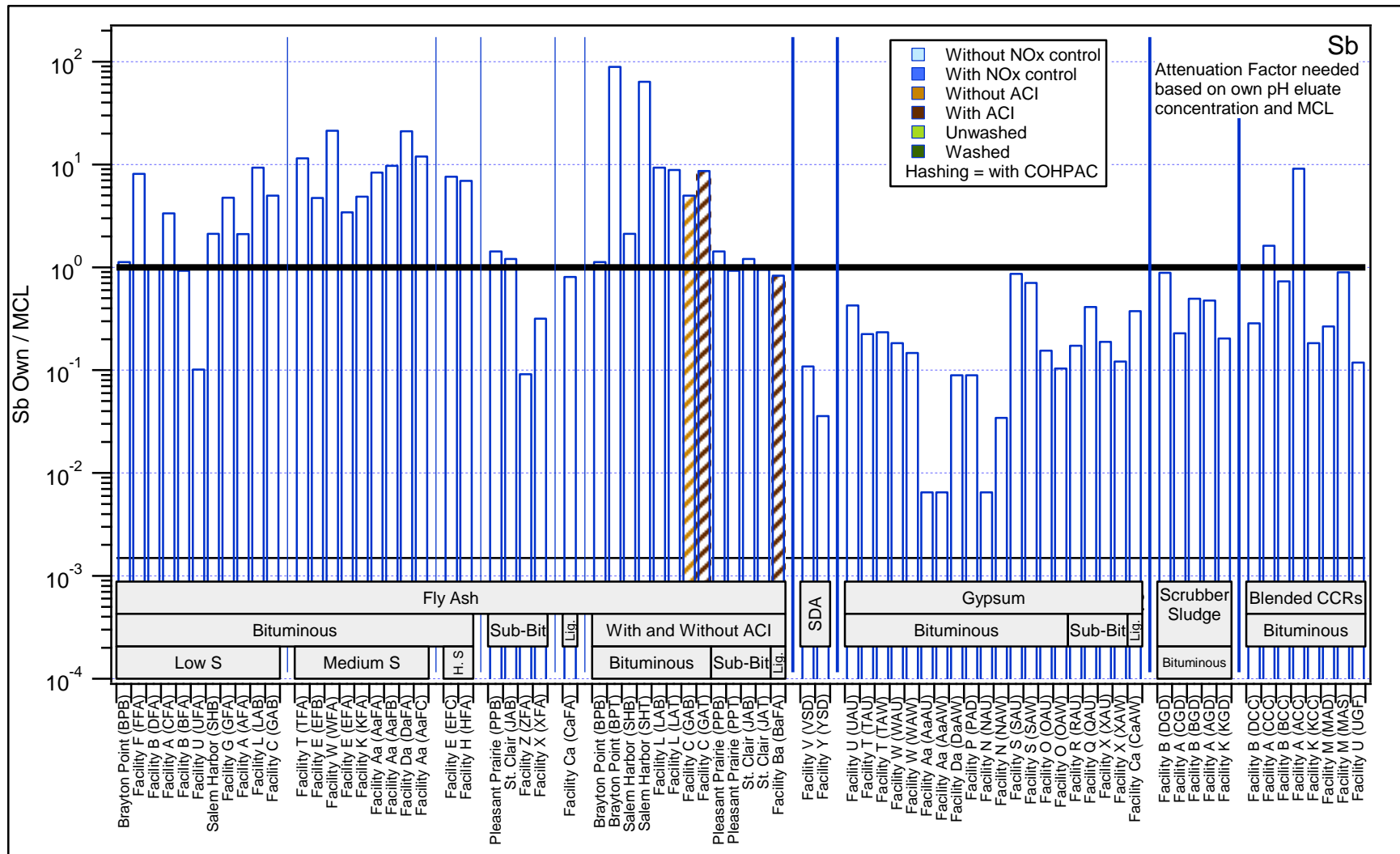


Figure L-18. Antimony - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

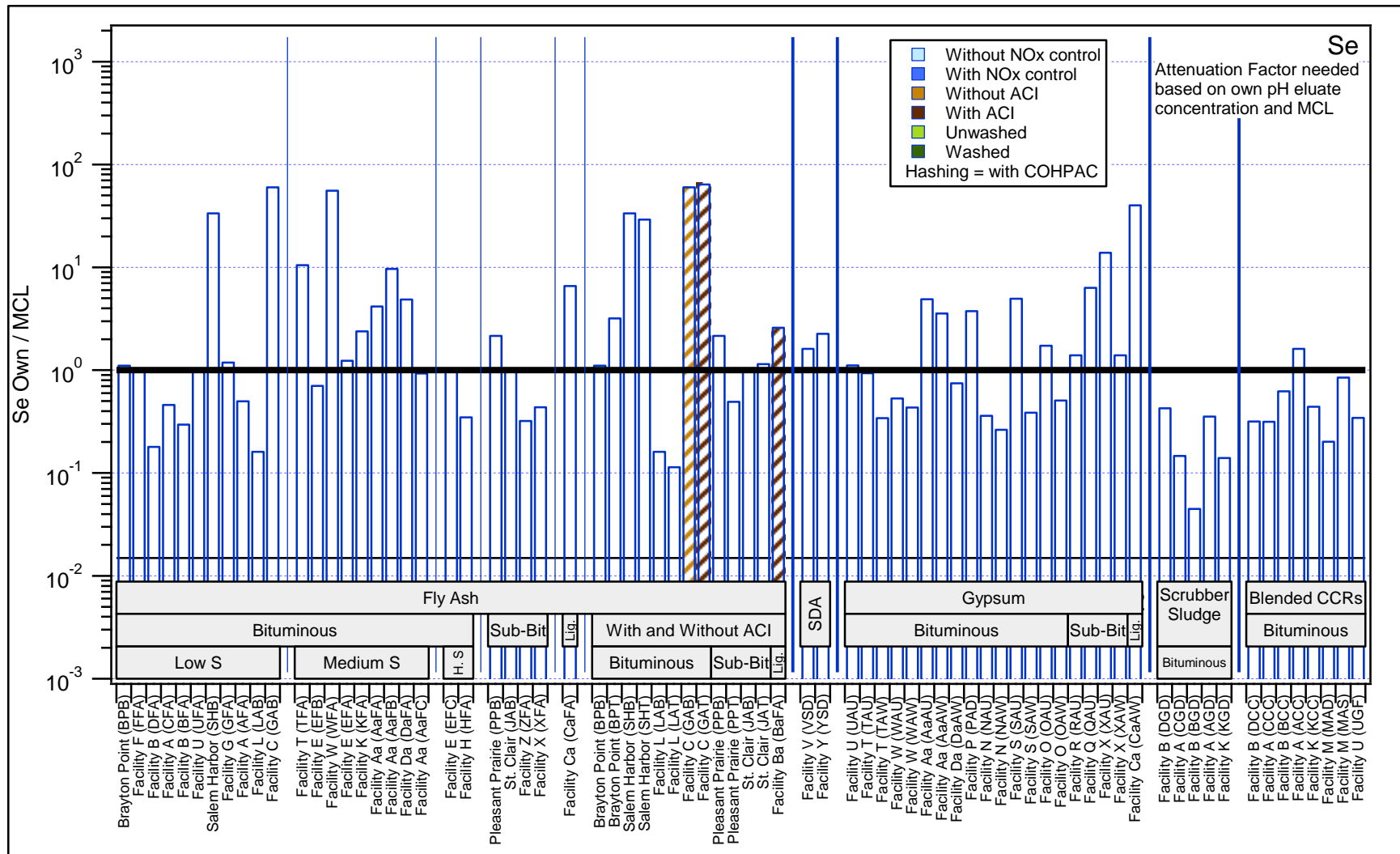


Figure L-19. Selenium - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

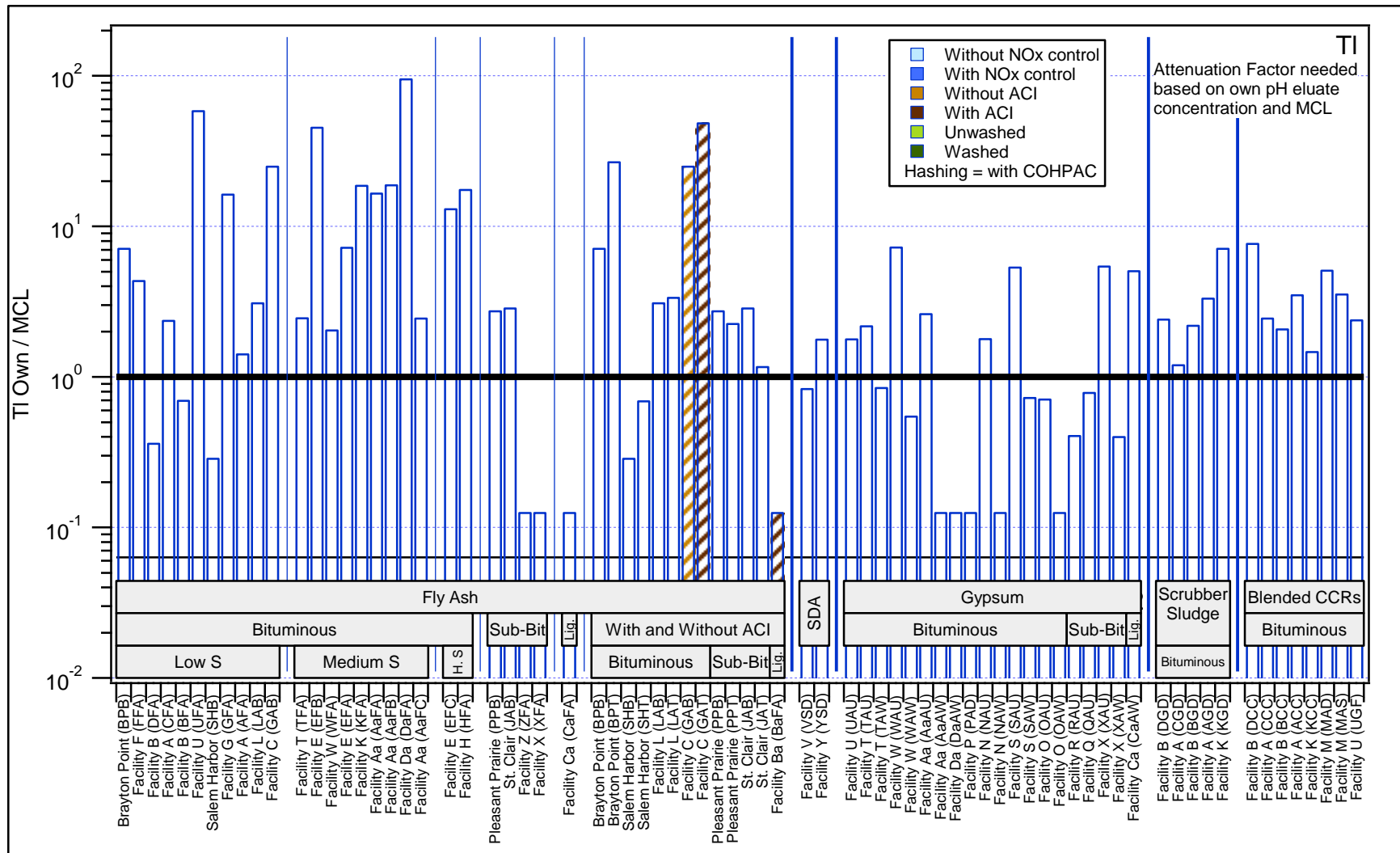


Figure L-20. Thallium - Minimum attenuation factor needed for the own pH eluate concentration to be reduced to less than the MCL for each CCR evaluated in this study.

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	TI	Maximum Attenuation Factor	Controlling COPC
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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	TI
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	TI
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	TI
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	TI

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	TI
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 = Attenuation Factor

AF < 1

1 ≤ AF < 10

10 ≤ AF < 100

100 ≤ AF

Attenuation factor needed based on maximum eluate concentration, $5.4 \leq \text{pH} \leq 12.4$, and MCL or DWEL

Facility	Sample ID	PM Capture	NOx Control	Hg										Maximum Attenuation Factor	Controlling COPC
				Sorbent Injection	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se		

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	TI

Sub-Bituminous & Sub-bit/bituminous mix

Table 1: Examples of the Key Findings																	
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
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	AF < 1	AF = Attenuation Factor
	1 ≤ AF < 10	
	10 ≤ AF < 100	
	100 ≤ AF	

Attenuation factor needed based on maximum eluate concentration, $5.4 \leq \text{pH} \leq 12.4$, 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	TI	Maximum Attenuation Factor	Controlling COPC
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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	TI
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	TI
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	TI
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	TI
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
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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	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

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
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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	AF = Attenuation Factor
	1 ≤ AF < 10	
	10 ≤ AF < 100	
	100 ≤ AF	

Attenuation Factor needed based on maximum eluate concentration, $5.4 \leq \text{pH} \leq 12.4$, and MCL or DWEL

[illegible]

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	TI
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

[illegible]

Attenuation Factor needed based on maximum eluate concentration, $5.4 \leq \text{pH} \leq 12.4$, 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

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
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	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																			
	Sample	Residue	PM	NOx	Wet	FGD												Maximum	
Facility	ID	type	Capture	Control	Scrubber	Scrubber	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Attenuation	Controlling
					type	additive												Factor	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	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 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
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	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

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	TI	Maximum Attenuation Factor	Controlling COPC
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Fly Ash without Hg Sorbent Injection

Bituminous, Low S

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	TI
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	TI
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	TI
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 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	TI
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	TI
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	TI
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	TI
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	TI
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 = Attenuation Factor

AF < 1

1 ≤ AF < 10

10 ≤ AF < 100

100 ≤ AF

Attenuation factor needed based on own pH eluate concentration and MCL or DWEL																	
Facility	Sample ID	PM Capture	NOx Control	Hg	SO ₃	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum	Controlling
				Sorbent Injection	Control											Attenuation Factor	

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	TI
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	TI

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

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
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	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

Facility	Sample ID	PM Capture	NOx Control	Hg Sorbent Injection	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	TI	Maximum Attenuation Factor	Controlling COPC
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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	TI
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
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AF < 1
 1 ≤ AF < 10
 10 ≤ AF < 100
 100 ≤ AF

AF = Attenuation Factor

Attenuation factor needed based on own pH eluate concentration and MCL or DWEL

Facility	Sample ID	PM Capture	NOx Control	Hg		SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum Attenuation Factor	Controlling COPC
				Sorbent Injection														

Mixed Fly Ash and Gypsum (as managed)

Sub-bituminous

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 AF = Attenuation Factor

 $1 \leq AF < 10$ $10 \leq AF < 100$ $100 \leq AF$

Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL																			
Facility	Sample ID	Residue type	PM Capture	NOx Control	Wet	FGD	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Maximum	Controlling
					Scrubber type	Scrubber additive												Factor	COPC

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
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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	WUA	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 = Attenuation Factor

	AF < 1
	1 ≤ AF < 10
	10 ≤ AF < 100
	100 ≤ AF

[illegible]

Bituminous, High S

Sub-bituminous

Lignite

[illegible]

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
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AF = Attenuation Factor

AF < 1

1 ≤ AF < 10

10 ≤ AF < 100

100 ≤ AF

Attenuation Factor needed based on own pH eluate concentration and MCL or DWEL																			
	Sample	Residue	PM	NOx	Wet	FGD												Maximum	
Facility	ID	type	Capture	Control	Scrubber	Scrubber	SO ₃ Control	Hg	As	B	Ba	Cd	Cr	Mo	Se	Sb	Tl	Attenuation	Controlling
					type	additive												Factor	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

AF = Attenuation Factor

	AF < 1
	1 ≤ AF < 10
	10 ≤ AF < 100
	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
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	AF < 1	AF = Attenuation Factor
	1 ≤ AF < 10	
	10 ≤ AF < 100	
	100 ≤ AF	