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Flue Gas Desulfurization (FGD) Wastewater Characterization and Management: 2007 Update

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PRODUCT DESCRIPTION

Tightened air regulations on acid-gas-forming emissions are leading more electric utilities to install flue gas desulfurization (FGD) systems, typically wet scrubbers. However, there are challenges associated with such decisions in terms of utility wastewater management. Volatile metals, such as selenium and mercury, are better captured in wet scrubber systems than in electrostatic precipitators and may be present at higher concentrations in utility wastewater systems. This report is designed to help power plants evaluate how FGD system wastewater will impact the overall wastewater management and compliance at a facility.

Results & Findings

Research has shown that the flow and composition of FGD system wastewater varies significantly between plants. This report identifies causes of the variation to help narrow projections for FGD system wastewater composition for a given set of plant circumstances. The report also summarizes FGD system wastewater management approaches and includes current best practices for system planning, process-specific design, and operation.

Challenges & Objective(s)

The key challenge in this study was comparing FGD wastewater data from approximately 30 sites. Due to the great variability in types of FGD systems, sampling techniques, fuels, and other factors, all conclusions in this report should be considered preliminary. The objectives of this 2007 update are to

- Assist power plants that are acquiring FGD systems in understanding the basic characteristics of the associated wastewater
- Share current best practices for the design and operation of FGD wastewater systems

Applications, Values & Use

This report will help coal-fired power plants understand FGD wastewater and its impact on general plant wastewater management. The report provides guidance to help plants determine if dedicated FGD system wastewater treatment is required, and, offers direction in planning, designing, and operating an FGD wastewater management system.

EPRI Perspective

This report synthesizes the available FGD wastewater data from several studies totaling approximately 30 power plants. It is important to note that the objectives and scope of work for the multiple studies varied and many focused on characterizing flue gas mercury removal, with solids and water samples often taken only for material balance purposes. In addition, the various principal investigators often employed different sampling and analytical protocols, which may lead to potentially significant uncertainties in the associated aqueous and solids data. This uncertainty led to significant challenges in comparing data across the multiple studies. EPRI employed best judgment in interpreting the data. The reader should consider this uncertainly when attempting to extrapolate the results and conclusions of this study to particular power plant applications. EPRI intends to conduct future FGD wastewater characterization studies as well as multimedia assessments in order to further evaluate the findings in this report, better characterize the fate of trace metals in wet FGD systems, and develop appropriate and cost-effective wastewater management strategies. Related EPRI research includes *Flue Gas Desulfurization (FGD) Wastewater Characterization* (report 1010162, March 2006).

Approach

The information contained in this report is based on previous studies, ongoing studies at coal-fired power plants, and the personal experience of the investigators.

Keywords

Ash ponds
FGD
Flue Gas Desulfurization
FGD Wastewater
Ash Pond Management
Wastewater Treatment

ABSTRACT

This report synthesizes flue gas desulfurization (FGD) wastewater data from several studies, involving, in total, 30 power plants. At some plants, multi-media sampling around the FGDs was performed, while other studies focused solely on wastewater. Untreated FGD wastewater varies significantly between power plants. The wastewater is typically high in suspended solids, salts, and trace metals. The solids include fines that are more difficult to settle than other solids in power plant wastewater, such as ash. Therefore, the suspended solids must be removed. Management of untreated FGD wastewater often requires removal of the more volatile metals such as mercury, selenium, and boron.

The report characterizes factors influencing untreated FGD wastewater to the extent possible. The FGD system's liquid/solid separation method, such as hydroclones, made the largest difference in suspended solids and particulate metals. Other variables such as metals content in coal, FGD system oxidation type, and selective catalytic reduction operation, influenced the concentration and mass loading of soluble metals. The soluble or very fine metal fraction is more likely to pass through settling systems and therefore impact the overall wastewater discharged from a plant.

To the extent possible, at this early stage of FGD system development, the report attempts to identify best practices for FGD wastewater management systems. Constructed treatment systems were the main focus, with additional discussion of pond-based systems. Practices for planning, overall and unit process-specific design, and operation of FGD wastewater systems are included. Technologies in the early stages of implementation for FGD wastewater treatment, such as biological treatment of selenium and newer organo-sulfides for mercury treatment, are described.

EXECUTIVE SUMMARY

Flue gas desulfurization (FGD) systems are being installed throughout the power industry in response the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule (CAVR), and the proposed Clean Air Mercury Rule (CAMR). FGD systems periodically blow down or purge a portion of the system slurry to limit buildup of chlorides and suspended solids. The purge stream is a slurry of water, dissolved solids, and suspended solids (principally calcium sulfate or gypsum solids, flyash and inerts from limestone). The purge is separated into coarse and fine solid fractions, usually using hydrocyclones, and the coarse fraction is dewatered by vacuum belt filters. The hydrocyclone overflow (fines) and the vacuum filter filtrate are returned to the FGD. However, to control buildup of chlorides and fines in the FGD system, a portion of the hydrocyclone overflow and/or vacuum filter filtrate is pumped to disposal. This wastewater stream is sometimes referred to as chloride purge stream or FGD purge water or FGD wastewater. We will use the term untreated FGD wastewater to refer to this new wastewater stream.

Concurrently with the introduction of this new wastewater stream, wastewater discharge limits on trace metals and salts are being tightened. This combination of factors has led utilities to assess the impact of this new untreated FGD wastewater stream on their overall water management systems.

Dozens of new FGD wastewater treatment systems are in the planning, design, or construction phase. Although there were close to a hundred power plants with existing FGD systems prior to 2000 [13], few had constructed treatment plants and most had fundamental differences in wastewater characteristics. Therefore, there is not a clear understanding of basic untreated FGD wastewater composition, what causes untreated FGD wastewater composition to vary, and how to manage this FGD wastewater. This report summarizes some initial efforts to better understand the characteristics and treatment processes being applied to FGD wastewater. Key findings are summarized in this executive summary and are discussed in greater detail in the report.

FGD Wastewater Characterization

Untreated FGD wastewater can significantly increase a site's overall wastewater loading of solids, metals, and other parameters of concern.

The first objective of typical FGD system treatment is the removal of total suspended solids (TSS), either in a pond or in a constructed system. Wastewater treatment plants and ponds remove TSS to below the typical 30 milligrams per liter limit. This solids removal also removes most associated particulate metals. However, based on limited ash pond data, ash ponds (and potentially treatment plants) designed for solids removal appeared to inefficiently remove soluble metals e.g. arsenic, selenium [12]. However, there may be the potential for mercury to

be removed as there are limited data that suggest mercury may precipitate or grow into larger particles with sufficient time.

Therefore, metals that will not be removed in TSS treatment (i.e., by settling) will be of more interest when assessing the impact of untreated FGD wastewater on a plant's final effluent. Therefore, it is important to differentiate liquid-phase metals and metals that partition into solids that will be removed as gypsum or in settling from the wastewater stream. Selenium was primarily soluble at most sites. Mercury was primarily particulate at most sites; mercury that passes through a filter may not always be dissolved. Although it is common practice to define the mercury passing through the 0.45-micron filter as "dissolved," often the mercury is in the form of fine particulates. It appears that a significant portion of the mercury that passes a filter may in fact be small particulate matter. If this proves to be the case, it may be possible to remove a portion of the mercury that passes through current systems by improving flocculation or by using microfiltration to improve fine particle capture.

FGD systems vary greatly. The water streams differ between sites making it challenging to compare samples across sites. For purposes of clarity, in this report the following terms are used:

- FGD Absorber Liquid: Samples collected from the FGD absorber, or other point upstream of liquid / solid separation in the FGD.
- Untreated FGD Wastewater: Samples collected from the liquid fraction after liquid / solid separation in the FGD. If multiple liquid / solid separation systems are used (i.e., Primary then Secondary Hydroclone), sample is taken after last system. Examples would include: hydroclone overflow, thickener overflow, stacking pond effluent, or FGD wastewater treatment system influent.
- Treated FGD Wastewater: Samples collected after treatment of FGD wastewater in a treatment plant or pond. Treatment of FGD wastewater differs between plants, which complicates comparisons.

Untreated FGD wastewater composition (TSS, total dissolved solids, and chlorides) varies widely. Data from several EPRI studies were used to identify causes of the variation to help narrow projections for untreated FGD wastewater composition for a given situation. Some definitive relationships were established, while other theories were developed based on limited data; therefore, additional research is needed to evaluate the causes of these variations.

- The oxidation design of the FGD appears to affect the untreated FGD wastewater. Limestone-forced oxidation (LSFO) FGDs showed different relationships in many of the variables evaluated. For example, LSFO FGDs appear to convert selenium to selenate, which is more difficult to treat than the more reduced selenite form of selenium.
- Coal is the largest source of metals to the metals load in FGD system liquid. For those metals that partition into untreated FGD wastewater, the more metals load in coal, the more there will be to capture in the FGD. Coal chloride and sulfur content at a plant, as well as equipment metallurgy, typically drive the number of times that water can be cycled through the FGD absorber. The more cycles the absorber water passes through in the FGD, the more the water picks up trace metals. The mass loading rate of trace metals in the blowdown stream will not be affected by the amount of cycling; only the concentration will be affected.

- FGD system purging is discontinuous. Typically, gypsum dewatering is cycled on and off to match purging. Hydroclone overflow can be equalized so that the untreated FGD wastewater is delivered continuously to treatment or may be sent at higher flow rates during gypsum dewatering.
- Iron from fly ash, limestone, and ball-mill grinding of limestone appear to have a significant effect on trace metals in untreated FGD wastewater. There appears to be a relationship between the concentration of particulate iron and concentrations of particulate mercury, selenium, arsenic, copper, chromium, and nickel at LSFO sites.
- Dibasic acid is an organic acid; it appears that its use yields a number of unknown forms of selenium (other than selenite and selenate), which have yet to be identified. EPRI research is ongoing to attempt to identify these unknown selenium peaks on the chromatograph.

Survey of Current Practices—FGD Wastewater Treatment

Wastewater from a wet FGD system can be recirculated for reuse in the FGD system or elsewhere in the power plant, discharged to a receiving water body or deep well, or reduced in a zero-liquid discharge system such as ponds from which the effluent is reused in the power plant. All of these discharge alternatives will require some treatment. Treatment options include co-management in an ash pond, treatment in a dedicated pond, or treatment in a constructed treatment system. Constructed systems can be designed to remove TSS only or can include additional treatment processes to further remove trace metals.

Under some circumstances, untreated FGD wastewater can be managed in ponds. In bench-scale testing, the settling time for TSS was found to increase when untreated FGD wastewater is diluted with other unsaturated water, such as when untreated FGD wastewater is co-managed in ash ponds. This may increase the pond size that is required for solids removal beyond that which is needed if untreated FGD wastewater is managed separately.

The FGD system and FGD wastewater systems should be coordinated closely to capitalize on the combined capacity of the overall system. Wastewater treatment requirements should be coordinated throughout FGD system planning, design, and construction. Additionally, the time period required for startup of the FGD wastewater system should be considered during planning stages to account for up to several months of startup prior to normal operations.

Constructed FGD wastewater treatment plants are predominately designed around solids removal and dewatering. As such, the choice and sizing of treatment processes depend on the peak flow and suspended solids concentration of the wastewater. Untreated FGD wastewater is most affected by the gypsum dewatering system selected for the FGD system. Depending on whether untreated wastewater comes from primary or secondary hydroclones or from thickener overflows or a stacking pond, the concentration of TSS in the untreated wastewater can range from hundreds of parts per million to over 7 percent. When TSS in the untreated wastewater is in the percent range, there is a tendency to remove solids in two stages, using primary and secondary clarifiers. Where TSS is less than 1 or 2 percent, a single-stage clarification process is employed.

Equalization is employed to even out flows from the FGD system as well as internal flows from the treatment process, such as sludge dewatering filtrate, effluent filter backwash water, and other process maintenance flows. Equalization is best designed in conjunction with the gypsum

dewatering system, rather than treating it as an independent process within wastewater treatment. There are advantages of adding equalization at the beginning of treatment as well as between primary and secondary treatment. Filtrate from sludge dewatering and final filter backwash water is generally low in TSS (less than 1,000 milligrams per liter) and therefore does not need primary treatment. The filtrate can best be placed in an equalization tank between primary and secondary treatment. If equalization is provided only before primary treatment, then these streams are returned to the primary treatment influent stream. These flows must then be accounted for in sizing of the primary treatment systems since recycle and internal streams can approach the flow rate of the influent wastewater.

Primary treatment usually consists of lime addition to reduce the concentration of calcium sulfate (desaturation) and to coagulate (grow) solids. Polymer is also added to assist the lime in flocculating solids, and the bulk of the suspended solids are removed in one or more primary clarifiers. Where solids are low in the wastewater, primary clarification can be skipped, and the waste flows directly from the lime addition tank to secondary treatment.

Secondary treatment consists of a series of mixed tanks where chemicals (organosulfides and iron) are added to precipitate metals, acid is added to lower pH, and coagulants (iron and polymers) are added to coagulate particles to improve their removal efficiency in one or more secondary clarifiers (in parallel). Effluent from the clarifier passes to a media filter (if metals removal is required or if more reliable TSS removal is required) or is discharged.

Primary and secondary clarifier sludges typically are combined to a sludge tank for feed to either belt presses or plate-and-frame filter presses for dewatering.

Wastewater and sludge piping are prone to plugging. Prudent design of piping for easy replacement and automated flushing whenever flows are shut down along with gravity flow wherever possible so that pipes drain upon shutdown is recommended. Pumping after solids formation should be low-shear-type to reduce the tendency for breaking up sludge solids.

Mixing is critical within all mixing tanks in the process. If mixing is insufficient, larger particles settle out, resulting in adverse chemical mixing and pH control. If there is too much particle mixing, shear will result, thereby reducing the effectiveness of downstream removal. Two impellers with the largest diameter possible and with minimum tip speed is an optimal condition for mixing.

Where there are sufficient provisions for maintenance shutdowns, treatment systems can be designed with a single train for tanks, with pumps and other smaller mechanical systems provided with online spares. Dual trains are employed where shutdown for maintenance is not feasible. With single-train design, each unit is sized for maximum flow or loading. With dual trains, individual units can be sized smaller than those in a single train, assuming a single unit is out of service and upstream or downstream treatment is compensating for reduced efficiency in the remaining unit. Having dual trains increases reliability of the treatment system but also increases the complexity and cost of piping because of the numerous crossovers required to remove a single unit from operation.

Most metals can be removed to meet regulatory requirements using organosulfide and iron addition combined with efficient solids removal; the exceptions are mercury and selenium. For some power plants, mercury regulatory limits are in the parts per trillion levels, and forced oxidation scrubbers may produce more selenium in the oxidized selenate form, which is not appreciably removed by organosulfide and iron precipitation processes. Improving mercury and selenium removal are priorities for EPRI research. The most promising mercury removal processes involve improving mercury precipitation/adsorption, biological reduction processes, and solids-removal processes. Selenium removal is dependent on improved chemical reduction or biological reduction processes, both of which are in development. Boron and chloride are potentially constituents of regulatory concern, as could be other constituents in the future. Boron and chloride are both difficult to remove in conventional treatment technologies.

ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
$Ca(OH)_2$	lime
DBA	dibasic acid
DO	dissolved oxygen
DRC	dynamic reaction cell
DTC	dithiocarbanate
EPRI	Electric Power Research Institute
FGD	flue gas desulfurization
gpm	gallons per minute
LSFO	Limestone, forced oxidation
MeSe(IV)	methylselininic acid
mg/L	milligrams per liter
mgd	million gallons per day
O	oxygen
O_2	oxygen gas
OH^-	hydroxide
P	phosphorus
pK_A	acidity constant
ppt	parts per trillion
RPD	Relative Percent Difference
S	sulfur
SCR	selective catalytic reduction
Si	silicon
SO_2	sulfur dioxide
SO_3	sulfur trioxide

Ti	titanium
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
USEPA	United States Environmental Protection Agency

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1
INTRODUCTION

This document has been developed as an update to two Electric Power Research Institute (EPRI) reports on flue gas desulfurization (FGD) wastewater. *Flue Gas Desulfurization (FGD) Wastewater Characterization: Screening Study (TR-1010162)* [1] summarized EPRI's work on characterization of untreated FGD wastewater through 2006. The *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers* (TR-1013313) [2] included an overall look at untreated FGD wastewater, including its composition; variables affecting composition; how to evaluate potential regulatory limits; untreated FGD wastewater management options, including how untreated FGD wastewater will impact ash ponds; and other FGD system operational issues. This document updates the characterization data with new information. This document also presents information assembled on current practices for untreated FGD wastewater management, treatment design, and treatment system operation.

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APPROACH

The purpose of this chapter is to summarize the approach used in developing this report.

Approach to FGD Wastewater Characterization

The data and findings of this report are based on several studies of FGD wastewater with which EPRI has been involved. Some of the studies served differing objectives and had some variation in the sampling locations and methods, as summarized in Table 2-1.

Studies Used in this Report

EPRI partnered with various host utilities that voluntarily participated. Because of this, the sites sampled were based in large part on willingness to participate. Few of the newest round of FGDs were yet installed and operational during these studies, so the FGDs tested were mostly older designs. To help encourage participation in these wastewater characterization studies, EPRI agreed to not identify the name of the utility and the power plant.

FGD Screening Study [1]

Study Overview

As power plants began to install FGDs in response to the CAIR (Clean Air Interstate Rule), CAVR (Clean Air Visibility Rule), and CAMR (Clean Air Mercury Rule), EPRI initiated a "screening" study to evaluate the potential issues associated with untreated FGD wastewater. The results were summarized in the EPRI Report 1010162 - Flue Gas Desulfurization (FGD) Wastewater Characterization: Screening Study ("Screening Study").

Grab samples of untreated FGD wastewater from seven facilities were collected in January to December 2005, and one earlier sample. Samples were collected of the untreated FGD wastewater at a point that the facility felt was representative of its final FGD wastewater entering the site's overall wastewater management (such as an ash pond). At sites that had no discharge of untreated FGD wastewater (Sites P, R and Y), they were asked to collect water from a location similar to where untreated FGD wastewater would be discharged at other facilities. Sampling locations included:

- L2: Thickener overflow
- P: Downstream of FGD blowdown holding tank, upstream of thickener

- R: Upstream of thickener
- S: From hydroclone overflow, before sent to ash pond
- T: Collected from a tank which contains a mixture of ~60% primary hydroclone overflow, belt rinse water, and hydroclone underflow water.
- U: At reclaim tank (after the thickener)
- Y: Downstream end of the gypsum ponds
- Z: From tank upstream of wastewater treatment plant

In order to minimize costs for this study, EPRI requested power plant personnel or other EPRI contractors on-site (primarily conducting flue gas measurements) to submit wastewater samples to a common laboratory for trace metals analyses. Mercury was analyzed by method SW7470A (cold vapor), other metals by EPA Method 200.7 (Inductively Coupled Plasma /Atomic Emission Spectrometry [ICP/AES]). Samples were collected and sent unfiltered, unpreserved and on ice to the laboratory. Three samples were generated for each site: a "total" sample generated by shaking the liquid, a settled sample generated by decanting water one hour after the shaking, and a filtered sample of decanted water passed through a 0.45-micron filter. No data outliers were noted. No matrix interference was documented, as the laboratory addressed interference issues by diluting samples, up to 100 times, to keep the major chemical interferants (such as Ca, Mg, Al, Fe) in the range in which they could be quantified. This was defined by quarterly Linear Dynamic Range studies on the analytical instrument. If an element such as calcium was above this range, the sample was diluted until the element was within the range. Getting a result within this range was necessary so that the result could be used in inner-element correction factors for the trace metals. However, no matrix spikes were done for these samples to quantify accuracy or qualify the results.

Study Limitations

In the Screening Study, the objective was to determine potential wastewater issues, and this work was conducted under a limited budget. The limitations in this Study include:

- Available personnel (either site personnel or EPRI contractors conducting air studies) were used to collect untreated FGD wastewater samples at the seven facilities; the water discharged to their larger wastewater management systems was targeted.
- Because samples were collected by plant personnel, the quality of sampling is not known, and consistency of approach is not certain. Sample collectors were instructed to collect at least 2 gallons in a 5-gallon cubitainer and ship the sample to the laboratory. Samples were collected and shipped on ice to an off-site laboratory, where they were filtered several days after being collected which could have affected the partitioning between the solids and aqueous phases for various metals.
- There were large variations between facilities' FGD systems, especially the solids separation and wastewater treatment. These variations in system configuration and sampling points led to widely varied samples. The 8 data sets represented vastly different levels of solids removal, ranging from ~35 to 170,000 mg/L total suspended solids (TSS).

- The focus was on limestone-based FGDs to the exclusion of other types of FGD. However, there was no "big picture" design in determining the sites so that the set represented a range of coal types and power plant and FGD designs. Few new FGDs were yet installed and operational during the time of these studies, so all the FGDs tested were older designs, i.e. began operation before 1996.
- No FGDs were tested with a wastewater treatment system specifically designed for trace metals.

Due to these limitations, EPRI believes that these data should not be used for regulatory interpretations, and should be limited to providing a first order estimate of potential trace metal levels in untreated FGD wastewater streams. The mercury partitioning data are the most uncertain, primarily because data exist that suggest different levels of mercury partitioning to the dissolved and particulate fractions. This is discussed in more details on the Sampling and Analytical Methods Section.

Fate of Mercury [3] and Update on Enhanced Mercury Capture by Wet FGD [4]

Study Overview

To address issues with mercury flue gas "re-emissions" as well as potential issues with the management of mercury in the FGD solids and gypsum, EPRI conducted a series of investigations to characterize the fate of mercury in wet FGDs. This work is summarized in two EPRI reports: The Fate of Mercury Absorbed in Flue Gas Desulfurization (FGD) Systems and its update in Section 3 of Update on Enhanced Mercury Capture by Wet FGD: Technical Update. These reports summarized the status of a multi-plant assessment of mercury partitioning in FGD systems. Only mercury and cations and anions were reported in these reports, but analyses on the sample results were provided for use in this report. Additional information from this evaluation will be presented in later reports. Results are presented for water at various points in the FGD system, though not specifically for the final wastewater produced.

In the Fate of Mercury study (1009955 and 1012673), samples were collected by EPRI's contractor, URS. Samples were collected and filtered on-site using a 0.7-micron filter.

Samples were collected from several locations in the FGD system from seven sites reported in the first report (1009955). Sample location varied between sites due to differences in the plants. Liquid sample locations included FGD absorber liquid, thickener overflow and underflow, primary and secondary hydroclone overflow and underflow, and "other liquor" (belt filter filtrate, pond discharge water, and wastewater treatment plant effluent). Samples were collected from a total of ten FGD systems (at seven sites) reported in the update (1012673). Results are presented for the FGD absorber liquid.

Study Limitations

The key objective was to understand the FGD mercury chemistry, and thus the results of the published reports were primarily limited to mercury. Many of the other constituents were analyzed after the analytical method's holding time, some several months after the holding time. These data are still considered usable, though considered somewhat questionable. Matrix spike / matrix spike duplicates (MS/MSD) samples were taken at each site. The MS recoveries were within the project's target range of 75 to 125%, with the exception of a few results just outside this range, none of which change the conclusions of this report.

The sites were selected to represent a range of FGD designs and operating conditions, such as reagent type, oxidation mode, fines blowdown, and coal type. The limitations in the sites selected are that most of the FGDs are older design (only one built after 1996), and only one of the sites was tested with the SCR in operation. Note four sites were tested in the non-ozone season with the SCR off-line. For the one power plant with the SCR on-line, this site measured flue gas mercury removals of about 35% - as compared to other EPRI, DOE, EPA, et. al. studies that indicate that for bituminous coals, the SCR/FGD combination were able to achieve ~85% flue gas removals. Thus EPRI believes that the tested SCR site may not be representative of other bituminous plants with SCR and wet FGD.

EPRI / CH2M HILL Post-Screening Study Samples

Study Overview

Samples were collected by EPRI's contractor CH2M HILL at two sites, the second including two sampling rounds. The sampling at the second site (L1) was timed to evaluate the impacts of DBA additive, by sampling before and during a DBA test.

Study Limitations

Towards the goal of evaluating the impacts of DBA, it is not possible to completely eliminate other variables to isolate the effects of DBA, so the cause of differences can not be ascertained. A MS/MSD, a field duplicate, and an equipment rinsate blank were collected in each of the three sample visits. Matrix spike results, for those parameters spiked at appropriate levels, all had a percent recovery in a range of 75 to 125%. The exceptions were dissolved mercury at Site L2 (67% recovery) and aluminum and iron in the first round at Site L1 (137% and 145% recovery, respectively). Some parameters were not spiked at sufficiently high levels to avoid masking by the native concentration—typically boron, calcium, magnesium. The blanks showed no contamination levels that made the sample results questionable. The field duplicate relative percent differences (RPD) fell within a <25% RPD target range, with the exception of 9 analytes across the 150 results. The only parameter of interest to conclusions in this report was selenium in FGD wastewater treatment plant influent at Site L1. This shows the difficulty in taking representative samples of this heterogeneous, high-solids stream.

The selenium and arsenic speciation in this report came primarily from the Screening Study and the post-Screening Study CH2M HILL studies. Matrix spike and duplicate samples were run on each batch. Three minor QC outliers were reported associated with the arsenic and selenium speciation analyses. These outliers included two (MeSe (VI) and Se (VI)) RPD outliers between sample duplicates above the 25% criterion and one As(V) recovery slightly above the 125% upper control limit. All other QC results were within the laboratory limits and the data are considered usable as reported.

EPRI / DOE / Consol Mercury Removal in FGD Optimization Study and EPRI / DOE / EERC - Characterizing Impact of SCR on Mercury

Study Overview

These mercury removal studies focused on flue gas measurements, but there are limited mercury data for some FGD water streams. Consol tested eight power plants with wet FGDs; their water sampling/analyses included the FGD absorber liquid itself, as well as around the FGD solids-removal systems [9,11]. Samples were collected and shipped on ice to an off-site laboratory. They were filtered at the lab several days after sampling. In addition to the differences in filtration, the Consol/DOE and the EPRI Fate of Mercury also tested different sites, the Consol study focused on FGDs with SCR while the Fate of Mercury study only tested one FGD with an SCR on-line.

Study Limitations

The study included mercury data only. No matrix spikes or other quality control information was available in these published reports to quantify accuracy or qualify the results.

EPRI / Western Kentucky University

Study Overview

EPRI's contractor, Western Kentucky University, conducted multi-media sampling around FGD systems. Liquid samples were sent to CH2M HILL's laboratory from two sites. Samples were filtered only through a 20-micron filter to separate liquid and solid portions. Therefore liquid results are considered total, not dissolved.

Study Limitations

As with the Screening Study, no matrix interference was documented, as the laboratory addressed interference issues by diluting samples, up to 100 times, to keep the major chemical interferants (such as Ca, Mg, Al, Fe) in the range in which they could be quantified. No matrix spikes or other quality control information was available in these published reports to quantify accuracy or qualify the results. At Site 2C the general chemistry and mercury analyses were run after the methods' holding time. The same was true for mercury at Site 2B because mercury

needed to be reanalyzed. The holding times were exceeded only by a few days. These data are still considered usable, though considered somewhat questionable.

Table 2-1
FGD Wastewater Characterization Studies

		Site Description									Streams Sampled											Analytes				
											FGD						FGD Wastewater Treatment									
Study	SiteID	FGD Type	FGD Wastewater Flow (MGD)	Coal %S	Coal Cl (ppm)	Coal	SCR?	ORGANIC ACID	FGD WW Mgmt.	Solids Separation (thickener, ponds, hydroclones)	Absorber	Solids Separation Overflow	Solids Separation Underflow	Makeup Water	Reagent	Gypsum	Influent	After Primary Clarifier (or pond)	After Secondary Clarifier	Final Effluent	WWTP Solids	Mercury	Full trace metals suite	Major ions	General Chemistry	Other
EPRI / CH2M HILL FGD Wastewater Screening Study	Site E	Limestone Forced Oxidation;	0.6	medium sulfur	600 (a)	Bituminous - Midwest	N	N	Constructed Treatment	Thickener		x										x	x	x	x	
	Site P	Limestone, Natural Oxidation	Estimate not available	3.6%	1,400	Bituminous - Appalachian	Y	N (b)	Recycles	Thickener	x											x	x	x	x	
	Site R	Limestone, Inhibited Oxidation	0.6	2.5%	360	Bituminous - Midwest	Y	DBA	Recycles	Thickener	x											x	x	x	x	x
	Site S	Limestone, Forced Oxidation	0.2	3.2%	1,100	Bituminous - Appalachian	Y	DBA ?	Pond	Hydroclones		x										x	x	x	x	x
	Site T	Limestone, Ex-situ forced oxidation	2	2.8%	130	Bituminous - Appalachian	Y	N	Pond	Hydroclones		x										x	x	x	x	x
	Site U	Limestone, Natural Oxidation	Estimate not available	<0.5%S during study; 1.5% (a)	120	Sub-bituminous	N	N	Pond	Thickener		x										x	x	x	x	x
	Site Y	Limestone, Forced Oxidation	None, recirculated	2.0%	380	Bituminous - Eastern	N	N	Pond	Pond		x										x	x	x	x	
	Site Z	Limestone, Forced Oxidation	0.2	4%	1,500	Bituminous - Western	N	DBA	Constructed Treatment	Hydroclones		x										x	x	x	x	x
EPRI / Western Kentucky University	Site 2B	Limestone, Forced Oxidation	0.1	0.5% (a)	10 (a)	Sub-bituminous	Y	N	Constructed Treatment	Hydroclones	x				x		x	x	x	x			x		x	x
	Site 2C	Limestone, Forced Oxidation	0.3	high sulfur; 3.0 to 3.5 %	1,500 to 2,100	Bituminous - Midwest	Y	DBA	Pond	Hydroclones	x			x	x		x						x			
EPRI / CH2M HILL Post-Screening Study Samples	Site L2	Limestone Forced Oxidation;	0.6	medium sulfur	600 (a)	Bituminous - Midwest	Y	N	Constructed Treatment	Hydroclones		x					x			x		x	x	x	x	
	Site L1	Limestone, Forced Oxidation	Estimate not available	1.0% (a)	1,100 (a)	Bituminous - Appalachian	Y	L1A = N; L1B = Y	Constructed Treatment	Hydroclones	x						x			x		x	x	x	x	x
EPRI / URS 2nd round	BLMNO	Mg-Lime, External Forced Oxidation	Estimate not available	High sulfur	600 (a)	Bituminous - Appalachian	N	N	Recycles	Thickener	x			x				x				x	x			
	BLSFO2	Mg-Lime, External Forced Oxidation	Estimate not available	medium sulfur	1,500 (a)	Bituminous	N	DBA	Constructed Treatment	Hydroclones	x	x	x							x		x	x			
	BLSFO3	Limestone, Forced Oxidation	Estimate not available	medium sulfur	1,800 (a)	Bituminous	N	Formic Acid	Constructed Treatment	Hydroclones	x	x	x					x	x	x		x	x			
	BLSIO	Limestone Forced Oxidation	0.6	medium sulfur	600 (a)	Bituminous - Midwest	N	N	Constructed Treatment	Hydroclones	x							x				x	x			
	PRBLSNO	Limestone, Natural Oxidation	Estimate not available	0.5% (a)	400 (a)	Sub-bituminous	N	Adipic Acid	Pond	Thickener	x							x				x	x			
EPRI / URS Fate of Mercury Study	1	Mg-Lime, ex-situ forced oxidation	Estimate not available	high sulfur	400 (a)	Bituminous - Appalachian	Y	N	Recycles	Thickener	x	x	x					x				x				
	4	Mg-lime with combined particulate removal	Estimate not available	high sulfur	400 (a)	Bituminous - Midwest	Y	N	Recycles	Thickener	x							x				x				
	6	Limestone, Forced Oxidation	Estimate not available	high sulfur	400 (a)	Bituminous - Midwest	Y	N	Pond	Thickener	x	x	x									x				
	7	Limestone, Forced Oxidation	Estimate not available	high sulfur	800 (a)	Bituminous	Y	N	Constructed Treatment	Hydroclones	x	x	x									x				
	8	Limestone, Inhibited Oxidation	Estimate not available	2.0% (a)	100 (a)	Lignite	N	N	Recycles	Thickener	x							x				x				
	9	Limestone, Inhibited Oxidation	Estimate not available	high sulfur	400 (a)	Bituminous - Midwest	Y	N	Pond	Thickener	x							x				x				
	10	Limestone, Natural Oxidation	Estimate not available	1.5% (a)	120	Sub-bituminous	N	N	Pond	Thickener	x							x				x				
EPRI / DOE / Consol Mercury Removal in FGD Optimization Study	C3	Limestone, Inhibited Oxidation	0.6	2.5%	360	Bituminous - Midwest	Y	DBA	Recycles	Thickener	x			x								x				
	C4 - Unit 1										x			x								x				
	C4 - Unit 2	Limestone, Natural Oxidation	Estimate not available	3.6%	1,400	Bituminous - Appalachian	Y	N	Recycles	Thickener	x			x								x				
	C5	Limestone, in-situ oxidation	Estimate not available	3.0% (a)	900 (a)	Bituminous	Y	N	Pond	Pond																
	C6	Limestone, Forced Oxidation	0.2	4%	1,100	Bituminous - Appalachian	Y	DBA ?	Pond	Hydroclones	x	x	x	x	x							x				
							N	DBA ?	Pond	Hydroclones	x	x	x	x	x							x				
	C7	Limestone, Ex-situ forced oxidation	2	2.8%	130	Bituminous - Appalachian	Y N	N	Pond	Hydroclones	x			x	x							x				
	C8	Lime, Ex-situ forced oxidation	Estimate not available	4.5% (a)	700 (a)	Bituminous	Y	N	Pond	Thickener	x				x							x				
	C9	Mg-Lime, External Forced Oxidation	Estimate not available	High sulfur	600 (a)	Bituminous - Appalachian	Y	N	Recycles	Thickener	x				x							x				
	C10	Lime, Inhibited Oxidation	Estimate not available	3.5% (a)	900 (a)	Bituminous	Y	N	Pond	Thickener	x			x	x							x				
EPRI / DOE / EERC - Characterizing Impact of SCR on Additional Selenium Data	S2	Lime, Inhibited Oxidation	Estimate not available	3.5% (a)	900 (a)	Bituminous	Y	N	Pond	Thickener	x											x				
	S4	Lime venturi scrubber	Estimate not available	3.0% (a)	700 (a)	Bituminous - Appalachian	Y	N	Pond	Pond	x											x				
	Se1	Limestone, Forced Oxidation	Estimate not available	3.5% (a)	1,100 (a)	Bituminous	N	DBA	Pond	Drum filter		x														x
	L1	Limestone, Forced Oxidation	Estimate not available	1.0% (a)	1,100 (a)	Bituminous - Appalachian	Y	N	Constructed Treatment	Hydroclones										x						x

Notes:
(a) From 1999 ICR coal database. Coal data from date of sampling not obtained. Sulfur percentages were rounded to the nearest 0.5 percent. Chlorine values to the nearest 100 ppm.
(b) Dibasic acid was only used for occasional higher sulfur coals. Typical coals at the time of the test were 1 -1.5% and did not require it.
Some of the sites were repeated in one or more studies but do not reference eachother in this table.

Given the differences in the various studies' objectives, work scope, and sampling/analytical protocols, there are many uncertainties when comparing the results across these various studies. EPRI has attempted to employ the best available data and to consider all uncertainties about the data when evaluating the potential impact of wet FGDs on wastewater. The reader is cautioned to consider this uncertainty when extrapolating the results to their power plant and FGD applications.

Definitions Used for Characterization in this Report

FGD systems vary greatly. The water streams differ between sites making it challenging to compare samples across sites. For purposes of clarity, in this report the following terms are used:

- FGD Absorber Liquid: Samples collected from the FGD absorber, or other point upstream of liquid / solid separation in the FGD.
- Untreated FGD Wastewater: Samples collected from the liquid fraction after liquid / solid separation in the FGD. If multiple liquid / solid separation systems are used (i.e., Primary then Secondary Hydroclone), sample is taken after last system. Examples would include: hydroclone overflow, thickener overflow, stacking pond effluent, or FGD wastewater treatment system influent.
- Treated FGD Wastewater: Samples collected after treatment of FGD wastewater in a treatment plant or pond. Treatment of FGD wastewater differs between plants, which complicates comparisons.

Data Coverage of FGD Wastewater Characterization

The range of FGD system conditions is shown in Table 2-1. Figures 2-1 to 2-3 also show the coverage of the data set used in this report. Data gaps identified include:

- Many of the FGD systems included in the EPRI field studies were older FGDs which began operation before 1996 (although it is unclear what level of upgrades have been conducted), as shown in Figure 2-1. There are significant differences between FGD systems in service over the past 30 years and those being constructed during this decade. The newer FGD systems typically have much tighter water balances than the older technologies. Therefore, the newer FGD systems tend to discharge at much lower flow rates.
- There were six constructed FGD wastewater treatment systems in the data set available for this report. Most of these systems were focused on solids removal, not trace metals removal.
- More work is needed to definitively determine whether onsite filtration (as compared with laboratory filtration) affects the results on trace metals partitioning.
- The data set included no western bituminous sites and limited sub-bituminous and lignite sites, as shown in Figure 2-2.
- The data set included a good mixture of liquid/solid separation devices, hydroclones, and thickeners, for removing gypsum solids from the FGD system absorber liquid, as shown in Figure 2-3. Only one site that used a stacking pond was included.

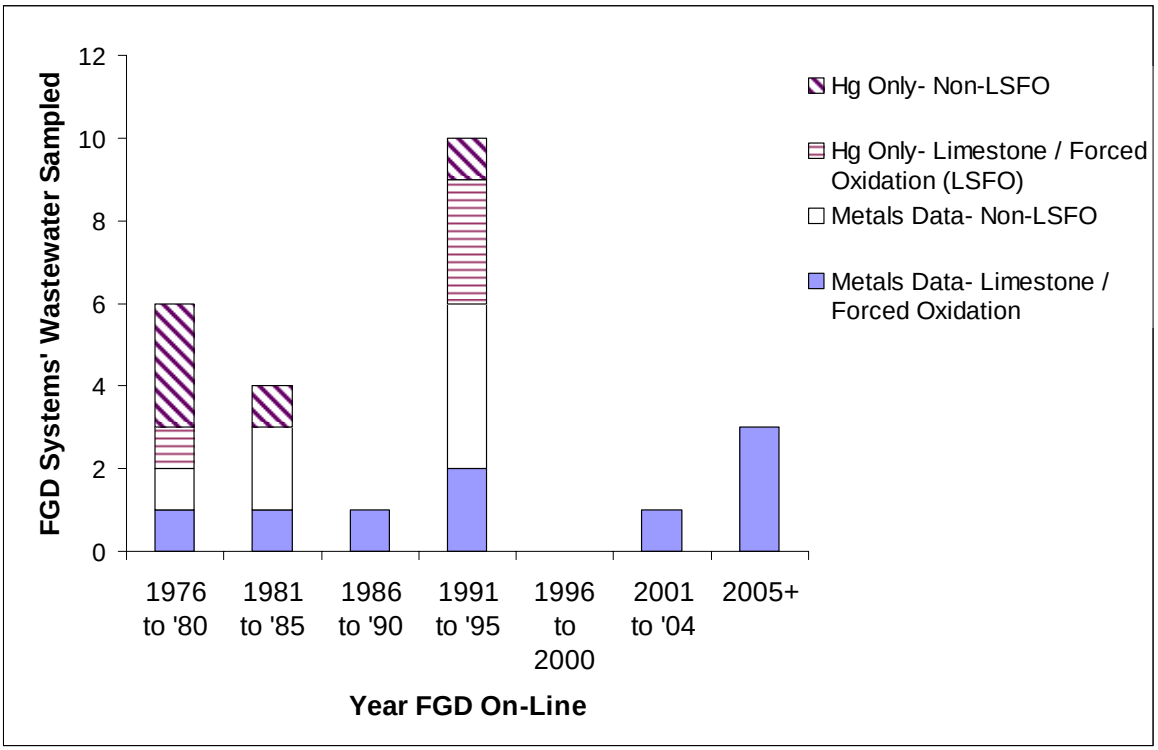


Figure 2-1
Type and Age of FGD Systems Characterized in this Report

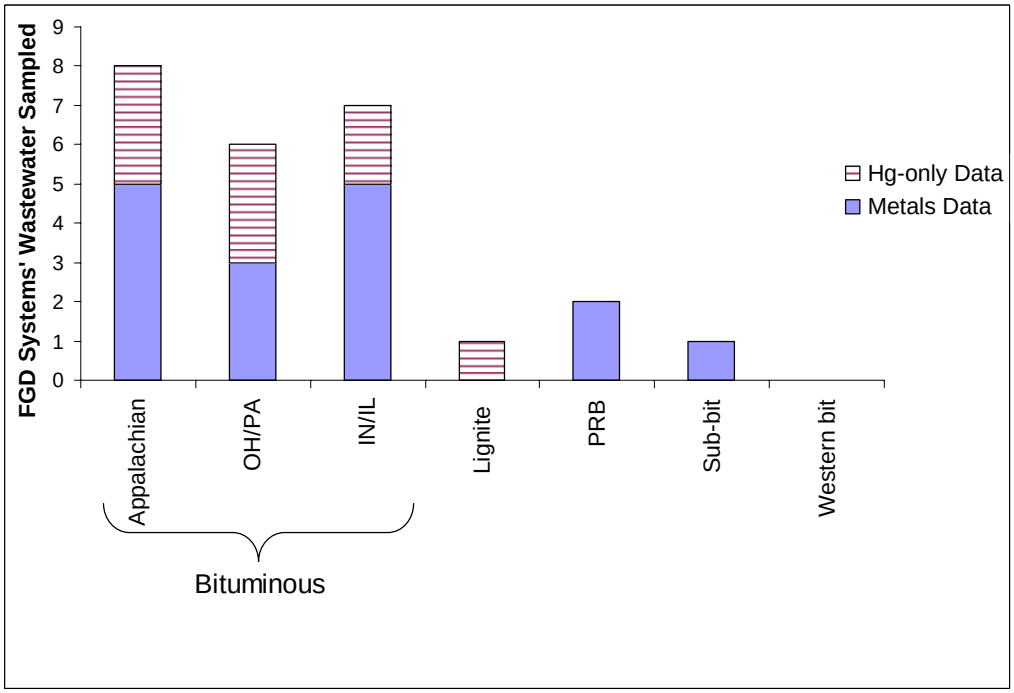


Figure 2-2
Coal Types Fired at FGD Systems Characterized in this Report

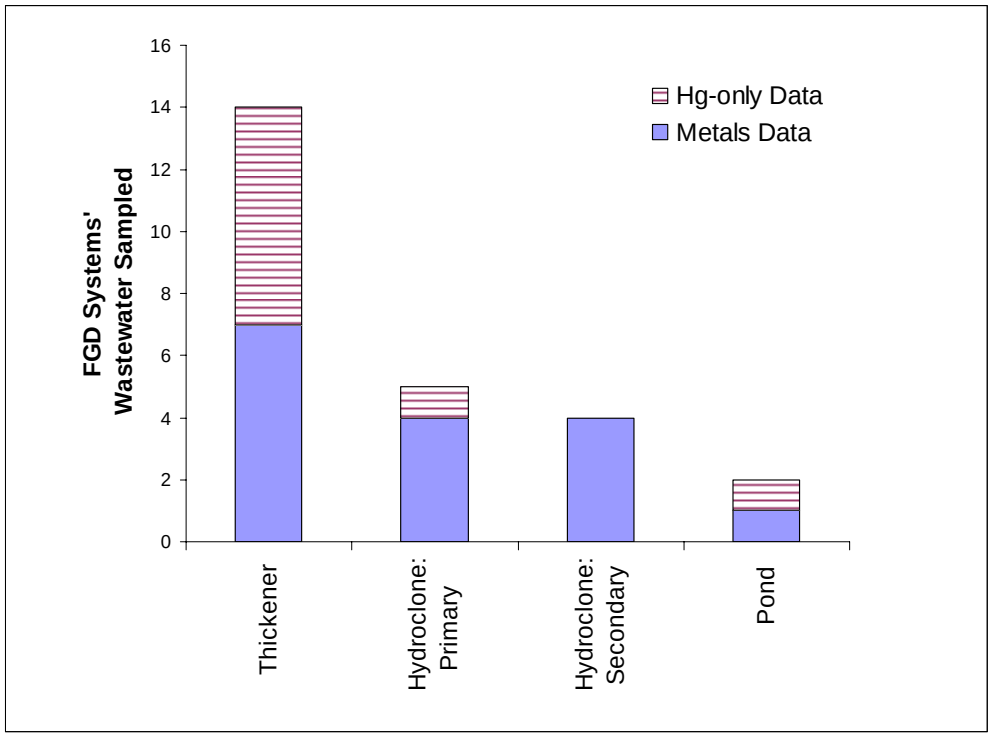


Figure 2-3
Liquid/Solid Separation Types in FGD Systems Characterized in this Report

Approach to FGD Wastewater Management Survey of Current Practices

Currently about 100 gigawatts (GW) of United States coal-fired power plant capacity is equipped with FGD system technology. It is anticipated that in response to the SO_2 regulations under CAIR and the co-benefit removal of mercury driven by the CAMR, many coal-fired power plants will install FGD systems. Wet FGD system capacity is projected to increase to roughly 200 GW by 2020 [5]. There is not a clear, consistent approach to FGD wastewater treatment to use for the design and operation of the current wave of systems. Therefore, utilities are challenged in assessing the impacts of the FGDs on their wastewater management systems. The timing of this report was scheduled to strike a balance—obtaining as much information as possible from the earliest of these new FGD wastewater treatment systems, while getting the information disseminated quickly so that it can be of use in design and operation. Therefore, all information in this report should be considered preliminary.

Current practices were compiled from site visits, from manufacturers of FGD system package treatment systems, and from experience gained in treatment system design and startup. Again, this information should be considered preliminary, as best practices are being adapted and developed rapidly as new systems come on line. The types of systems visited are summarized in Table 2-2. The FGD system and FGD wastewater systems for each of the sites in the screening study and fate of mercury study are provided in Appendix A. Examples from one site are shown in Figures 2-4 and 2-5.

Table 2-2
FGD Wastewater Current Practices Sources

FGD System Management	Phase Observed	Notes
Constructed plant	Operating	Metals removal targeted
Constructed plant; secondary clarification filtration	Operating	Metals removal targeted
Constructed plant; primary clarification, secondary clarification	Design and startup	Primarily for solids removal
Constructed plant; primary clarification, secondary clarification	Design and startup	Primarily for solids removal
Constructed plant; primary clarification (Densadeg clarifier/thickener); filter	Startup	
Pond-based; channel to pond used for stacking; pond is co-management of sluice water and other plant wastes	Operating	

Site L2 – Newer Scubbers FGD

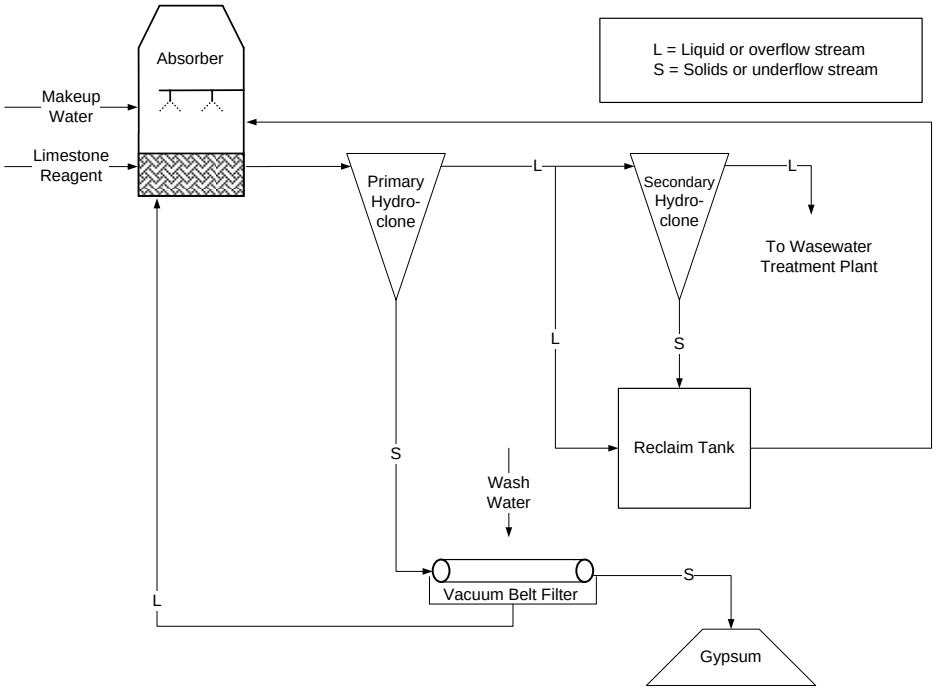


Figure 2-4
Site L2 FGD System Process Flow Diagram

Site L2 – Newer Scrubbers WWTP

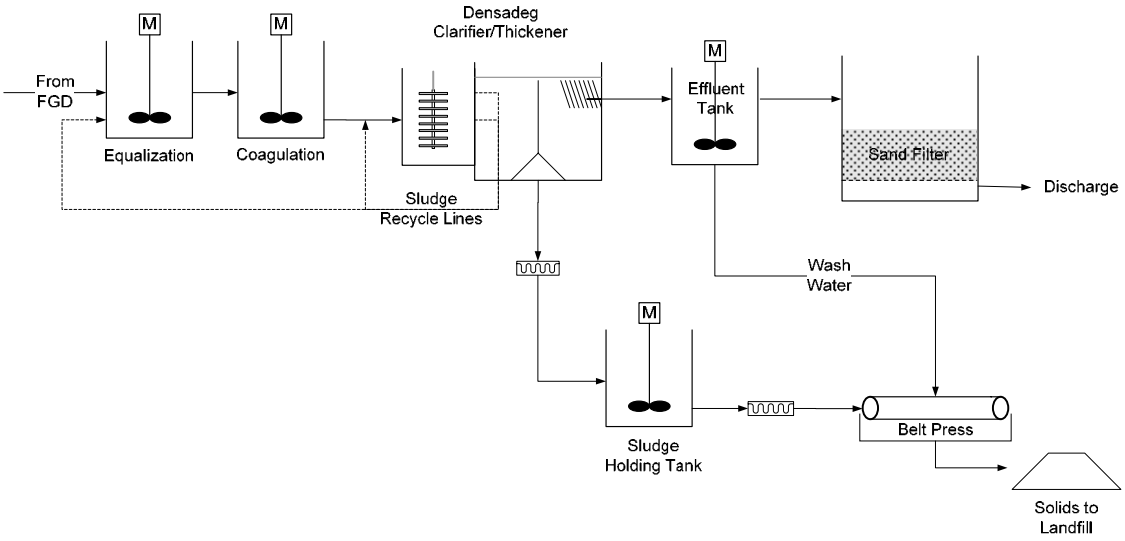


Figure 2-5
Site L2 FGD Wastewater Treatment Plant System Process Flow Diagram

3
FGD SYSTEM WASTEWATER CHARACTERIZATION

This chapter describes the nature of untreated FGD wastewater. Untreated FGD wastewater varies significantly between plants. The causes of variation, to the extent understood, are described herein.

Summary of Untreated FGD Wastewater Characterization

Blowdown of untreated FGD wastewater removes chlorides and fine particulate material from the FGD system. It will also contain other materials removed from the flue gas and contributed by the FGD system reagent. The following key observations are drawn from the available data:

- Untreated FGD wastewater can significantly increase a site's overall wastewater loading of solids, metals, and other parameters of concern. Untreated FGD wastewater has a highly variable composition including total suspended solids (TSS), total dissolved solids (TDS), and chlorides.
- Removal of TSS is the main objective of typical untreated FGD wastewater treatment, either in a pond or in a constructed system. Metals not removed in suspended solids treatment (i.e., settling) will be of more interest when assessing the impact of untreated FGD wastewater on a plant's final effluent. Therefore, it is important to differentiate liquid-phase metals and metals that partition into solids that will be removed as gypsum or in settling from the wastewater stream. Observations from available data included:
  - Selenium was primarily soluble at most sites.
  - Mercury was primarily particulate at most sites.
  - Particulate mercury concentration varied between sites, while soluble mercury was relatively consistent ranging from 0.1 to 12 micrograms per liter (µg/L).
  - Mercury that passes through a filter may not always be dissolved. Although it is common practice to refer to the mercury passing through the 0.45-micron filter as "dissolved," often it is in the form of fine particulates. It appears that a significant portion of the mercury that passes a filter may in fact be small particulate matter.
- SCRs oxidize flue gas mercury, which will generally improve flue gas mercury capture in a wet FGD system. This results in higher mercury mass loadings in the FGD absorber liquid. However it is not clear whether the increased mass loadings consistently increase the loading of "dissolved" mercury, being defined as filterable through a 0.45-micron filter.

- There are many causes of the variation of untreated FGD wastewater composition:
  - Forced oxidation appears to convert selenium to selenate, which cannot be treated via traditional iron coprecipitation.
  - The concentration of mercury in untreated FGD wastewater appears to be directly correlated with the concentration of mercury in the coal fired.
  - Iron from fly ash, limestone, and ball-mill grinding of limestone appears to have a significant effect on trace metals in untreated FGD wastewater. There is a relationship between the concentration of particulate iron and concentrations of particulate mercury, selenium, arsenic, copper, chromium, and nickel at limestone forced oxidation sites.
  - It appears that dibasic acid (DBA) results in conversion of soluble mercury to particulate, thereby improving mercury removal in treatment.
  - DBA is an organic acid; it appears that its use yields other forms of selenium (other than selenite and selenate), including unknown and organic selenium compounds.
- Wastewater treatment plants and FGD wastewater ponds remove TSS to below the typical 30 mg/L TSS limit, and most associated particulate metals. However, ponds and treatment plants designed for solids removal do little to remove soluble metals.

FGD Wastewater in the Context of Power Plant Wastewater Management

Untreated FGD wastewater can significantly increase a site's overall wastewater loading of solids, metals, and other parameters of concern. Sites with wet-fly-ash handling will have higher metals loading then dry-ash handling sites, so the increases from the new untreated FGD wastewater stream will be more notable at dry-ash handling sites. The actual increase to the final discharge stream will depend on the untreated FGD wastewater stream itself and the current plant wastewater system.

Increases in metals loading can be seen in comparisons for several metals across sites shown in Figure 3-1. Untreated FGD wastewater loading of boron, mercury, and selenium was significant compared to other wastewaters. These metals are more impacted because mercury, selenium, and boron are more volatile than other metals. Therefore, these metals pass through electrostatic precipitators more significantly than other metals. Regulations on selenium and mercury are getting tighter, especially in some regions such as the Great Lakes region.

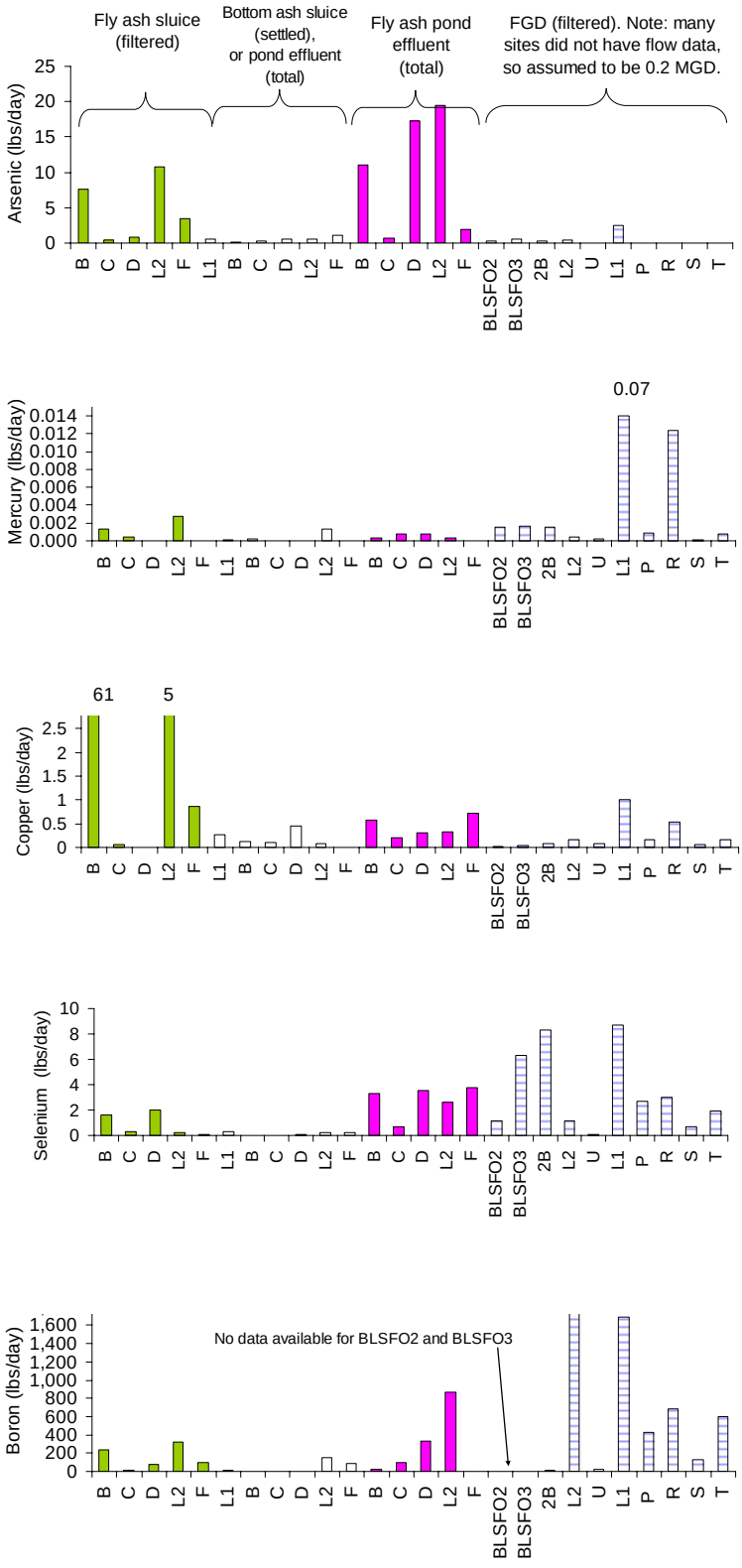
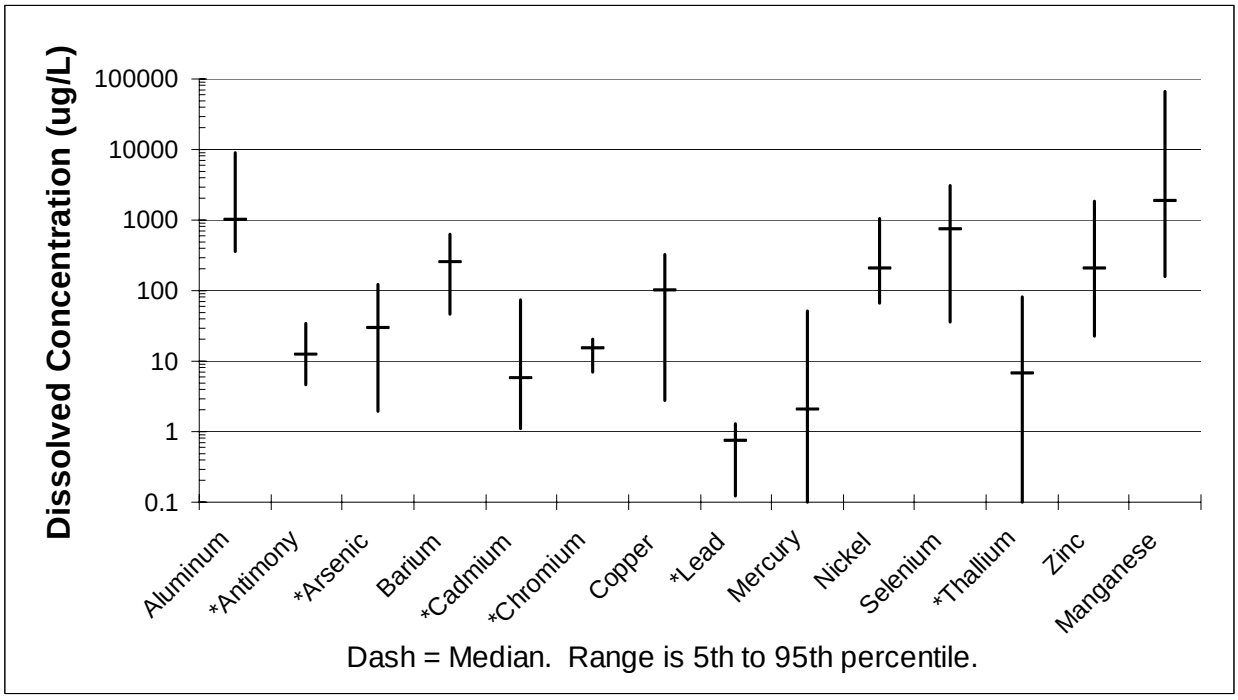


Figure 3-1
Dissolved Metals Load in Untreated FGD Wastewater Compared to Other Streams

Untreated FGD Wastewater Characterization—Range of Results

Untreated FGD wastewater varies widely between sites as seen in Figure 3-2. This is due, in part, to variations in FGD water management, but even FGD absorber liquid itself varies very widely because of differences in coal, FGD water cycling, and reuse of water. The causes of variation are discussed later in this report. Differences in the FGD systems included in this report are shown as process flow diagrams in Appendix A.

A full tabulation of the FGD characterization data is included in Appendix B. However, although data from the mercury capture studies have been used in some of the cross-site analyses of this report, they are not included in Appendix A. The data are presented in their respective source reports.



** - One or more results for this metal were below the detection limit (see Appendix B for all results). Results were used only when the detection limit was below value of a detected result from another sample. This was done to avoid high detection limits biasing statistics high. Silver had no detected results, with detection limits as low as 0.17 µg/L. Dissolved metals are shown for both Absorber Liquid and untreated FGD wastewater.*

Figure 3-2
FGD Absorber Liquid and Untreated FGD Wastewater Dissolved Metals

Specific characteristics of untreated FGD wastewater include:

- TSS – FGD absorber liquid typically contains percent-level concentrations of solids. Most of these solids are removed for gypsum production or landfilling, but a portion remains in the wastewater stream. Pond-based or constructed treatment will be required to reach 30 milligrams per liter (mg/L) TSS, which is a categorical limit for the utility industry [6]. The untreated FGD wastewater from the numerous studies included in this report had a median TSS of 7,700 mg/L.
- Trace metals – Untreated FGD wastewater contains trace metals, especially those that pass through particulate control devices in the gas path. In addition, ions in untreated FGD wastewater can increase the solubility of cationic metals in ponds.
- TDS – Untreated FGD wastewater contains high parts-per-million, and even percent, concentrations of TDS, including fluoride, chloride, and sulfate. In addition, mixing of the gypsum solids with high flows of lower-sulfate water (such as an ash pond) can result in dissolution of gypsum solids; thereby releasing more calcium and sulfate mass, as well as fluorides and metals, that were tied up in these solids.
- Chloride – If a facility reuses water from an ash pond, chloride corrosion may be a concern. Chloride in untreated FGD wastewater will typically cause the pond water chloride concentration to increase above levels recommended for most common steels. For example, if a 12,000 mg/L chloride untreated FGD wastewater is mixed 10:1 in an ash pond, the resulting pond water will have over 1,000 mg/L – above the typical recommended service condition for 304 stainless steel. Chlorides and fluorides may have environmental compliance implications as well. Salts may also contribute to whole effluent toxicity, upon which some sites are regulated.
- Ammonia – If ammonia is added to the flue gas stream for SCR or selective non-catalytic reduction operation, SO_3 mitigation, or ash conditioning, most of it will be captured in a particulate-control device, such as the electrostatic precipitators. However, the portion that passes such devices will mostly be captured in the FGD system.

While concentrations provide insight on the untreated FGD wastewater composition, the mass flow rate is more important to the impacts on overall wastewater management. The concentration will be affected by how a FGD system operates. Higher blowdown flows will lower the concentration of metals, though not the mass loading. Flow data were not consistently available, thereby precluding the ability to compare metals on a mass loading basis. Table 3-1 shows both selenium and mercury concentration and mass. Mass is computed from concentration and untreated FGD wastewater flow rate. Flow rate is often difficult to determine at plants because flow meters are often not placed on these streams. Therefore, flow rates have been obtained from only the nine sites shown in Table 3-1.

Table 3-1
Untreated FGD Wastewater Dissolved Metals

Plant	Size (MW)	Wastewater Flow (mgd)	Selenium		Mercury	
			Concentration (µg/L)	Mass (lb/day)	Concentration (µg/L)	Mass (lb/day)
Site L1 (no DBA)	2100	0.6	778	3.9	4.2	0.021
Site L1 (with DBA)	2100	0.6	685	3.4	>0.1	0.0005
Site L2	1500	0.57	1,420	6.8	0.52	0.0025
Site R	500	0.58	1,810	8.7	7.4	0.035
Site S	500	0.17	485	0.68	0.1	0.0001
Site T	600	1.7	1,150	17	0.44	0.0063
Site Z	1,000	0.22	1,070	1.9	>0.1	0.0002
Site 2B	1300	0.11	10,000	9.0	12	0.011
Site 2C	200	0.23	385	0.7	0.17	0.0002

Notes:

Site T may have high selenium and mercury in makeup water because it recycles water (zero-discharge plant), while other plants add makeup water from clean sources such as a lake or river. Therefore, the mass of selenium and mercury in the waste stream may not be representative of daily mass.

The size (MW) noted in this table corresponds to the wastewater flow (mgd). For example, Site L2 has three units that are each 500 MW, and the wastewater flow produced from all three combined is 0.57 mgd.

The mass of selenium and mercury varied at each site more than the concentration at each site, as shown in Table 3-1. This indicates that a difference in flow is not the cause of the concentration differences between these sites.

Larger power plants have higher mass flow rates of dissolved mercury and selenium. However, the increase is not linearly related to size of power plant or wastewater flow alone. Site L2 has FGD systems on roughly three times the power of Site S, but had 10 and 25 times higher selenium and mercury mass flow, respectively.

Other variables, such as coal content, likely play a role in the dissolved selenium and mercury concentrations.

Partitioning Between Liquid and Particulates

Removal of TSS is the main objective of typical FGD wastewater treatment, either in a pond or in a constructed system. Therefore, dissolved or sub-micron metals will be of more interest when assessing the impact of FGD wastewater on a plant's final effluent. Generally, FGD wastewater treatment systems are designed before any wastewater is available for testing. Therefore, much effort is expended in getting limestone and coal analyses and estimating how much of each metal ends up in the wastewater. When this approach is used, it is important to differentiate liquid-phase metals and metals that partition into solids that will be removed as gypsum or in settling from the wastewater stream.

The partitioning of metals between that which can pass a filter (soluble and solids small enough to pass through a filter) and filterable (solids large enough to be caught on a filter) vary across sites, but general trends can be observed. Some parameters typically partition into soluble form, such as boron, selenium, cadmium, and antimony. Other parameters found in the particulate form include iron and mercury. Key among these metals, from an environmental compliance standpoint, are mercury and selenium, which are described further below.

Selenium Partitioning

Selenium was primarily soluble at most sites, with the exception of Sites BLSFO3 and S, as shown in Figure 3-3. This relationship includes FGD system waters before treatment, such as FGD slurry and hydroclone overflow and underflow. Once streams are treated, the particulate form is even lower; as can be seen in the very low particulate selenium at the sites with better solids removal – those with thickener and pond effluent. The particulate concentration at BLSFO3 was much higher than at other sites. It is not clear what caused the difference at these two sites, they are not unique in this data set in terms of being forced oxidation FGD systems. Soluble selenium ranged from 0.1 to 2 mg/L, with a median of roughly 1 mg/L. Selenium is of concern at many sites due to low current or potential limits.

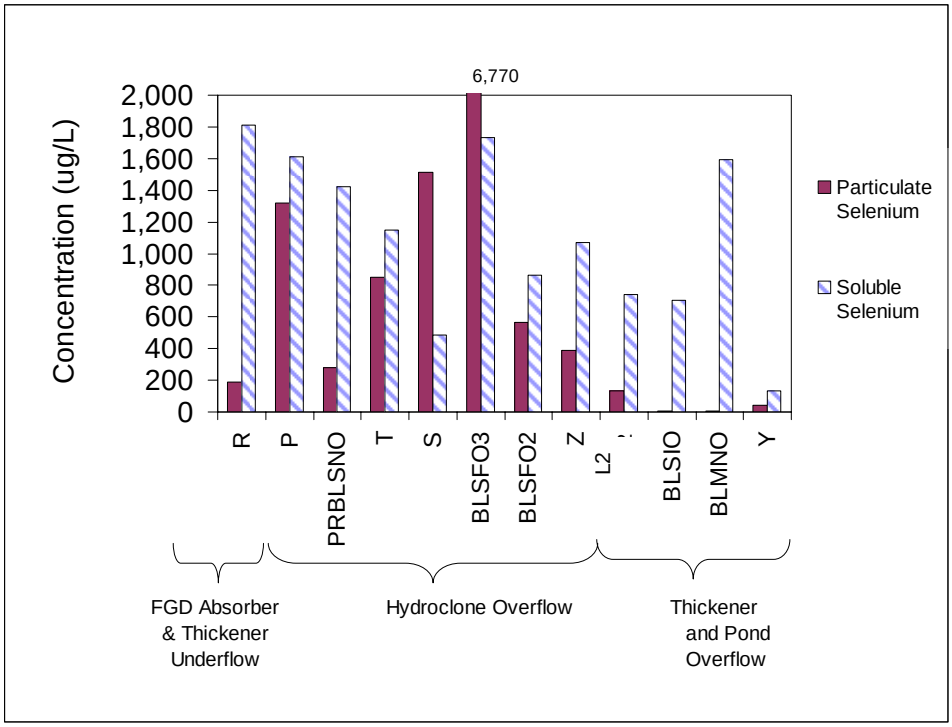


Figure 3-3
Variation in Partitioning of Selenium between Liquid and Solid Phase in Untreated FGD Wastewater

Mercury Partitioning

Mercury was primarily associated with particulate (material removed by filtering) at most sites, though not all, as shown in Figure 3-4. This relationship includes FGD system waters before treatment, such as FGD slurry and hydroclone overflow and underflow. Once streams are treated, the relationship does not hold because the particulate form is removed. This can be seen in the Thickener and Pond overflow data in the right side of the figure. Soluble mercury (in actuality, all mercury not removed by filtering) ranged from <0.1 to 48 µg/L (only one point above 13 µg/L), with a median of roughly 2.0 µg/L. Some of the sites with higher dissolved mercury, such as Site Y, recirculated water to the FGD makeup, thereby increasing dissolved mercury in the untreated FGD wastewater. This varied less than particulate mercury, which is based in large part on the solids remaining in the water. Mercury is of concern at many sites due to low current or potential limits, which could range into the low parts-per-trillion (ppt or ng/L) range. Therefore, the amount of mercury remaining from untreated FGD wastewater contribution after settling either in a pond or in a constructed FGD wastewater treatment plant can be important to environmental compliance. Particulate mercury is likely to be removed in settling, while soluble or small particles that pass a filter are likely not to be removed.

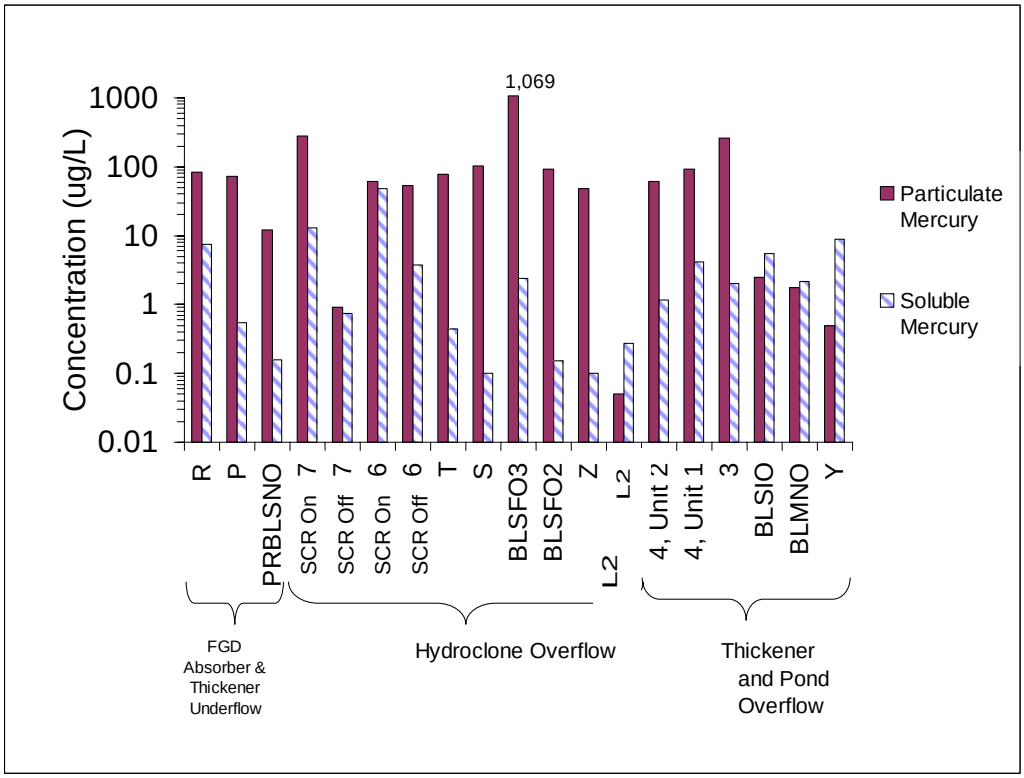


Figure 3-4
Variation in Partitioning of Mercury between Liquid and Solid Phase in Untreated FGD Wastewater

Mercury that passes through a filter may not always be dissolved. Although it is common practice to define the mercury passing through the 0.45 micron filter as "dissolved;" often it is in the form of fine particulates. It appears that a significant portion of the mercury that passes a filter may in fact be small particulate matter. Mercury has been found in the flue gas stream, in large part, as a soluble form such as mercuric chloride ($HgCl_2$). We theorize that this apparent change from soluble to particulate form is caused by mercury becoming associated with less soluble forms such as hydroxides and sulfides. We do not have data for other metals, but theorize that other cations could behave similarly.

Mercury was a focus of each study included in this report. Observations on mercury in untreated FGD wastewater that can be made from evaluating data from these studies are described below.

- Observations from Consol Optimization of Mercury Removal Studies (Sites 3 to 7 in Figure 3-4) [9]
  - Flue gas measurements and material balance calculations conducted suggest that significant flue gas mercury removals are accomplished for most eastern bituminous coal-fired power plants with SCRs and wet FGD systems.
  - During most tests, over 90 percent of mercury in the FGD system slurry was particulate, the exceptions being during ozone season at Sites 6 and 7.

  - The mass of mercury to FGD system wastes (liquid and solid) was roughly 80 percent of the total mercury entering the FGD systems.

- Observations from URS Fate of Mercury Study (Sites PRBLSNO, BLSFO3, BLSFO2, BLSIO, BLMNO in Figure 3-4) [4]
  - The mass of mercury in recirculated FGD system liquor (which was the overflow from the FGD systems' dewatering device such as hydroclone or thickener), showed a wide range of mercury in the particulate form (ranging from 2 to 1,000 µg/L), which led to a wide range in partitioning fractions. The soluble mercury was relatively consistent, between 0.2 to 6 µg/L. This range was likely due to variations in suspended solids concentration of the water.
- Observations from CH2M HILL Screening Study (Sites P to Z in Figure 3-4) [1]
  - Most mercury in untreated FGD wastewater partitioned into the particulate fraction – 92 to 99 percent for those samples with typical suspended solids loading.
  - As in the Fate of Mercury Study, sites with low suspended solids had lower percentage of mercury as particulate.
- Observations from Western Kentucky University Study [7]
  - Overall, 85 percent of the mercury entering the FGD system partitioned into the gypsum, with most of the rest in air emissions and untreated FGD wastewater. This indicates that mercury is captured in the FGD absorber liquid but then partitions into particulate form, which is then removed.
  - In the untreated FGD wastewater, 99 percent of the mercury partitioned into the particulate portion.

Potential Effect of Mercury Size on Apparent Partitioning

Evaluation of particle size distribution of mercury in untreated FGD wastewater that passes a 0.45-micron filter is currently in progress. Figure 3-5 below shows the particle size distribution of Oak Ridge National Laboratory industrial wastewater treatment plant water, a high-chloride wastewater stream, though not untreated FGD wastewater.

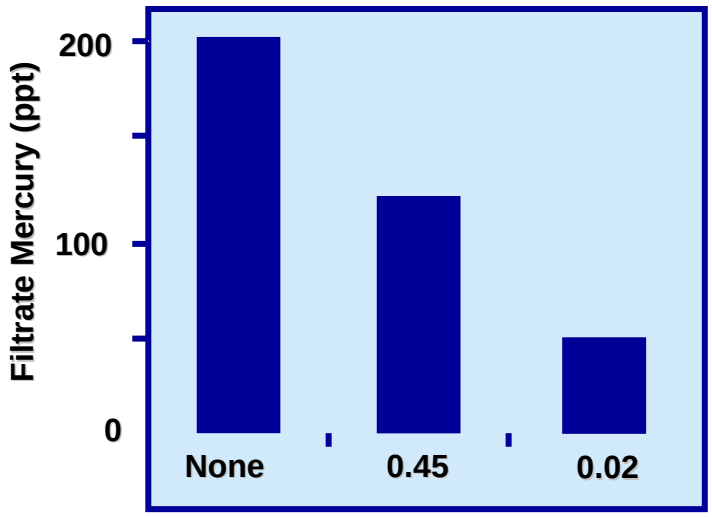
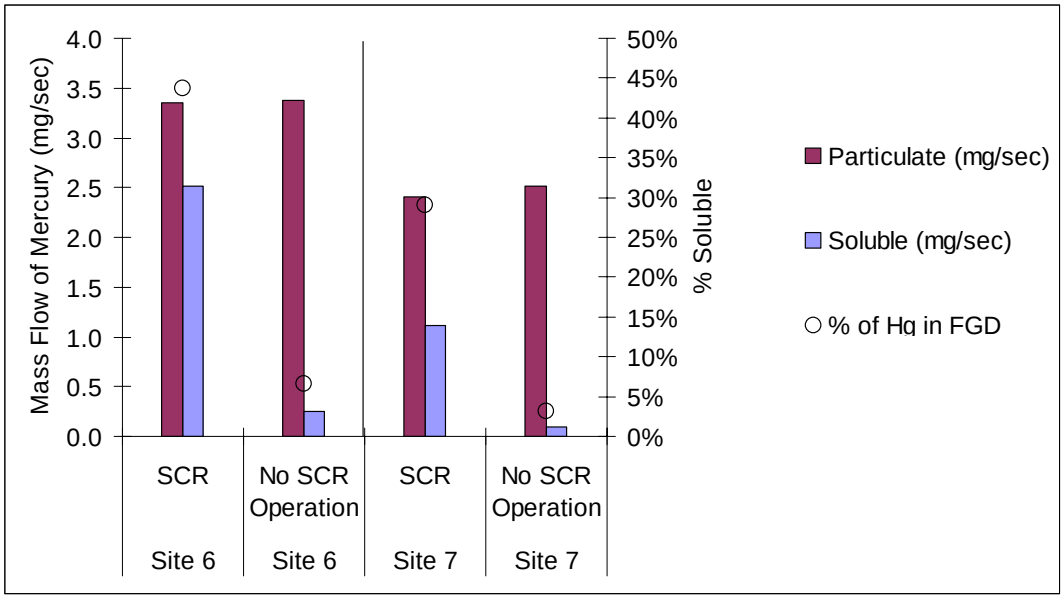


Figure 3-5
Effect of Filter Pore Size (microns) on Filtrate Mercury Concentration [8]

Apparent Effect of SCR Operation on Mercury in Untreated FGD Wastewater

SCRs oxidize flue gas mercury, which will generally improve flue gas mercury capture in a downstream wet FGD system. This results in higher mercury mass loadings in the FGD system absorber liquid [9].

Two sites in the Optimization of Mercury Removal Studies included testing of units with and without SCR operation [9]. From this limited data set (Figure 3-6), it appears that SCR operation may increase the soluble mercury concentration in the FGD absorber liquid.



Note: Mercury in slurry is the net of mercury in slurry out of the absorber minus mercury in slurry recirculated back into the absorber.

Figure 3-6
Effect of SCR Operation on Mercury in FGD Absorber Liquid

Potential Effect of Sampling Method on Mercury Partitioning

It was noted during data reviews that the different studies used in this report used different methods for filtration. Therefore, there was a concern about comparing the data. The Screening Study and the Optimization of Mercury Removal Study used filtration at the lab (after sample shipment), while the Fate of Mercury Study used field filtration. Therefore, a comparative study was performed to assess if this variable would cause a difference in mercury partitioning between sites or in concentration reported as soluble. As shown in Table 3-2, there did not appear to be a significant difference between field and lab filtering. What variability was seen is within the normal variations of the accuracy of the analysis. However, this is a very limited data set and the effect of time of filtration on mercury partitioning deserves further study.

Table 3-2
Comparing Effect of Filtration Methods for Dissolved Mercury

Site		Total Hg (µg/L)	Dissolved Hg (µg/L)			
			Field Filtered	Lab-Filtered Day 1	Lab-Filtered Day 3 or 4	Lab-Filtered Day 1, Not Iced
L1	FGD WWTP Influent	59	4.2	3.4	6.4	4.8
	FGD Wastewater after Primary Clarifier	8	6.8	7.2	7.5	6.9
L1 with DBA addition	FGD WWTP Influent	43	<0.1	<0.1	0.27	<0.1
	FGD Wastewater after Primary Clarifier	0.2	<0.1	<0.1	<0.1	<0.1
L2	FGD WWTP Influent	496	<1.0	<1.0	<1.0	<1.0
	FGD Wastewater after Primary Clarifier	7	<1.0	1.6	1.7	<1.0

The Fate of Mercury update [3] showed a comparison that analyzed FGD absorber liquid through three methods: filtering at the sample tap, filtering within 15 minutes, and filtering after 90 to 120 minutes. Results were shown in the graph included below as Figure 3-7 and the investigators concluded that there was a "slight bias." Differences often appear to be random and could be within the normal variations of the accuracy of the analysis; therefore, are likely not to change significantly the measured soluble concentration or partitioning of mercury. We theorize that the amount of difference between filtering methods may be site-specific and may differ with other FGD system water chemistry characteristics.

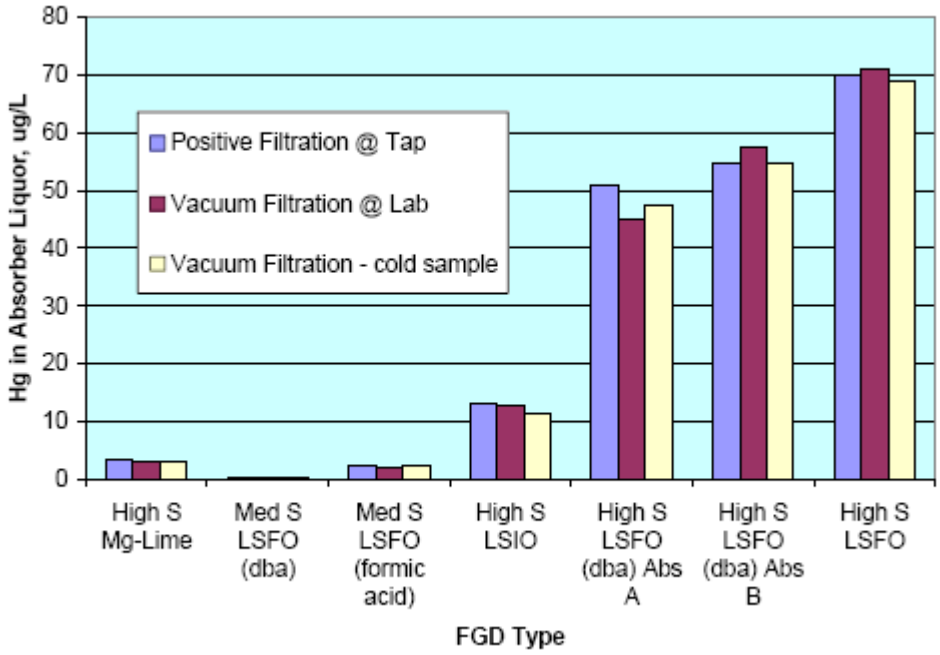


Figure 3-7
Effect of Time Elapsed between Collection and Filtering on FGD Liquor Sample Mercury Concentration [3]

Causes of Variation in FGD Wastewater

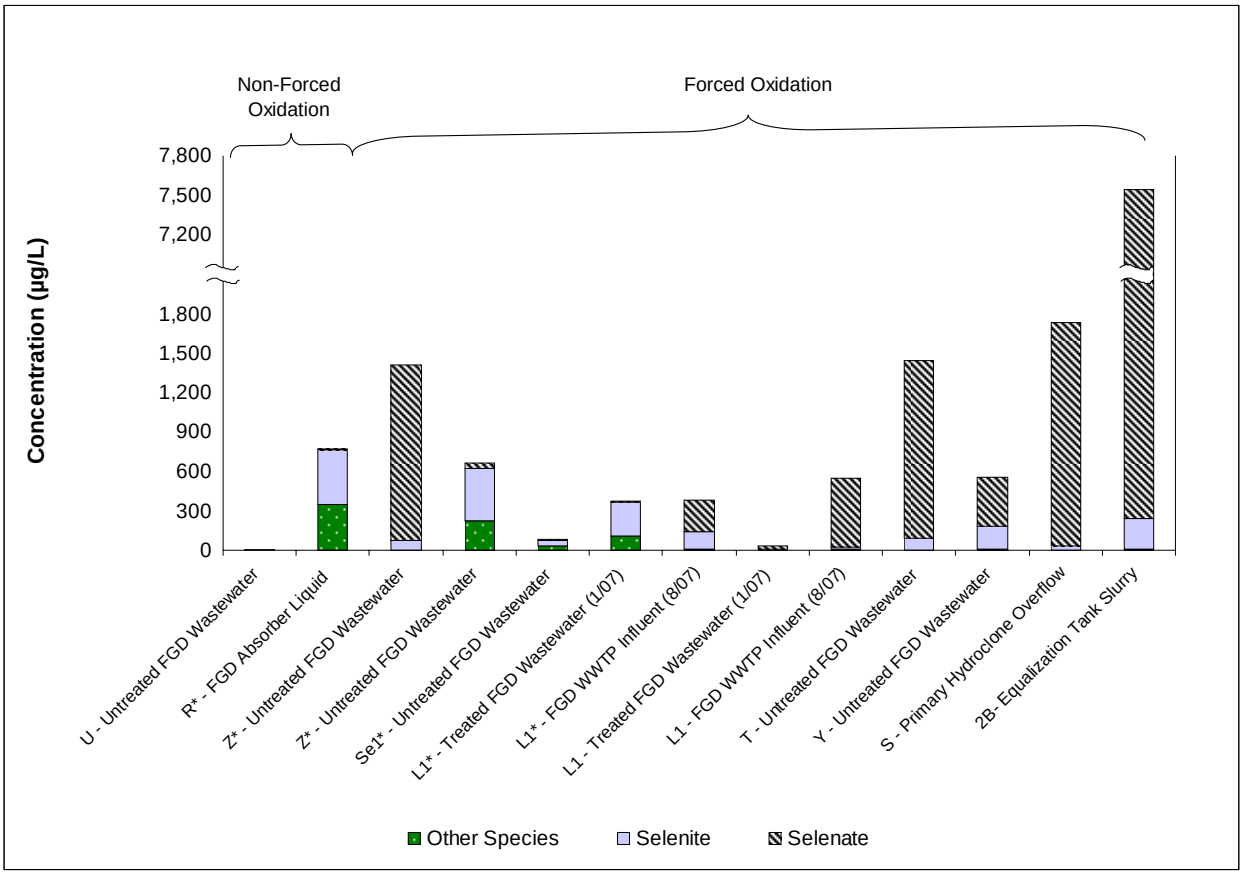
There are a number of potential variables that may impact untreated FGD wastewater, including coal properties, coal combustion, FGD system type, and FGD system operation. There is potentially very wide variability in untreated FGD wastewater characteristics at a given site as coals and plant operations change. FGD systems may vary widely in the way water is managed in terms of method of solids removal (hydroclones, thickeners, and settling ponds), how the blowdown is managed to control chlorides and/or fines, where the blowdown stream is taken, and trace metals treatment. All of these factors may result in a wide range of wastewater characteristics between facilities. These are discussed below.

Flow

Flow varies significantly between FGD systems observed during these studies. A range from 75 gpm to 1,200 gpm was observed. The flow also varies significantly over time at most FGD systems. The flow is often not monitored or metered, which makes characterizing the mass of parameters in the stream problematic. Flow of FGD system blowdown is typically based on controlling chlorides and fines in the FGD absorber liquid, as described in the section on Coal Chlorides below. Chloride limits due to metallurgy, and gypsum dewatering equipment can also affect untreated FGD wastewater flow.

FGD Oxidation Design

Some metals are affected by the oxidation design of the FGD system. In inhibited oxidation FGD systems, metals stay in a more reduced state. Most important of these is selenium. In forced oxidation, the absorber environment is reducing, but slurry passes to the forced oxidation reactor where air is added to oxidize sulfite to sulfate. This oxidation appears to convert selenite to selenate, as shown in Figure 3-8. Selenate is less toxic but harder to remove using iron chemistry so this conversion can result in later treatment difficulties. In plants with forced oxidation with DBA addition such as Sites 2 and 6, some of the selenium appears to convert into these unknown selenium compounds. EPRI has an ongoing laboratory study with Trent University to further evaluate the selenium chemistry in the FGD absorber. The objective of this effort is to understand and then manage the selenium chemistry to optimize selenium water management with SO_2 removal.



** = Site where DBA was added.*
Only selenite and selenate were analyzed for at Site S, T, and Z (treated FGD wastewater).

Figure 3-8
Effect of Forced Oxidation on Selenium Speciation in FGD System Liquid—12 Sites

Forced oxidation FGD systems are further divided into two types. In spray tower absorbers, limestone is ground into a fine powder, slurried, and sprayed into the tower for contact with flue gas under reducing conditions. The slurry passes to the oxidation reactor. Spray tower components must be able to resist the hot (400 degree F) acidic flue gas. As a result, the cycles of concentration are limited to about 12,000 mg/L of chlorides before purging.

In jet bubble FGD systems, a coarser gypsum solid is produced, since the slurry is not sheared in recirculation pumps to be sprayed in a tower. Also, only the bubblers are exposed to the hot corrosive flue gas, and reactors can be made out of fiberglass. As result, these systems generally can withstand higher chlorides, and have higher cycles of concentration (lower purge flows).

FGD System Liquid/Solid Separation

An important variable that affects untreated FGD wastewater properties, especially solids content, is how the system dewaters gypsum and from where purge flow is taken. Some systems employ a single hydroclone to separate fines from the coarser solids, which typically are dewatered on a vacuum belt. Untreated FGD wastewater is typically generated from all or a portion of the hydroclone overflow. When single hydroclones are used, the purge stream is typically are greater than 3 percent TSS. Some FGD system designers return a portion of this flow to the scrubber to reduce water usage. Gypsum filtrate can also be purged to control chlorides. When a second hydroclone is employed, the purge solids content is lower, and more solids are dewatered with the gypsum. Large thickeners can also be used and are even more effective at removing solids into the gypsum stream.

Jet bubbler FGD systems take advantage of the coarseness of the limestone and have been effective in dewatering gypsum at one site in the US by stacking in a pond rather than mechanical dewatering. This is shown in Figure 3-9. However, like other FGD systems, jet bubbler FGDs may also be designed with mechanical gypsum dewatering and blowdown treatment for removal of solids and metals.

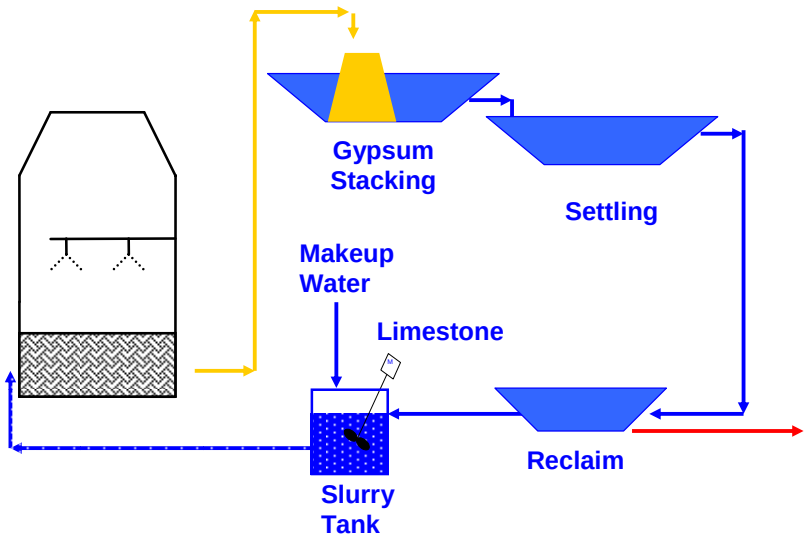


Figure 3-9
Example of Pond-based Solids Separation

Some plants also employ settling ponds as part of water reclamation systems. In this case, purge water can be very low in TSS where the ponds provide large settling areas. FGD pond water can also be reused, as is done at one Midwestern facility where effluent from a pond receiving FGD system blowdown and fly ash sluice water is returned to the plant for use in the plant. Care is required in these cases to account for potential corrosion and scaling issues.

It is expected that the TSS in untreated FGD wastewater at plants varies by the type of liquid / solids separation at the plant. Plants with a thickener would generally have the lowest solids, followed by plants with a secondary hydroclone, followed by sites with a primary hydroclone (Figure 3-10). A plant's untreated FGD wastewater TSS is subject to plant operating conditions. Thickeners can be overloaded, leading to higher TSS than typically seen from thickener overflow. Further, TSS may be lower than expected from any device during periods of low FGD untreated wastewater flow.

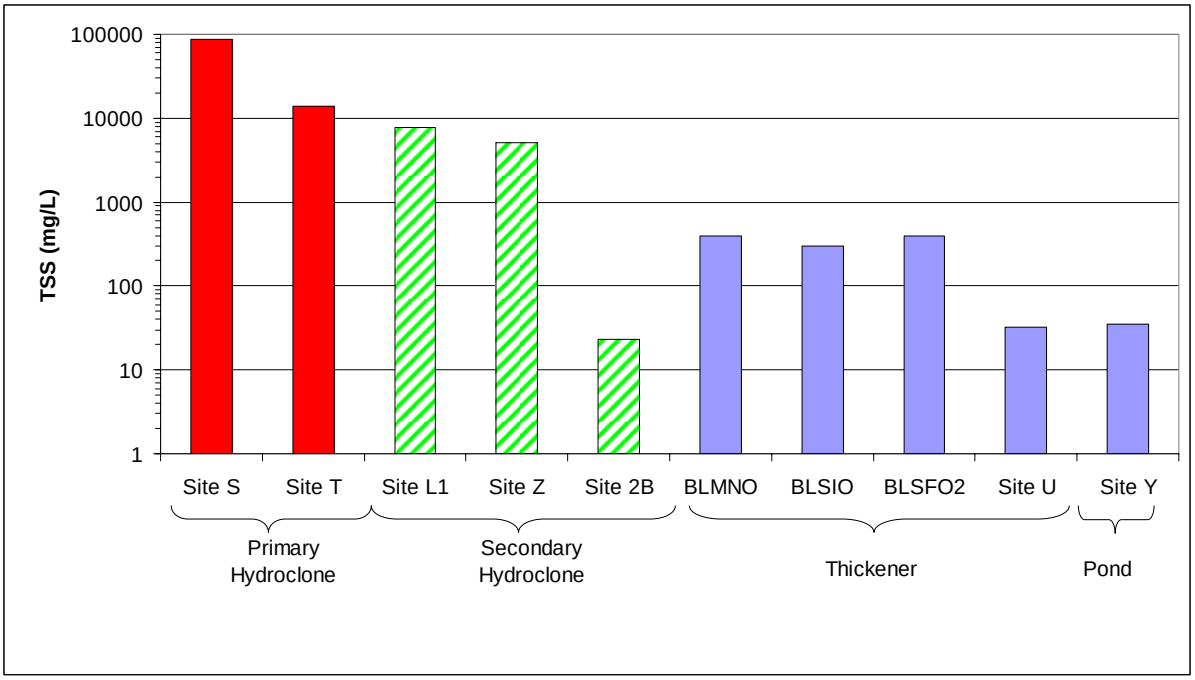


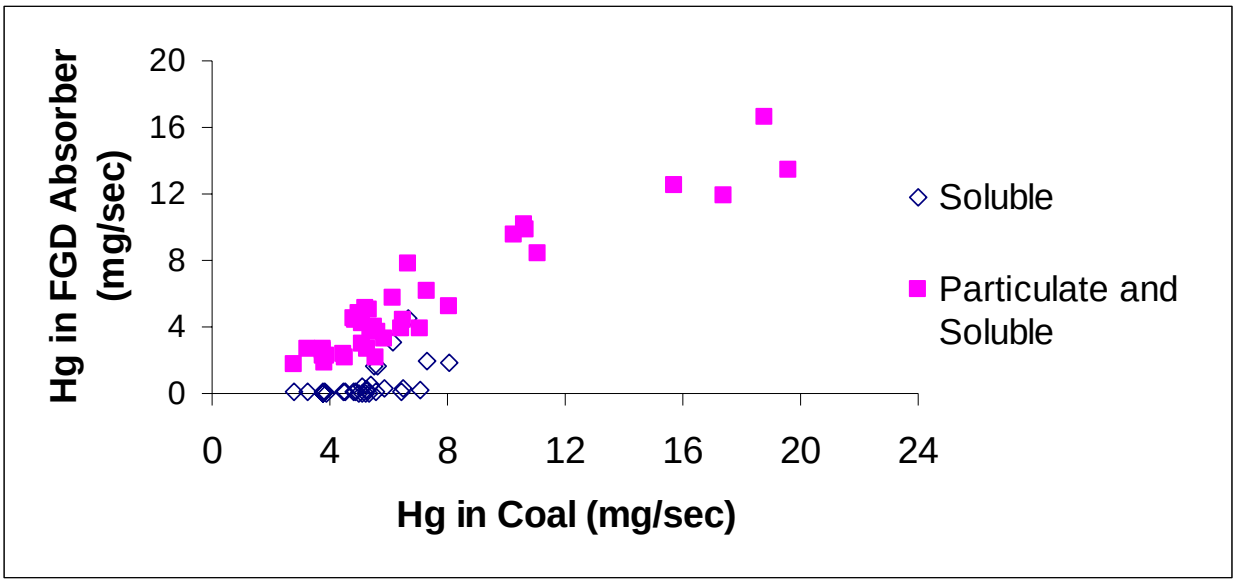
Figure 3-10
Untreated FGD Wastewater TSS Concentration by Liquid/Solid Separation

Settling of solids also can be expected to remove a portion of particulate-phase trace metals. For example, mercury was found in primary hydroclone overflow at 80 to 1,000 µg/L in four samples, while in thickener overflow ranged from 4 to 12 µg/L in three samples. Differences in soluble metals such as mercury could also be expected, with values lower in thickener overflow. This is believed to be due to "soluble" mercury actually containing significant amounts of sub-micron particles. Thickeners remove these small particles much better than hydroclones. However, the limited data available did not show clear differences in soluble mercury concentrations in the different types of separation devices.

Coal Metals Content

Coal is the largest source of metals load in FGD system liquid. For those metals that partition into untreated FGD wastewater, the more metals load in coal, the more there will be to capture in the FGD system. Coal is the ultimate source of the metals, but the form of the metals, and hence their fate, is determined post-combustion. Coal type can affect this, but post-combustion characteristics are also important to the understanding of effects on untreated FGD wastewater. Therefore, including dry fly ash samples, as well as coal, are recommended in future FGD studies.

Limited coal data are available that are associated with the untreated FGD wastewater data to quantify this relationship. One set that is available is mercury data from the Optimization of Mercury Removal Studies, which shows a strong correlation between mercury in the coal and mercury in the FGD system slurry, as shown in Figure 3-11.



Note: Mercury in slurry is the net of mercury in slurry out of the absorber minus mercury in slurry recirculated back into the absorber.

Figure 3-11
Relationship of Mercury in Coal to Mercury in FGD Absorber Liquid [9]

Coal Chloride Content

Coal chloride and sulfur content as well as FGD equipment metallurgy typically drive the number of times that water can be cycled through the FGD system absorber. The more cycles the absorber water goes through in the FGD system, the more trace metals are concentrated. Therefore, high-chloride coal may lead to less cycling and lower concentrations of trace metals than an FGD system that is able to run at higher cycling. It is important to note that the mass loading rate of trace metals in the blowdown stream will not be affected by the amount of cycling, only the concentration will be affected.

High-chloride coals will likely lead to FGD system blowdown flow control based on limiting chlorides. FGD systems with lower-chloride coals may have to blow down due to buildup of fines before chlorides become a corrosion issue. For low-chloride coals, water from gypsum dewatering can be recycled to the FGD system, resulting in less blowdown to a treatment plant. Therefore, chlorides will not always have a direct influence on cycling and subsequently on metals concentrations.

Reagent Characteristics

Lime, limestone, and other FGD system reagents will introduce varying amounts of solids and trace metals. Typically, the contribution of trace metals from reagents to the mass loading of dissolved metals in untreated FGD wastewater is overshadowed by the amount from coal (via the flue gas). However, reagents may impact the untreated FGD wastewater, especially for those metals typically found in limestone impurities such as aluminum in limestone's clay matter.

These clay fines are also a potential source of fine particulate material that is difficult to settle, and could affect TSS levels in untreated FGD wastewater.

These observations are based on very limited data. It is recommended that reagents be included in future FGD wastewater mass-balance assessments. Evaluation should include the dissolved metals concentration in the reagent slurry. Reagent slurry flow should be recorded.

Iron Contribution from Limestone Slurry

Limestone and coal are typically considered the primary sources of iron and other metals in an FGD system. There may be a significant amount of iron in coal, but due to its volatility, this iron typically ends up in bottom ash and fly ash. The limestone slurry contains iron from the limestone as well as from the ball mill grinding of limestone. This iron appears to have a significant effect on trace metals in the FGD system, incorporating what otherwise would be a soluble trace metal in an iron hydroxide matrix.

This is important because the iron appears to affect mercury, selenium and other metal chemistry in the untreated FGD water—and may possibly affect metals capture from the flue gas. A certain amount of particulate mercury and particulate selenium appear to form because of the available iron sites. Above this amount, additional mercury and selenium either has to partition into soluble form in the FGD system slurry, or will not be captured, thereby leaving with the flue gas. A portion of any particulate mercury and selenium formed in the FGD system slurry will be removed with the gypsum solids removed. For example, in a multimedia study by Western Kentucky University for EPRI, 85% of mercury entering a FGD system partitioned into the gypsum [7]. Solids formed in the FGD solids are split by liquid-solid separation devices such as hydroclones. It is theorized that trace metals will concentrate in the fines, which end up in hydroclone overflows and subsequently untreated FGD wastewater. However, the coarser solids (hydroclone underflow) removed for gypsum recovery carry a significant portion of the slurry's metals because the mass of gypsum solids is many times higher than the fine solids in the untreated FGD wastewater.

Data from various FGD absorber liquid and thickener/hydroclone underflows were analyzed, allowing evaluation of the potential effect of particulate iron. It appears from the data collected that there is a relationship between the particulate iron and particulate selenium–as well as between particulate iron and particulate mercury–in the untreated FGD water from limestone forced oxidation FGD systems (Figure 3-12). There did not appear to be a similar relationship within natural oxidation and inhibited oxidation FGD systems. It is theorized that other variables have a larger effect on metals concentrations. Other variables may include the reaction of sulfite with iron (whereas forced oxidation systems drive reaction to sulfate), oxidation may impact the chemical form of iron, and different reagents (magnesium-enhanced lime) and FGD chemistry (e.g. pH) in these older natural and inhibited oxidation systems.

This relationship includes FGD system waters before treatment, such as FGD slurry and hydroclone overflow and underflow. Once streams are treated, the relationship does not hold because the particulate iron is removed. The data include untreated FGD wastewater from multiple studies. Additional data are needed to further evaluate the potential impact of particulate iron on trace metals. It is recommended that a full mass balance of iron around an FGD system

be performed to understand the sources of the particulate iron associated with the mercury and selenium—as well as a multimedia study characterizing the fate and distribution of mercury and selenium in the FGD system.

There appears to be a direct correlation of particulate mercury to soluble mercury within the forced oxidation data set (Figure 3-13). This indicates that soluble mercury (as defined as passing a 0.45 micron pore size filter) is not "soluble" in the sense of individual ions of mercury, but rather includes particles that are smaller than the filter pore size. The higher the total particle concentration, the higher the particle concentration with particle size less than 0.45 microns and, therefore, reported as soluble. There did not appear to be a similar relationship within natural oxidation and inhibited oxidation FGD systems, as is seen in Figure 3-13. It is theorized that this is because these FGD systems have much higher concentrations of sulfite which may adversely impact iron precipitation with mercury and selenium, and/or natural/inhibited oxidation systems have more variability in their design and operation.

It appears from the data collected that there is also a relationship between the particulate iron and soluble mercury—but not a relationship between particulate iron and soluble selenium—in the untreated FGD water from limestone-forced oxidation FGD systems (Figure 3-14). The mercury relationship reinforces the theory that mercury is present as small iron-mercury particles rather than truly soluble mercury. If the reaction phenomena were primarily adsorption on iron particles, the relationship would be an inverse one. The lack of relationship between particulate iron and soluble selenium reinforces the theory that most of the selenium is present as actual soluble form. There was not a relationship between dissolved iron and mercury, nor dissolved iron and selenium.

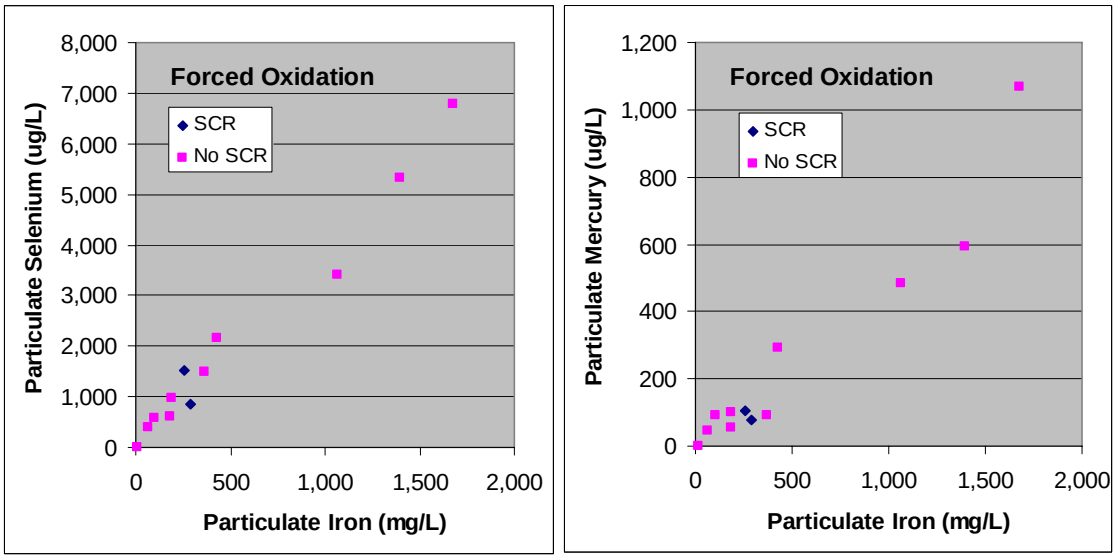


Figure 3-12
Particulate Selenium and Mercury Compared with Particulate Iron at Forced Oxidation Sites in Untreated FGD Wastewater

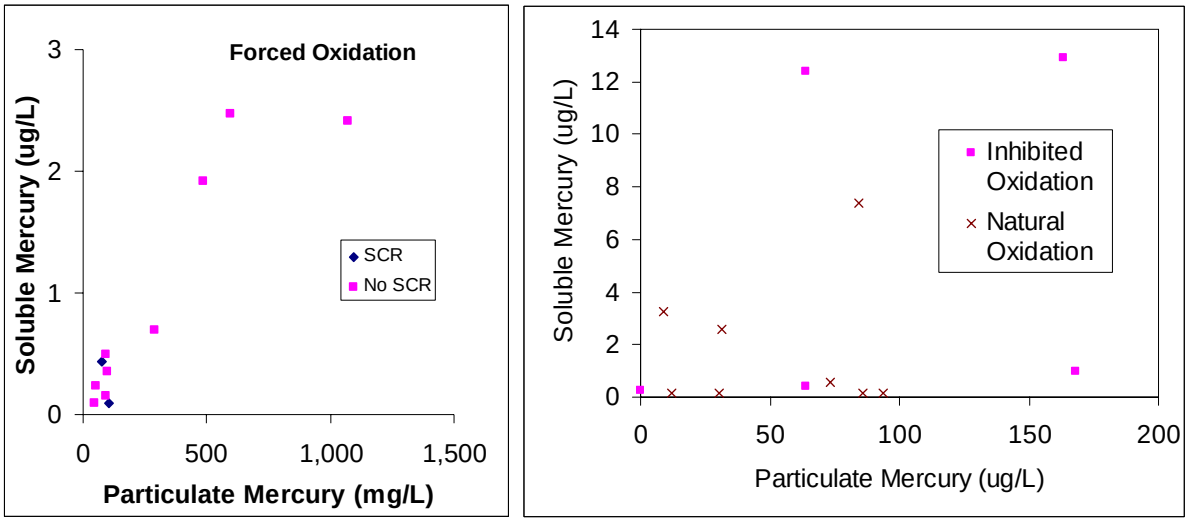


Figure 3-13
Soluble Mercury Compared with Particulate Mercury in Untreated FGD Wastewater

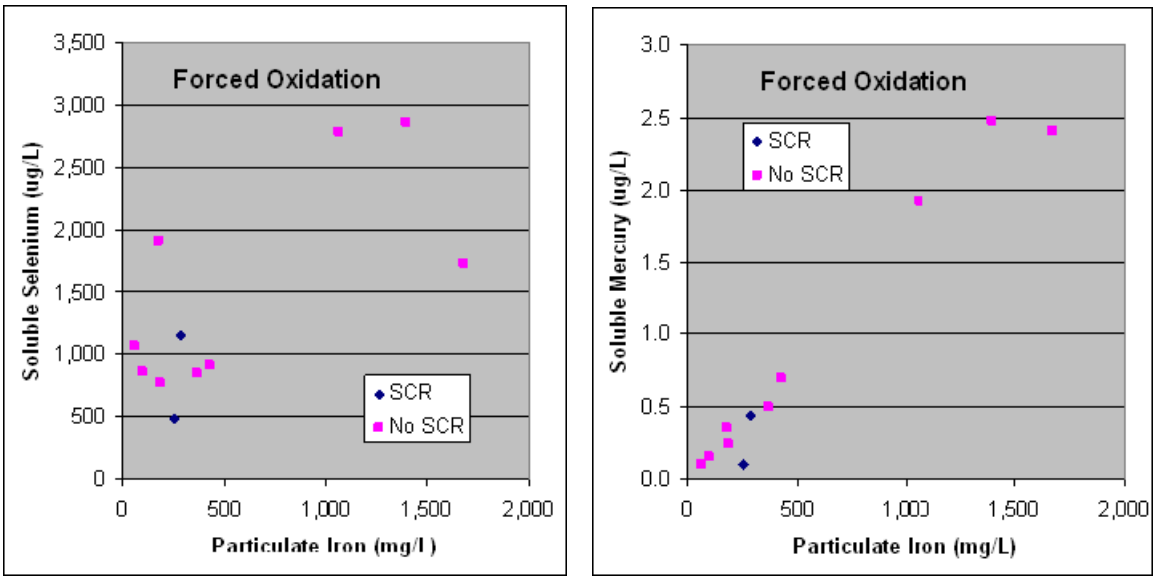


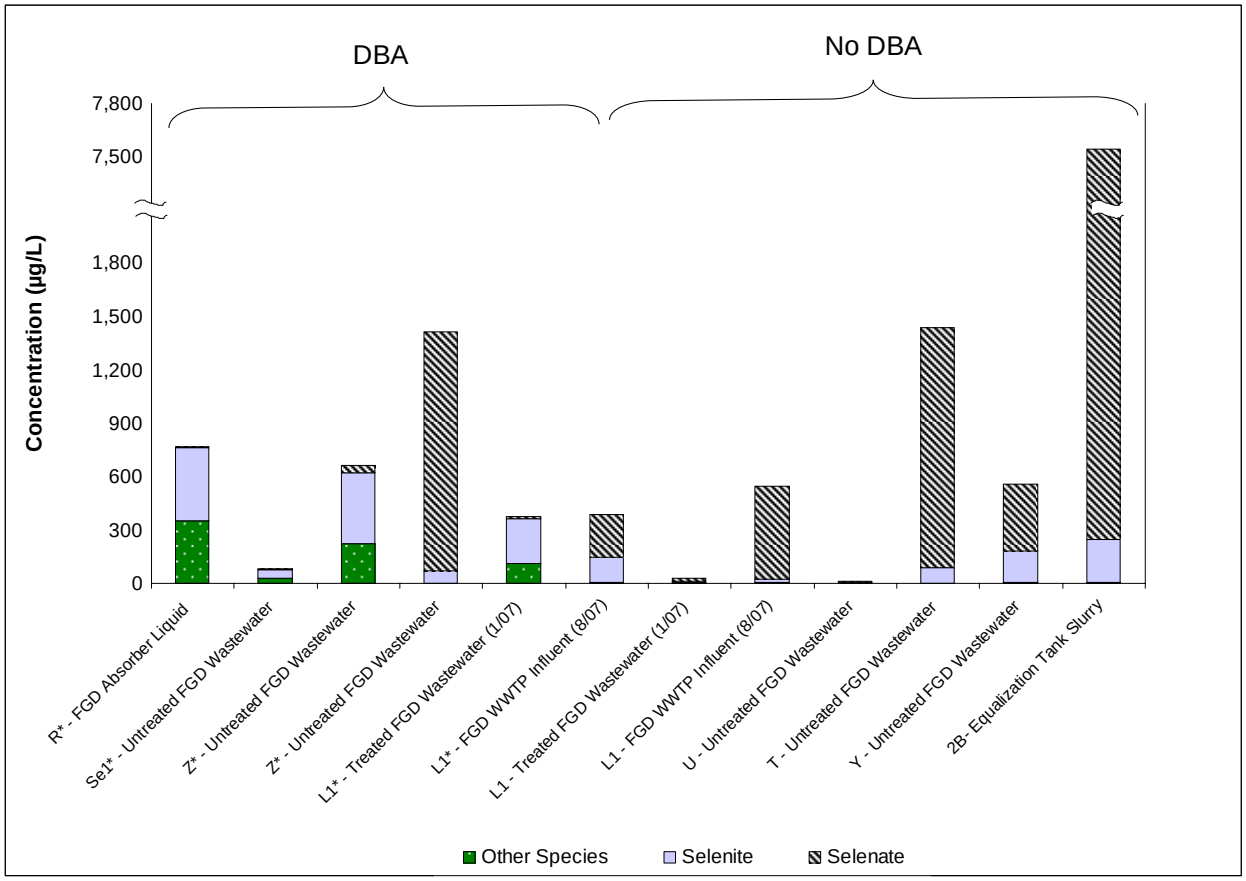
Figure 3-14
Soluble Selenium and Mercury Compared with Particulate Iron in Untreated FGD Wastewater at Forced Oxidation Sites

Whether Gypsum Must Meet Specifications for Sale

If gypsum produced in an FGD system is sold for wallboard production, it will likely be washed, thereby sending more fine particulate matter to the untreated FGD wastewater stream. If the wastewater is treated in a constructed plant, this could significantly increase the flow of solids that must be dewatered.

Effect of FGD System Additives on Selenium

Selenium in FGD absorber liquid and untreated FGD wastewater speciates into inorganic species (selenate and selenite) and organic species such as methylselininic acid [MeSe(IV)], selenium cyanide (SeCN), and selenomethionine (SeMe). As is shown in Figure 3-15, selenium speciation varied between sites with and without DBA, an organo-acid FGD system additive. Sites with DBA have significantly more of other species of selenium, which includes the organic species (MeSe(IV), SeCN, SeMe) and other species that were only identified by their peak on the chromatograph.



All Sites are forced oxidation except Sites U and R.

Only selenite and selenate were analyzed for at Sites T, and Z (treated FGD wastewater).
* = Site where DBA was added.

Figure 3-15
Effect of DBA on Selenium Speciation in FGD Liquid

Effect of Organo-acid Additive on Speciation of Inorganic Selenium

As seen in Figure 3-15, sites with DBA tended to have more selenate then selenite, while sites without DBA tended to have more selenite. However, Site Z was an exception to this tendency. Some of this variation may be caused by differences between sites, such as different coals. To isolate the variable of site differences, a comparison within one plant was made (Site L1). This study corroborated the trend of increasing selenite and decreasing selenate in the FGD system liquid waste stream when adding DBA. As can be seen in Figure 3-16, during DBA addition, the percentage of selenite increased and the percentage of selenate decreased. This is significant for wastewater treatment because, while selenite is toxic, it is easier to remove using traditional iron coprecipitation.

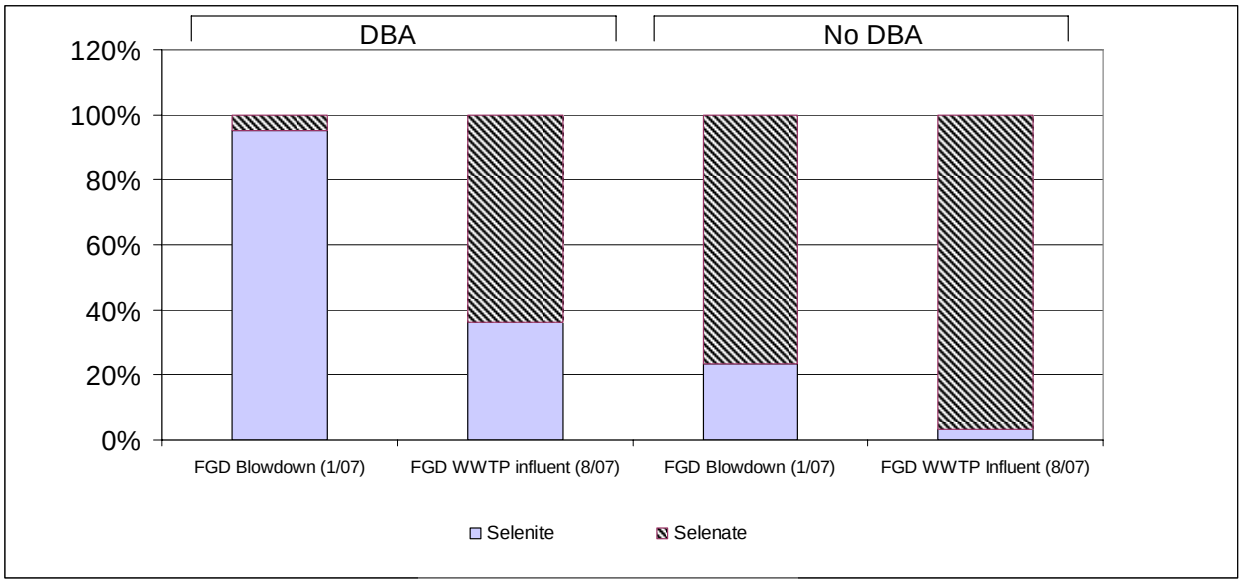


Figure 3-16
Effect of DBA on Inorganic Selenium Speciation in FGD Wastewater Treatment Plant Influent—Site L1

Effect of Organo-acid Additive on Speciation of Organic Selenium

DBA is an organic acid; it appears that its use creates organic forms of selenium as was seen in Figure 3-15, as well as other species that do not correspond with a known selenium compound. The MeSe (IV) concentration was higher when DBA was added. SeCN and SeMe were predominantly not detected in the untreated FGD wastewater. SeCN was detected at Site L1 in the FGD absorber liquid with DBA at 43 µg/L but not in the untreated FGD wastewater treatment plant influent or effluent. SeCN was also not detected in any of the samples without DBA at Site L1.

The treatability of these organo-selenium compounds and unidentified selenium compounds is not known. It appears that SeCN was reduced from the FGD absorber liquid to the untreated FGD wastewater effluent, but the MeSe(IV) was not. The FGD absorber liquid goes through a hydroclone or a thickener, which drops out solids, but the SeCN is dissolved so therefore this is not believed to be the treatment mechanism. It should be noted that the reduction in a Se species may not correspond to treatment, as it may also represent conversion to some other species present in the treated effluent.

Characterization of Treatment

Wastewater treatment plants and FGD ponds remove TSS and most associated particulate metals. However, ponds and treatment plants designed for solids removal do little to remove soluble metals, with the exception of precipitation of cationic metals under some pH conditions. This is shown in Table 3-3.

Aluminum and barium increase in concentration across the wastewater treatment plant at Site BLSFO2. Site BLSFO2 adds lime for desaturation which causes as increase in pH. Aluminum is more soluble at a higher pH. Also, lime can be added to lower the sulfate concentration. As the sulfate concentration decreases barium becomes more soluble and some of the particulate barium becomes soluble. This is a possible explanation for the increase in aluminum and barium at Site BLSFO2.

Aluminum and barium decreased at Site U which does not add lime. Site L2 does not add lime but aluminum increased across the treatment plant. The increase in aluminum at Site L2 is therefore more difficult to explain. Because only one grab samples was collected, there is the possibility that the effluent samples do not correspond with the exact sample at the influent. Composite and long-term sampling would help show if there is a consistent increase in aluminum across the wastewater treatment plant.

Table 3-3
Soluble Metals and TSS Across the Treatment Plant

Site Information	Dissolved Metal (µg/L)	FGD WWTP Influent	FGD WWTP Effluent
Site BLSFO2 **Primary Clarifier:** Yes. Lime, ferric chloride, sodium sulfide. **Secondary Clarifier:** Yes. Ferric chloride, sodium sulfide. **Filtration:** Yes **Biological:** Yes	Al	3.5	300
	Sb	11	8
	As	120	140
	Ba	520	860
	Cd	15	1.5
	Cr	40	37
	Cu	64	17
	Pb	4.4	0.5
	Hg	0.38	0.88
	Ni	1,500	50
	Se	1,300	680
	Tl	40	23
	Zn	860	130
	Mn	71,000	4,000
Site BLSFO3 **Primary Clarifier:** Yes. Lime. **Secondary Clarifier:** Yes. Ferric chloride, polymer. **Filtration:** Yes **Biological:** Yes	As	300	270
	Hg	1.3	1
	Se	6,200	3,800

Table 3-3 (continued)
Soluble Metals and TSS Across the Treatment Plant

Site Information	Dissolved Metal (µg/L)	FGD WWTP Influent	FGD WWTP Effluent
Site 2B **Primary Clarifier:** Yes. Lime, polymer. **Secondary Clarifier**: Yes. Organo-sulfide, ferric chloride, polymer. **Filtration:** Yes **Biological:** Yes	Hg	12	1.7
	Ni	960	<200
	Se	10,000	9,300
	Tl	120	<100
	Zn	670	<200
Site L2 **Primary Clarifier:** Yes. **Secondary Clarifier:** Yes. Ferric chloride, polymer. **Filtration:** Yes **Biological:** Yes	Al	1,300	2,900
	Cd	290	220
	Hg	0.52*	0.27*
	Ni	3,100	2,500
	Se	1,400	740
	Tl	240	170
	Zn	6,200	4,800
Site U **Primary Clarifier:** Yes. **Secondary Clarifier:** No. **Filtration:** No **Biological:** No	Al	400	<200
	As	16	11
	Ba	210	150
	Cu	140	45
	Hg	3.3	0.13
	Ni	170	47
	Zn	53	<40
	Mn	5,400	870
Site L1 (w/DBA) **Primary Clarifier:** Yes. Polymer. **Secondary Clarifier:** No. **Filtration:** No. **Biological:** No.	Se	690	670
	Zn	220	<200

* Associated MS had recovery below target range. Was 67% recovery.

As discussed in the previous section, treatment removes the forms of mercury and selenium speciation differently. The soluble mercury concentration increased through treatment while the particulate mercury concentration decreased (Figure 3-17). Therefore it is likely that particulate mercury is agitated into small fines that pass through the sampler's 0.45-micron filter and therefore are considered dissolved. This is important because particulate mercury is more likely to settle out during treatment than the dissolved mercury.

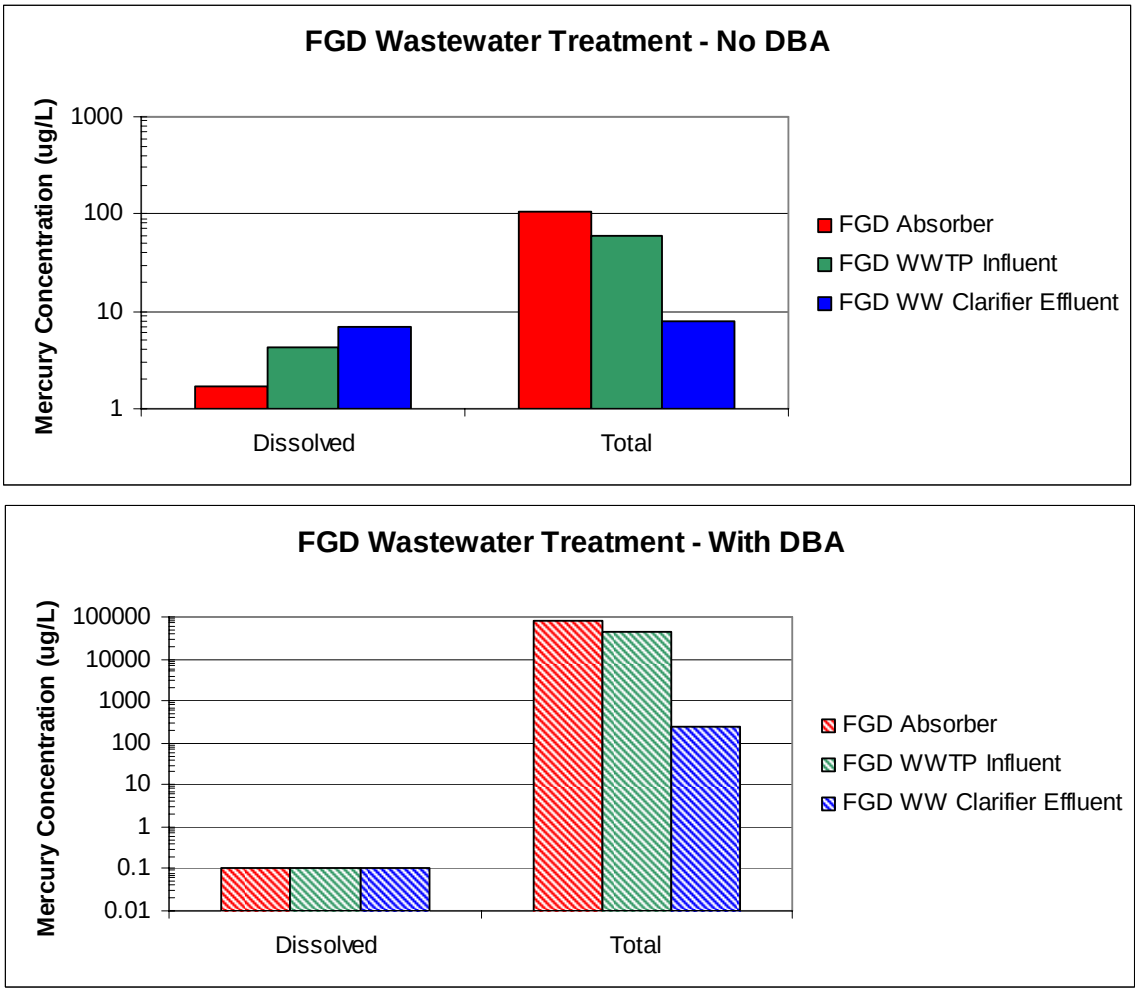


Figure 3-17
Treatment of Mercury at Site L1

The selenite concentration decreased through treatment while the selenate was not removed (Table 3-4). Selenite is easier to treat than selenate through precipitation. There appears to be an increase in the concentration of the selenate between the FGD absorber liquid and the FGD wastewater treatment plant influent and effluent. This may be explained by the effects of removal of solids from a very high solids solution with the selenate remaining in the liquid.

Treatment mechanisms for the organo-selenium compounds are not known. It appears that the SeCN was removed from the FGD absorber liquid to the FGD wastewater effluent but the MeSe(IV) was not removed.

Table 3-4
Selenium Removal across the Treatment Plant

		FGD Absorber Liquid	FGD WWTP Influent	FGD WWTP Effluent
Selenite	L1 (DBA)	305	140	48
	L1 (no DBA)	87	17	14
	2B (no DBA)	575	240	194
	U (no DBA)	Not available	4.3	1.0
Selenate	L1 (DBA)	96.4	240	320
	L1 (no DBA)	228	530	580
	2B (no DBA)	3820	7300	7900
	U (no DBA)	Not available	6.0	4.4

Lessons Learned while Performing FGD System Sampling and Analysis

Several lessons were learned during the various FGD system sampling and analysis efforts including:

- Plants vary significantly, so samplers must understand the FGD water system before sampling. It is imperative to understand the operation of the system in order to collect representative wastewater samples. If planning with site personnel is limited to the phone, it should be performed with process flow diagrams or other tools to clarify sampling locations.
- It is imperative to design proper sampling protocols in advance of any FGD system sampling. The protocols must also address proper techniques for preserving the samples until analysis.
- It is recommended that future samples be collected for wastewater as discharged (as was done in the Screening Study) but also at a point that can be standardized between facilities to allow cross-plant comparisons. Collecting liquid directly from the FGD absorber and filtering it on site is recommended.
- Determining which solids will settle and which will carryover into a plant's discharge if treatment consists solely of settling, is important to truly understand impacts of untreated FGD wastewater on a plant's discharge. This can be done by taking samples after a set period of settling. Settling time available will vary by site, but to provide a consistent data set for comparisons, a set time such as 1 hour is recommended. During the Screening Study [1] it was found that filtered samples had very similar concentrations as settled samples, so filtration can be used as a surrogate for determining what metals can be settled out. However, this raises a second issue of needing to understand the difference between small particles that pass a sampling filter and truly soluble metals. Small particles can be removed by membrane filtration; soluble metals cannot. If goals of a site study include treatability, a range of filter sizes should be used to understand particle size distribution of target metals. This has primarily been a concern with mercury but is also believed to occur with other cationic metals as well.

- Trace metals analysis of coal is important to many of the relationships evaluated. These data should be collected when characterizing untreated or treated FGD wastewater. It should be noted that changes in the composition of the coal due to combustion are potentially significant. If budget and time allow, the FGD reagent should also be characterized.
- Wastewater flow information is important to understanding the mass loading of metals. Flow information should be collected whenever characterizing untreated or treated FGD wastewater. Instantaneous flow rate is not as important as average daily discharge. The average should be taken over a period similar to the residence time of water in the FGD system.
- Analysis of untreated or treated FGD wastewater is very complicated due to the high salt concentrations in the sample, which can result in matrix interferences in the trace metals analysis procedure. The easiest approach to address this type of matrix interference is dilution of the sample prior to analysis, which reduces the concentrations of solids, salts, and ions. Sample dilution increases the method detection limit and reporting limits for all parameters, and this may be a concern since the trace metals often of interest in a wastewater study (e.g., arsenic, selenium, copper, mercury) are often present at much lower concentrations than some common interferants (e.g., calcium, chlorides, sulfate). The laboratory method detection limit and reporting limits must be considered, along with the estimated dilution necessary, to avoid matrix interference in assessing whether dilution will be an acceptable approach to addressing matrix interference.
- Matrix spike and matrix spike duplicate samples should be run whenever FGD waste streams are submitted. Untreated or treated FGD wastewaters can differ greatly in their composition and, therefore, in their matrix effects, so it is not sufficient to batch their quality control with other samples at a laboratory.
- EPRI is evaluating means to avoid or minimize sample dilution, both in conventional inductively coupled plasma analysis as well as through dynamic reaction cell (DRC) technology. DRC allows for use of a reaction gas, such as ammonia or methane that can reduce interferences. It is recommended that this technique undergoes further evaluation.
- Laboratories should be warned ahead of time of the complexity of the FGD system matrix. This will facilitate proper preparation for analysis, as well as help protect laboratory instrumentation from the high-solids, high-salt matrix.
- Because it is known that potentially-interfering elements are present in some waste streams at significant concentrations, it is strongly recommended that:
  - Laboratories be notified that certain waste streams are likely to contain high concentrations of interfering elements by a notation on the chain-of-custody record.
  - Laboratories be requested to ensure current interelement correction factors are sufficient for the subject matrices and, if not, the laboratories be required to re-establish correction factors specific to the waste streams submitted for analysis. At a minimum, the sufficiency of the current factors should be evaluated by running a matrix spike on each of the sample matrices (especially the untreated FGD wastewater). If matrix spike recoveries are outside data quality requirements of the test method and the EPA program Quality Assurance Project Plan, the interelement correction factors should be re-established specifically for the waste streams.

  - Physical interferences associated with the subject waste streams are mainly solids that can interfere with sample transport into the nebulizer. In addition, the presence of high concentrations of salts may also interfere with sample analysis by deposition on the nebulizer. Some of the subject waste streams contain both high chloride and solids concentrations (see Table 1). Recent untreated or treated FGD wastewater samples analyzed at CH2M HILL's Corvallis laboratory for an EPRI study required dilutions up to 1 part in 100 to reduce these types of physical interferences. Future work should consider biphasic separation (extracting the solids from the liquid) in analyzing FGD wastewater, especially for samples containing more than 1% solids. Both the solids and liquid are digested and analyzed separately.
  - It is also recommended that the use of the internal standard method be considered. The internal standard method is based on adjustment of the response of a non-target analyte such as yttrium or scandium to mitigate the effect of physical interferences.
  - To obtain valid matrix spike/matrix spike duplicates, it is necessary to spike the matrix at a level between 1 and 5 times the native concentration. In order to better target these levels, it is recommended that the laboratory conduct a prescreening analysis and tailor the levels of individual elements in the spiking solution to achieve the desired concentrations.

- EPRI conducted a separate study of arsenic and selenium speciation and found that results for the same waters vary, sometimes significantly, between laboratories. The arsenic and selenium speciation methods used in the FGD system studies varied. In the screening study, Sites R and U used the inductively-coupled plasma mass spectrometry (IC-ICP-MS) method, while Sites S and T used the hydride method (USEPA 1632). The latter method is not capable of accurately measuring the various forms of organic selenium that may be present in some untreated FGD wastewaters.

4
ASSESSING THE IMPACT OF FGD WASTEWATER ON PLANT WASTEWATER MANAGEMENT

This chapter describes how a power plant installing an FGD system can assess its impacts on the overall plant wastewater system. This topic was covered in depth in the *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers (TR*-1013313) [2], and is only summarized here.

Evaluating FGD Wastewater Management Options

In deciding how to manage and route the untreated FGD wastewater, a plant must consider the projected discharge characteristics against current and projected limits. Metals limits vary, and projecting future limits may be difficult. However, all steam electric plants have 30 mg/L TSS limits due to Categorical Effluent Standards of Title 40 Code of Federal Regulations 423; therefore TSS removal is a factor for all plants to consider.

Evaluating Solids Removal in Ponds

Both dedicated FGD wastewater ponds and ash ponds used for treatment of ash and FGD wastewater are options for treating untreated FGD wastewater. Results from treatability tests [2] show that a dedicated FGD wastewater treatment pond could achieve typical TSS discharge limits if sufficient settling time is provided.

Treatability studies conducted on four untreated FGD wastewater samples to determine the pond overflow rates (defined as the ratio of the ash pond discharge divided by the area of the ash pond) required to achieve TSS removal to 30 mg/L, the categorical standard, showed that the overflow rates that were required varied between 0.4 and 1.3 million gallons per day per acre [2]. The lower the overflow rate, the better settling a pond can achieve. The differing results illustrate the significant variation in the fines in various FGD systems.

The untreated FGD wastewater is saturated with calcium sulfate. It appears that dilution results in the dissolution of calcium sulfate particles. Ash pond water is not saturated in calcium sulfate and will dilute untreated FGD wastewater if it is routed to an ash pond. The large gypsum particles settle fast, leaving smaller particles that appear to be selectively dissolved, making them smaller and slower to settle. The dissolution was evident in an increase in the sulfate, fluoride, and total dissolved solids in the combined water over and above that predicted from mass balance of the constituents in the two liquids.

This is not to say that co-treatment is not feasible, in fact it is being used at several facilities successfully. However, the reduced settling rate and release of these salts need to be considered when using an ash pond for FGD wastewater treatment for suspended solids removal.

Evaluating Metals Removal in Ponds

A range of expected metals concentrations for effluent from dedicated FGD ponds is summarized in past EPRI work [2]. Trace metals and anions that do not settle in an FGD pond will be present in pond effluent. Those metals of primary concern will be dictated by a site's limits, which are typically set based on the receiving water body's capacity for given metals without degrading its classified uses. Typical parameters of concern include arsenic, mercury, selenium, copper, fluoride, and whole effluent toxicity caused by the salts. Other metals are occasionally found to be issues.

Operational Considerations in Routing FGD Wastewater

Issues other than environmental compliance caused by addition of a untreated FGD wastewater stream were discussed in past EPRI work [2].

5
FGD WASTEWATER MANAGEMENT

This section discusses the various options for managing and discharging FGD wastewater. The function and basic design elements of FGD wastewater treatment processes was discussed in Section 4 of the *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers (T*R-1013313) [2].

Discharge Options for Wastewater

FGD wastewater from a wet FGD system can be recirculated for reuse in the FGD system or elsewhere in the power plant, discharged to a receiving water body or deep well, or reduced in a zero-liquid discharge system such as ponds from which the effluent is reused in the power plant. All of these discharge alternatives will require some treatment. Treatment options include co-management in an ash pond, a dedicated pond, or a constructed treatment system. Constructed systems can be designed to remove suspended solids only, or can include additional treatment processes to further remove trace metals.

Disposal Options for Solids

Solids from FGD systems can be grouped as coarse particles (consisting mainly of gypsum) and fine particles that are removed during treatment of FGD wastewater. Gypsum that is collected from FGD systems can either be sold or landfilled. Fines collected from blowdown treatment are typically landfilled. FGD wastewater treatment with ponds results in solids accumulation within ponds.

Practices and Issues—Upfront Planning Issues

FGD systems and wastewater treatment are closely linked. Eliminating all fines from gypsum dewatering can reduce sizing of a vacuum belt, but can greatly increase the load on wastewater treatment, and increase capacities required for solids dewatering equipment. Care must be taken not to introduce too high a fines content to the FGD system's gypsum dewatering system as this will affect the ability of the gypsum dewatering process to achieve the desired moisture content. Designs must also account for the tendency of hydroclones to become less effective with age at cleanly separating solids by size.

The FGD system and FGD wastewater systems should be coordinated closely to capitalize on the combined capacity of the overall system. Wastewater treatment requirements should be coordinated throughout FGD system planning, design, and construction. Treatment may be a fraction of the size of the FGD system, but normal construction requires about the same time as

the FGD system or premium charges will apply. In addition, the time period required for startup of FGD wastewater system should be considered during planning stages to account for up to several months of startup prior to normal operations.

Untreated FGD wastewater varies significantly. FGD system characteristics vary also during the life of the plant due to coal changes and regulatory requirements, so a treatment plant needs to be flexible to allow adjustments or additions to treatment processes throughout the life of the plant.

It is also important to consider life cycle costs in implementation of a constructed FGD wastewater treatment system. A system with low capital costs may produce a wastewater that is difficult to treat and may involve high costs for long-term operations. Space requirements should also be considered during planning to ensure that systems are not undersized due to space constraints. Adequate contingency storage should be planned for startup and upsets during operations of the system.

Another consideration of treatment system design is to keep the process control system within the plant simple. Control screens should be created using terms and methods with which plant operators will be familiar.

Practices and Issues—Technical

Pond Management

Untreated FGD wastewater is treated either by constructed wastewater treatment or settling within one or more ponds. A large area is required for adequate storage capacity for accumulation of solids. Construction of a settling channel or pond leading to the main pond can be useful for management of solids. At one plant that employs settling ponds for FGD system wastewater treatment, it has been observed that the majority of solids settling in FGD system wastewater occurs within a long channel leading to a settling pond. Solids within this channel are periodically collected and landfilled. It is important to provide a quiescent area for bulk removal of solids rather than allowing the main FGD system wastewater stream to go directly into the pond to preserve the life of the pond by minimizing solids accumulation within the pond itself. Use of ponds may therefore be a best practice for FGD system wastewater as it can be a cost-effective method of solids settling. The ability to use ponds will be based on space available and, if solids are to be hauled away after settling, on disposal requirements for the solids such as minimum percent solids accepted by landfill. EPRI research to date has not focused on best practices regarding management of FGD system wastewater treatment ponds; this may be the focus of future research. The remaining section focuses on current practices associated with constructed FGD wastewater treatment systems.

Constructed FGD Wastewater Treatment

A typical constructed FGD wastewater treatment system is shown in Figure 5-1. Table 5-1 provides typical design criteria for each of the treatment units. The function and basic design elements of each unit processes was discussed in Section 4 of the *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers (TR-10*13313) [2]. The sections below build on that information to provide, to the extent possible, at this early stage of FGD system development, a summary of best practices for the design and operation for the unit processes.

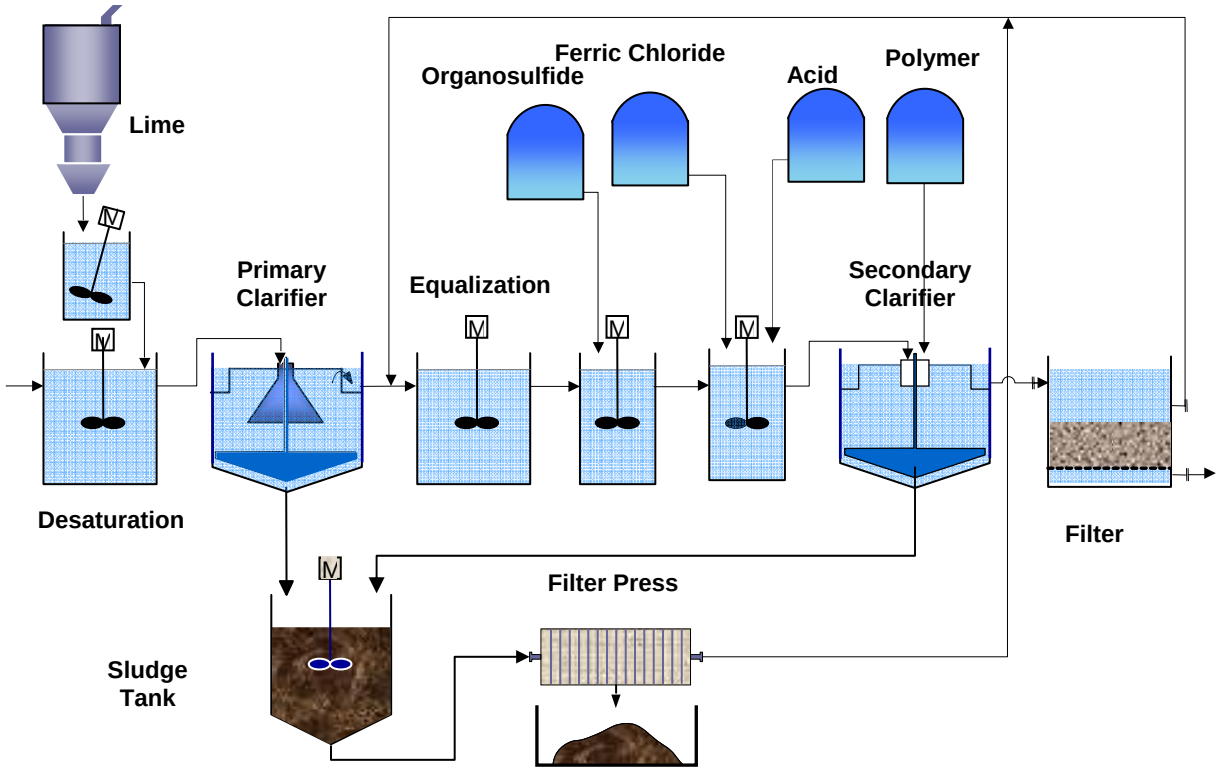


Figure 5-1
Typical FGD Wastewater Treatment System Process Flow Diagram

Table 5-1
Typical Loading Rates for FGD Wastewater Treatment

Equipment	Design Criteria	Sizing
Desaturation Tank	Target pH	8.5
	Lime Dose, ppm	1,500 - 2,500
	Hydraulic Detention Time, Minutes	50
Primary Clarifiers/Thickener	Overflow Rate Peak, gpm/sf	0.50
Organosulfide Mix Tank	Organosulfide Dose, ppm	10
	Hydraulic Detention Time, Minutes	30
Ferric Chloride Mix Tank	Ferric Chloride Dose, ppm	100
	Hydraulic Detention Time, Minutes	20
Secondary Clarifier	Overflow Rate Design, gpm/sf	0.33
Gravity Filters	Media	Anthracite and Sand
	Hydraulic Loading Rate, gpm/sf	3
	Backwash Rate, gpm/sf	20
	Backwash Duration, Minutes	15
Plate and Frame Filter Press	Feed Solids Concentration	10% - 20%
	Minimum Dewatered Solids	40%
	Preferred Dewatered solids	60%
	Solids Capture Efficiency	99%
	Cycle Duration, hour	2

Notes:

ppm = parts per million.
gpm/sf = gallons per minute per square foot

Gypsum Desaturation

Untreated FGD wastewater tends to be supersaturated with gypsum. The tendency of the gypsum to continue precipitating can result in significant scale formation on surfaces of treatment units, such as the overflow weirs of clarifiers and the insides of pipes (Figure 5-2). To reduce the tendency of the water to scale, the water is typically treated with lime ($Ca(OH)_2$) to reduce the concentration of sulfate by precipitation of calcium sulfate. Desaturation is performed as soon as possible to take advantage of the reduced solubility of gypsum at elevated temperature (Figure 5-3).

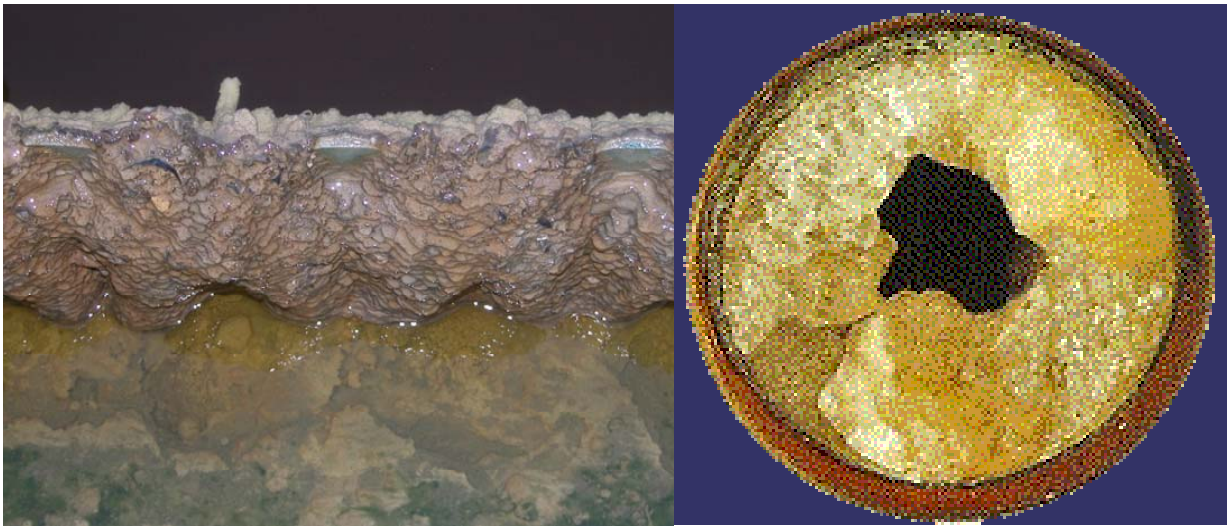


Figure 5-2
Mineral Scale Formation on Clarifier Overflow Weir and Process Piping

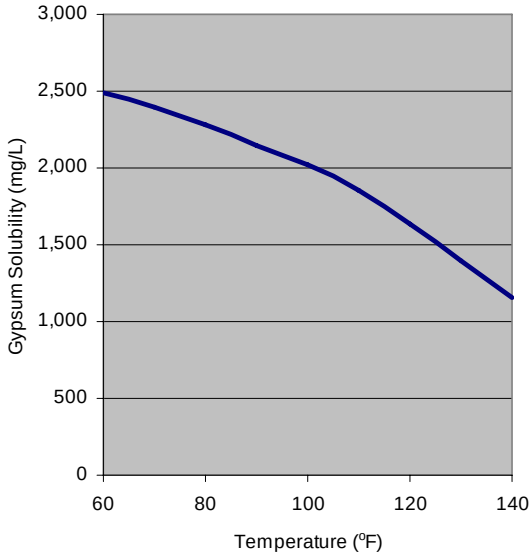


Figure 5-3
Effect of Temperature on Gypsum Solubility

The goal of desaturation is to reduce the concentration of sulfate without precipitation of a significant amount of calcium carbonate. At laboratory temperature, the pH that results in the maximum desaturation without significant calcium carbonate precipitation is about 9.2. However, as the temperature rises, the solubility of calcium carbonate also decreases (Figure 5-4). The result is that the same dose of lime that would achieve a pH of 9.2 in the laboratory will only raise the pH of the FGD wastewater to around 8.2 or 8.4 at 130 degrees. It is therefore advisable to perform jar tests of desaturation at the temperature expected in the

desaturation tank, rather than relying on laboratory tests performed at lab temperature. This can be done by running jar testing in a water bath (Figure 5-5). If purge water tanks are located outdoors, the wastewater temperature can vary considerably from winter to summer, and the dose or pH setpoint should be adjusted accordingly. Even though pH setpoint is a convenient way of controlling calcium dosing, the lime dosage is the important control.

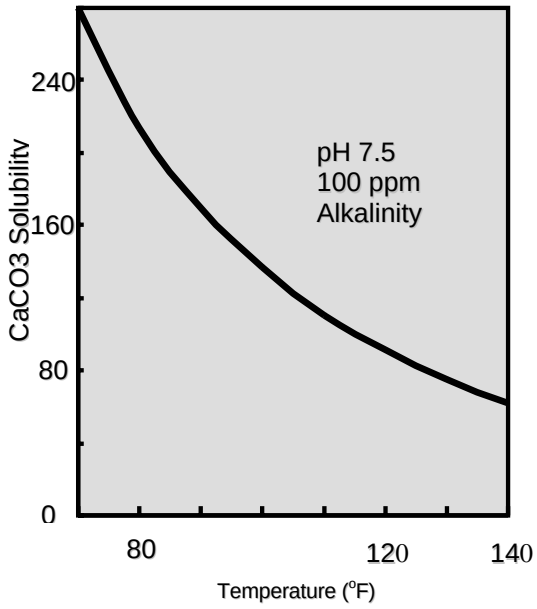


Figure 5-4
Effect of Temperature on Calcium Carbonate Solubility

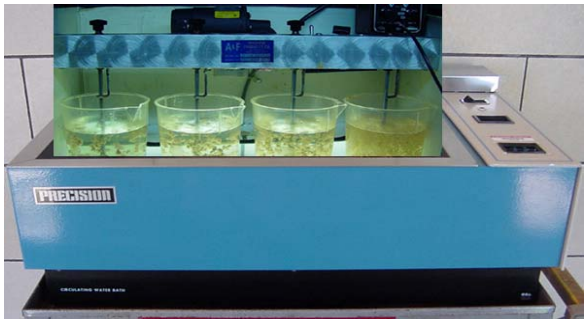


Figure 5-5
Perform Jar Testing at Operating Temperature

Desaturation may not be feasible if the sulfate concentration of the untreated FGD wastewater is high. One FGD system produced a wastewater with soluble sulfate concentration of between 20,000 and 30,000 mg/L of soluble sulfate, probably due to burning low sulfur coal with very low chloride content. Low chloride content results in less hydrochloric acid to neutralize in the flue gas, resulting in less calcium dissolved from the limestone. With this concentration of dissolved sulfate, it may not be feasible or desirable to desaturate the water, as the resulting calcium demand will be too great to satisfy with lime, and a large quantity of gypsum and calcium carbonate sludge would be generated.

Recycling of sludge from the primary clarifier has been found to be beneficial in gypsum desaturation. Recycling encourages crystallization of gypsum, and growth of particles. The fine particles get a second chance to grow by fresh precipitation of calcium sulfate on its surface or combines with other particles to form larger agglomerates. Figure 5-6 shows the result of sludge recycle on the particle size distribution in the desaturation reactor treating wastewater from a limestone forced oxidation FGD system. It is important to note that particle size distribution is by number of particles. Before recycle (blue lines), the volume of particles below 20 microns in size constituted 2 percent of the total volume of particles (Figure 5-7). After recycle (pink lines), this was reduced to 0.2 percent. Moreover, since the growth of the smaller-size particles resulted in a reduction in the total number of particles by 75 percent, the net result is a reduction in the volume by 98 percent. This reduction in particles of the smaller size results in improved clarifier performance and sludge dewaterability.

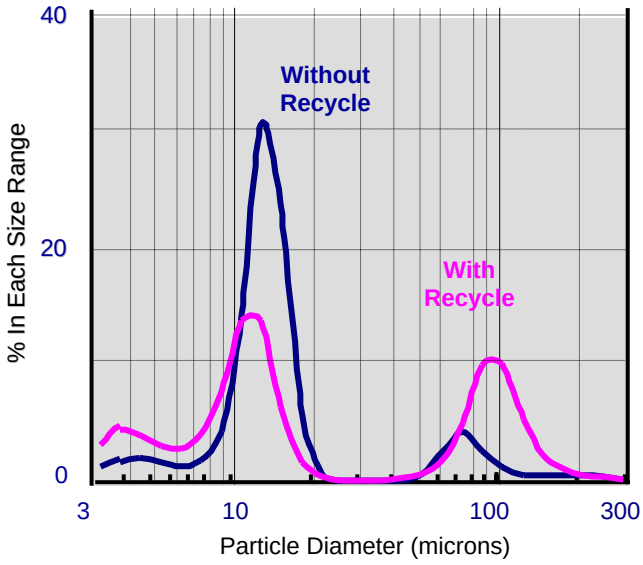


Figure 5-6
Effect of Primary Sludge Recycle on Desaturation Particle Size Distribution by Number

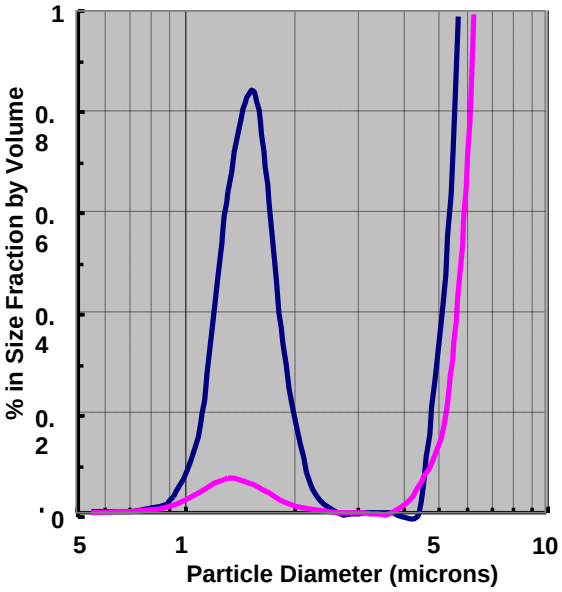


Figure 5-7
Effect of Primary Sludge Recycle on Desaturation Particle Size Distribution by Volume

General Plant Design—Piping Layout and Mixing

Piping layout is critical when dealing with high solids wastewater, particularly since gypsum solids have a tendency to cement to each other. In earlier designs, wastewater either entered or exited the bottom of the reactor to avoid short-circuiting of the reactor. If the effluent leaves from the top of the tank, there will be a tendency for larger particles to build up in the tank. One problem with this arrangement (Figure 5-8) is that after shutdown, the solids in the pipe settle in the pipe. This is particularly a problem in vertical sections of the pipe, as solids from the entire vertical section of pipe can settle to the elbow and plug it there.

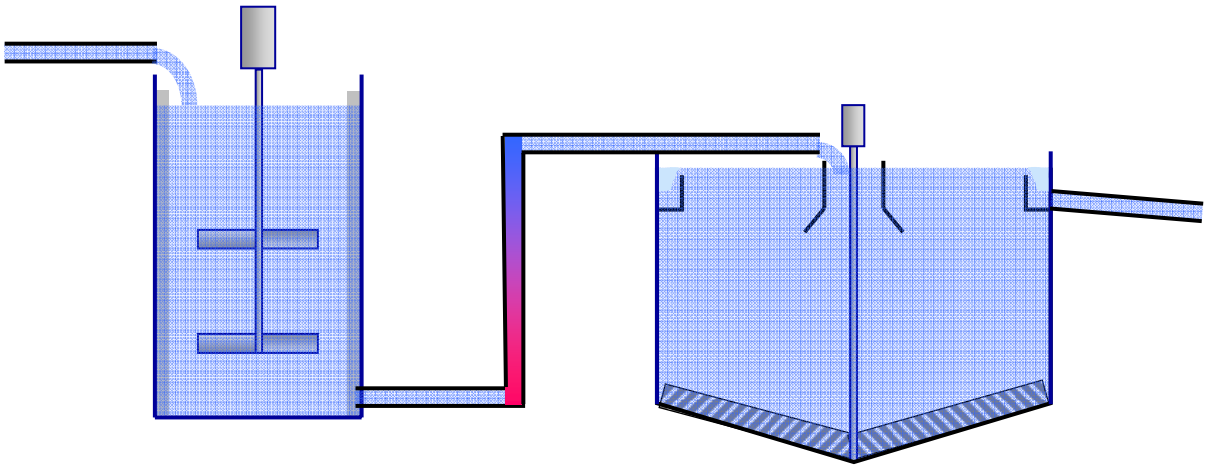


Figure 5-8
Connecting Desaturation Tank with Primary Clarifier with Submerged Pipe

The problems of short-circuiting, settling in pipes and particle stratification can be reduced if a dip tube is employed for the outlet (Figure 5-9).When the flow is stopped, solids in the dip tube (shown in red on Figure 5-9) drain into the tank. By using a gravity pipe that discharges to the primary clarifier's center well above the water level, the pipe will flow at less than full maintaining a velocity that is higher than if the pipe flows full with a submerged outlet. The pipe is also self-draining when flow is shut down, reducing the potential for solids plugging.

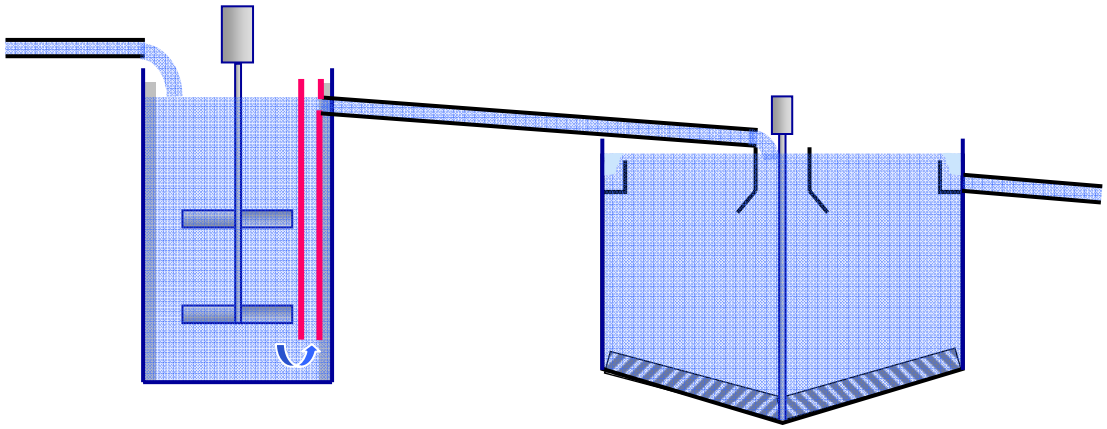


Figure 5-9
Connecting Desaturation Tank with Primary Clarifier using Dip Tube (red) and Gravity Pipe

Mixing is critical within all mixing tanks in the process. If mixing is insufficient, larger particles settle out resulting in adversely affecting chemical mixing and pH control. If there is too much mixing particles shear will result, reducing effectiveness of downstream removal. Higher speed mixers can be used in traditional chemical mix tanks, where hydraulic detention times are less than one minute, but most of the reaction tanks in an FGD system have design hydraulic detention times from 20 minutes to an hour, which means much higher times at low flow rates. It is desirable to have two impellers, as shown in Figure 5-9, and that the impeller be as large a diameter as possible, and with minimum tip speed. Radial flow impellers (Figure 5-10) or axial flow impellers designed specifically for low shear flocculator applications should be employed. Impeller tip speed should be limited to less than 3 feet per second. It is desirable to have a mixer with variable speed so that the mixing intensity can be adjusted during startup to the optimum balance between mixing intensity and particle shear. Where a variable speed mixer is used, then adequate mixing for solid suspension should be achieved at the midpoint of speed. Baffles are needed for circular mixing tanks to eliminate the tendency of the mixed fluid to simply rotate.

Figure 5-10
Axial Flow Flocculating Mixer

Primary Clarification

Untreated FGD wastewater can vary widely in suspended solids, depending mainly on the methods chosen for gypsum dewatering by the FGD system vendor. Mechanical dewatering has employed centrifuges and rotary vacuum drums in the past, although vacuum belts are typically employed today. To attain low moisture content in a large-capacity gypsum dewatering system, the purge water is first treated to remove fine particles of immature gypsum crystals, clays, and other inerts using a single-stage or dual-stage hydroclone. Where single-stage hydroclones are used and gypsum is to be sold, the hydroclones may be set to minimize fines in the underflow, resulting in TSS in the wastewater (hydroclone overflow) as high as 7 percent. Where gypsum solids are to be disposed and secondary hydroclones are employed, TSS can be less than 2 percent in the wastewater (secondary hydroclone overflow). The treatment plant designer must account for the effect of aging on hydroclone efficiency. At one plant, the overflow TSS measured in excess of 10 percent in overflows when the hydroclones drifted out of calibration.

Where gypsum dewatering is carried out using a stacking pond–that is, a pond where the gypsum solids are deposited and dredged into piles for gravity drainage–the ponds will remove a large portion of the wastewater TSS, and the wastewater (overflow from pond) appears to have TSS much less than 2 percent. A general rule of thumb has been to use a primary clarifier if the TSS in the wastewater is ever going to be greater than 2 percent. If stacking ponds are employed, primary clarification may not be required. If hydroclones are used to separate fines from the purge water, then treatment should include primary clarification.

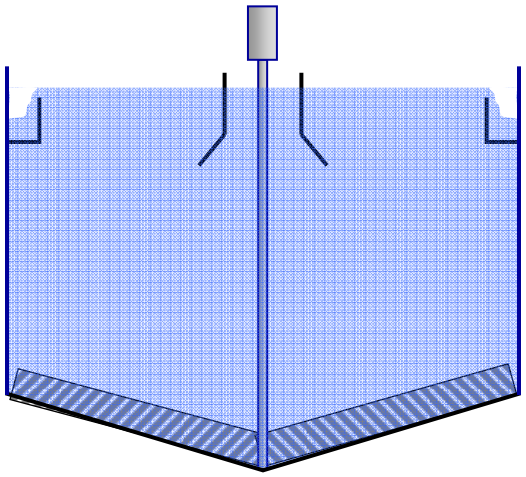


Figure 5-11
Primary Clarifier

Primary clarifiers for FGD wastewater treatment are designed as sludge thickeners, with a steeply-sloped floor and high torque mechanisms (Figure 5-11 and Figure 5-12). It is more desirable to have high torque capability than to have a clarifier rake mechanism lifter, as the properties of lime gypsum sludge is to form a solid that may set before the mechanism can be lowered and restarted.

The goal of primary clarification is not to remove all suspended solids, but rather to reduce TSS to less than 1,000 mg/L so that subsequent treatment can be optimized to remove the remaining solids and other parameters (metals) to be removed.

Optimally, solids should thicken to approximately 10 to 20 percent solids in the underflow from the primary clarifier/thickener. Less than 10 percent solids can result in poor dewatering, high moisture sludge cake, and sticking of sludge to filter cloths, and can result in increased operator attention and long cycle times. If sludge is greater than 20 percent solids, dewatering will be hampered by poor distribution of sludge to a filter cloth and plugging of sludge distribution piping. Overthickening can be prevented by controlling sludge recycle rate or sludge wasting.

Clarifier performance and solids density can be improved by recirculating sludge from the primary clarifier back to the desaturation tank to promote growth of particles as gypsum is precipitated when lime is added. Variable sludge recycle rate is desirable, as too much recycle can result in solids overloading of the clarifier, particularly if the wastewater predominately consists of particles that are less than 20 microns in diameter. Initial operation may be at low recycle to avoid overloading the clarifier with solids, and the flow rate may be increased when a denser sludge is produced. It is desirable to flush the sludge lines when the sludge pumps are shut down to reduce the tendency of these lines to plug.

Figure 5-12
Primary Clarifier with Gravity Inlet

Recycle sludge pumps should be low-shear to reduce the tendency for breaking up sludge solids. The purpose of sludge recycle is to grow larger particles to improve settling and sludge dewatering. Of the various choices for recycle pumps, positive displacement/hose pumps are the best choices for sludge recycle. Conventional centrifugal pumps create too much shear for this application. Centrifugal pumps with recessed impellers have been employed in this application, although flat pressure/head curve results in low suction head. Progressive cavity and air-operated diaphragm pumps operation results in excessive wear and low service life for sludge recycle due to the high abrasiveness of the solids. Positive displacement pumps have the ability to produce a high head if needed to open a plugged line while creating low shear. Hose pumps appear to be well suited for the low-flow recycling of sludge because only the hose is in contact with the abrasive and corrosive sludge (Figure 5-13). The main disadvantage of a positive displacement hose pump is the large size due to the low rotational speed recommended to extend hose life.

Figure 5-13
Positive Displacement Hose Pump

Clarifier performance can also be enhanced by addition of polymers. It is therefore prudent to include a flocculation well in the primary clarifier and to provide the ability to add polymer at this point. This may not be needed based on effectiveness of sludge recycle to promote a dense sludge. Care must be taken not to overfeed polymer as this can cause blinding of filter press cloths. Polymer addition should be considered to be supplemental to achieving a dense, fast-settling particle through sludge recycle and use of low-shear sludge pumping and reactor mixing. Polymer addition optimization (use of high-speed mixing) should not be at the expense of the generation of dense sludge. Polymers capture solids but tend to trap water in the resulting matrix, thereby reducing the density of the resulting sludge.

Primary clarifiers must be sized for solids holding capacity as well as for hydraulic overflow. Peak overflow rate of 0.5 gallons per minute per square foot (gpm/sf) with one unit out of service (for more than one treatment train) seems to be sufficient for solids settling, but may not provide enough sludge storage, particularly when treating high-solids wastewater with low sludge densities. Sludge wasting should be based on density of the sludge (maintaining this between 10 and 20 percent for optimal dewatering). Sludge level measurement seems to be of limited usefulness, as there is a broad range of densities that look the same to the eye or to an optical instrument. Measuring sludge density at a fixed depth would be more useful in controlling sludge wasting.

Equalization

Equalization serves three functions in wastewater treatment. Equalization reduces the variability of flow, which reduces the loads on treatment processes and enables the use of smaller treatment systems than would otherwise be required to handle peak loads. Equalization also reduces the variability of wastewater composition, further improving stability of treatment processes particularly when chemical additions are needed to respond to changing requirements. Finally, equalization allows for storage of intermittent internal wastewater flows.

Traditionally, equalization is placed at the beginning of a treatment train, and this is the case at most FGD wastewater treatment plants. Providing equalization prior to primary clarification has some benefits, including providing a constant flow to the desaturation tank with sludge recycle. Loading of the primary clarifier with solids over a short period of a day also adds difficulty to control of sludge solids and dewatering. Where the FGD system is located some distance from the wastewater treatment plant, it is desirable to locate any purge water storage (for equalization) at the FGD system and then pump a continuous flow to the wastewater treatment plant. If initial equalization is considered, it should be compared to the advantages of increasing volume for primary clarification, as increasing primary clarifier volume increases volume available for sludge storage and thickening, as well as increasing hydraulic capacity.

Where purge flows are expected to be fairly constant, it can be desirable to locate some equalization volume after primary clarification. For FGD systems where purge solids are high, the internal recycle streams (filter backwash water, filter press filtrate, filter press cloth washwater, stormwater from process areas, washdown and floor drain water, sludge line purge water, etc.) can be greater than the purge flow, with much of the water returned as relatively low solids filtrate. If returned to an initial equalization tank, this flow increases the hydraulic load on

desaturation and primary clarification, eliminating the load reduction gained by putting in an equalization tank and diluting the solids that must be thickened again.

By desaturating FGD wastewater before equalization, the water can be treated at a warmer temperature, where solubility of gypsum is lower. After cooling, increased solubility of gypsum reduces subsequent scaling potential. Moreover, if low salt wastewater streams (such as stormwater, filter cloth washwater, and floor drain and washdown water) are introduced after desaturation, the scaling potential is further reduced.

It is also desirable to provide for flushing of pipes containing high solids when flow is shut down in these lines. This can be automated using a flushing water system and control valves. If equalization is placed after primary clarification, then this relatively low solids water can be used for flushing, with “dirty flushwater” returned to this equalization. This practice results in the water not having a hydraulic load on the treatment units, as would be the case if final effluent (or plant water) were used for this purpose and were returned to an initial equalization tank.

Therefore there may be significant advantages to splitting equalization before and after desaturation and primary clarification. This would be a balance between the cost of providing the same volume of equalization in two tanks as compared to the reduced cost in primary treatment due to not having to return filter press water to the head of the plant. Equalization is best designed in conjunction with the gypsum dewatering system, rather than treating it as an independent process within wastewater treatment. Equalization should be designed to provide continuous flow to the treatment plant. Internal recycle flows are better directed to an intermediate equalization tank; however, ultimately, either can be modified effectively.

Chemical Addition to Promote Metals and Suspended Solids Removal

Metals in untreated FGD wastewater are present in a soluble or particulate form. Soluble fraction is somewhat arbitrarily defined as that which passes through a 0.45-micron membrane filter and consists of those species that are present as single ions or molecules that are truly dissolved, as well as (colloidal) particles that are smaller than 0.45 microns. The 0.45-micron filter was developed for microbial analysis as capturing all bacteria, and the filter has been adopted for water and wastewater analysis.

Metals removal consists of taking cationic (positively charged) metal ions and combining these ions with anions to form solid precipitates. For most metals, the anion used is hydroxide, resulting in a mixed metal hydroxide precipitate. The solubility of metals is dependent on the concentration of hydroxide, and generally metals are less soluble at higher pH. However, when excessive hydroxide is available, the result is formation of a negatively charged metal hydroxide molecule, and solubility increases at higher pH. The solubility of individual metals is presented in Figure 5-14. With metals being regulated to parts per billion (ppb) or ppt levels, it would be difficult to have a common pH for precipitation of a mixed metal waste.

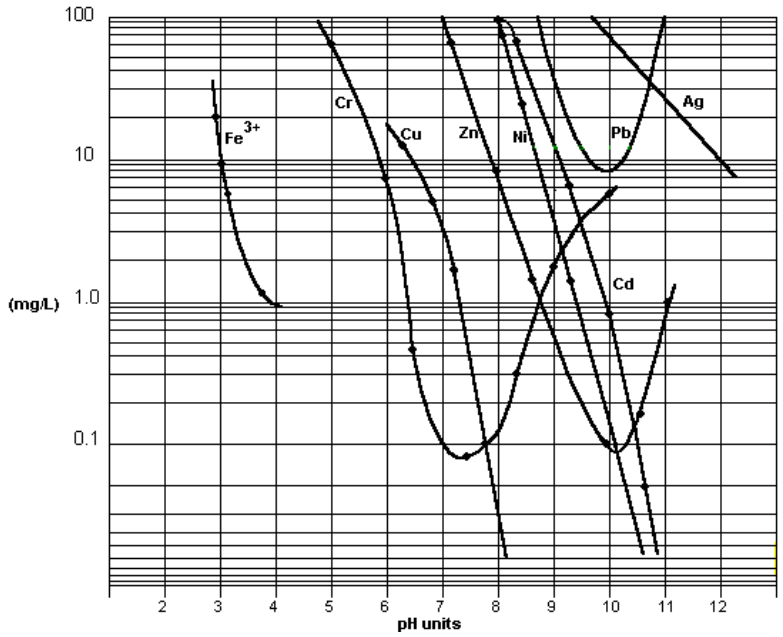


Figure 5-14
Solubility of Cationic Metal Hydroxides as a Function of pH

For this reason, there was a move to exploit the low solubility of metal sulfides. Theoretical solubility for various metals is shown on Figure 5-15. The most insoluble metal sulfide is mercury sulfide or cinnabar. The theoretical solubility of cinnabar is so low that it would take over 300 liters of water to dissolve one molecule.

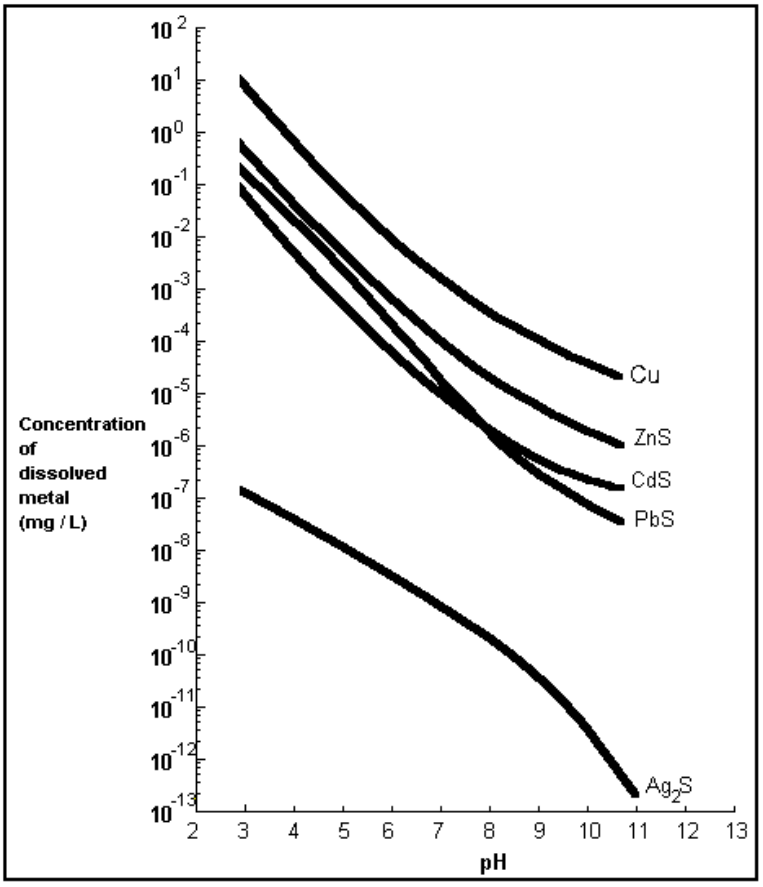


Figure 5-15
Solubility of Cationic Metal Sulfides as a Function of pH

Exploiting the low solubility of metal sulfides is difficult, paradoxically due to the low solubility of the metal sulfides. Since the metals solubility is so low, metal sulfide rapidly precipitates, forming particles that are so small that they are essentially soluble. As a result, there have been various attempts to develop larger organic molecules with sulfides like functional groups. These include solid (ion exchange media), as well as chemicals that can be added to a wastewater to precipitate cationic metals.

One of the earlier forms of organosulfides for metals precipitation in wastewater was dithiocarbamate (DTC). DTC (Figure 5-16) is a relatively small molecule, and metal precipitates tended to be relatively fine. Its use was therefore limited to use in combination with microfiltration. Control of dosing relied on oxidation-reduction potential (ORP) measurement. Since some DTC usually ended up in the effluent, problems were encountered with effluent toxicity.

One organosulfide that was promoted by Degussa Chemical for treatment of mercury in FGD wastewater is TMT 15®. This compound is reported to be less toxic than DTC and is effective at treating mercury to ppb levels with conventional suspended solids removal processes (flocculation, clarification and media filtration).

Both TMT 15® and DTC are monomers, and this size may explain why they do not remove mercury down to the theoretical solubility of mercury sulfide. Some of the precipitated mercury-organosulfide is likely to be present in particles smaller than can be removed by conventional solids removal methods. Analysis of mercury in various treatment systems have shown that there is a considerable amount of mercury present as particles smaller than 0.45 microns (Figure 5-17). Figure 5-17 below shows the particle size distribution of Oak Ridge National Laboratory industrial wastewater treatment plant water, a high-chloride wastewater stream, though not FGD wastewater.

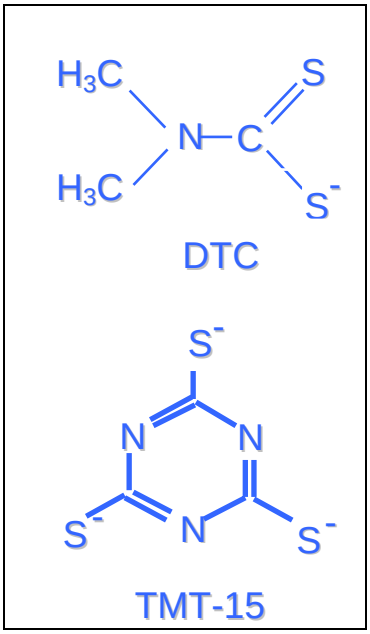


Figure 5-16
DTC Molecular Structure

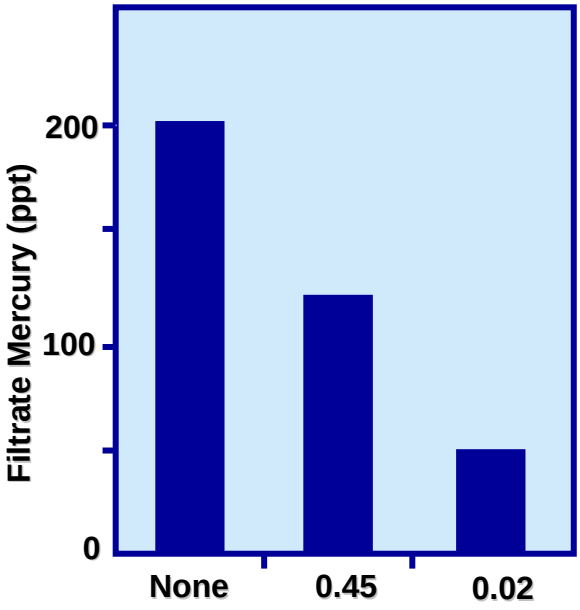


Figure 5-17
Effect of Filter Pore Size (microns) on Filtrate Mercury Concentration [8]

Nalco developed a polymeric organosulfide with a molecular weight of between 200,000 and 500,000 that is marketed under the NALMET Trademark (Figure 5-18). Nalco reports that it reduces soluble mercury concentrations to the tens of ppt, reportedly because it acts as a coagulant as well as a precipitating agent. Plans are underway to test this agent on an FGD wastewater to determine if it can be optimized further.

Metals removal can also be enhanced over that achieved by metal hydroxide precipitation through iron co-precipitation (Figure 5-19). In this process, iron is added in concentrations much higher than the trace metals targeted for removal. Iron co-precipitation removes anionic metals as well as cationic metals, with cationic metals favored at high pH and anionic metals favored at lower pH. As the ratio of iron to trace metal increases, removal efficiency increases. With untreated FGD wastewater, primary treatment acts as a pretreatment step, employing metal hydroxide precipitation to lower metal concentrations. Secondary treatment is then needed to polish or remove lower concentrations of metals.

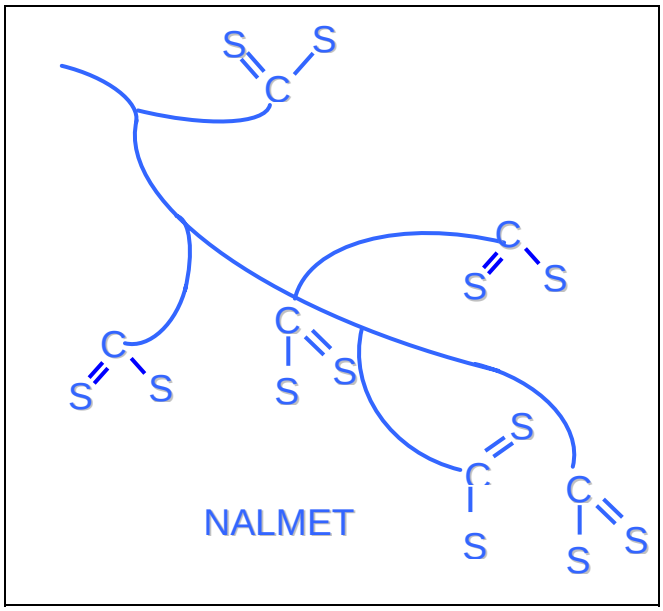


Figure 5-18
NALMET Molecular Structure

After metals precipitation, the resulting suspended solids (along with residual suspended solids in the primary effluent) are coagulated to produce larger particles for removal by settling and filtration. Ferric chloride is typically employed as a coagulant for this purpose along with cationic and anionic polymers. Ferric iron has the advantage of also providing iron coprecipitation to enhance trace metals removal. Ferric chloride acts as an acid, lowering the pH from the level used in desaturation. Additional acid may be added to optimize coagulation and metals removal. Selenite removal with iron is favored at pH below 6.5.

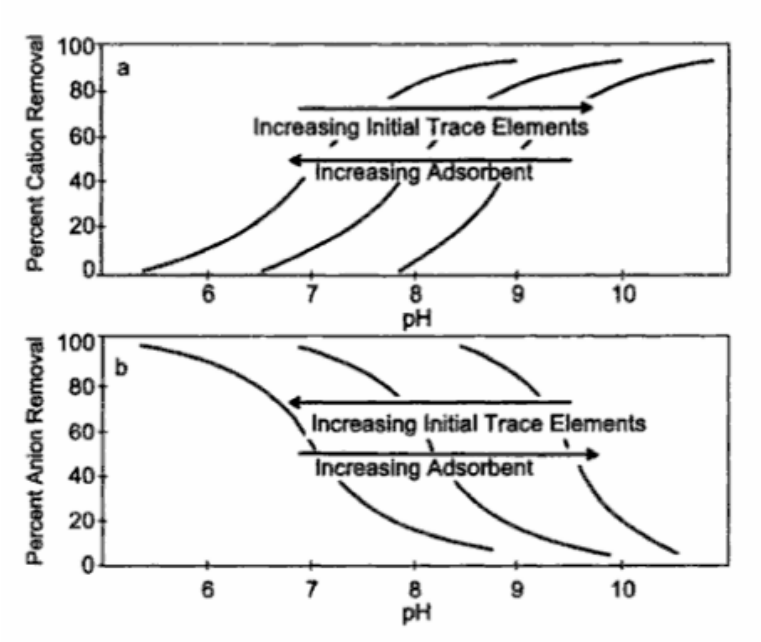


Figure 5-19
Effect of pH on Iron Co-precipitation of Cations and Anions (EPRI Rep No. CS-4087)

Metal precipitation and coagulation reactors should be designed with flocculating mixers, and should minimize shear, which produces fine solids that are then difficult to remove. This may not be a factor if only solids are to be removed to 30 mg/L, but when metals are now regulated to ppb or ppt levels, even a small loss of metal precipitates can be significant. Figure 5-20 illustrates the impact of use of a ferric chloride mix tank mixer with a small-diameter, high-speed mixer. The mixer had an rpm of 115 and an impeller tip speed of over 10 feet per second. The apparent flocculation size was higher in the surface of the tank where the chemical was added and appeared to be smaller in the effluent pipe.

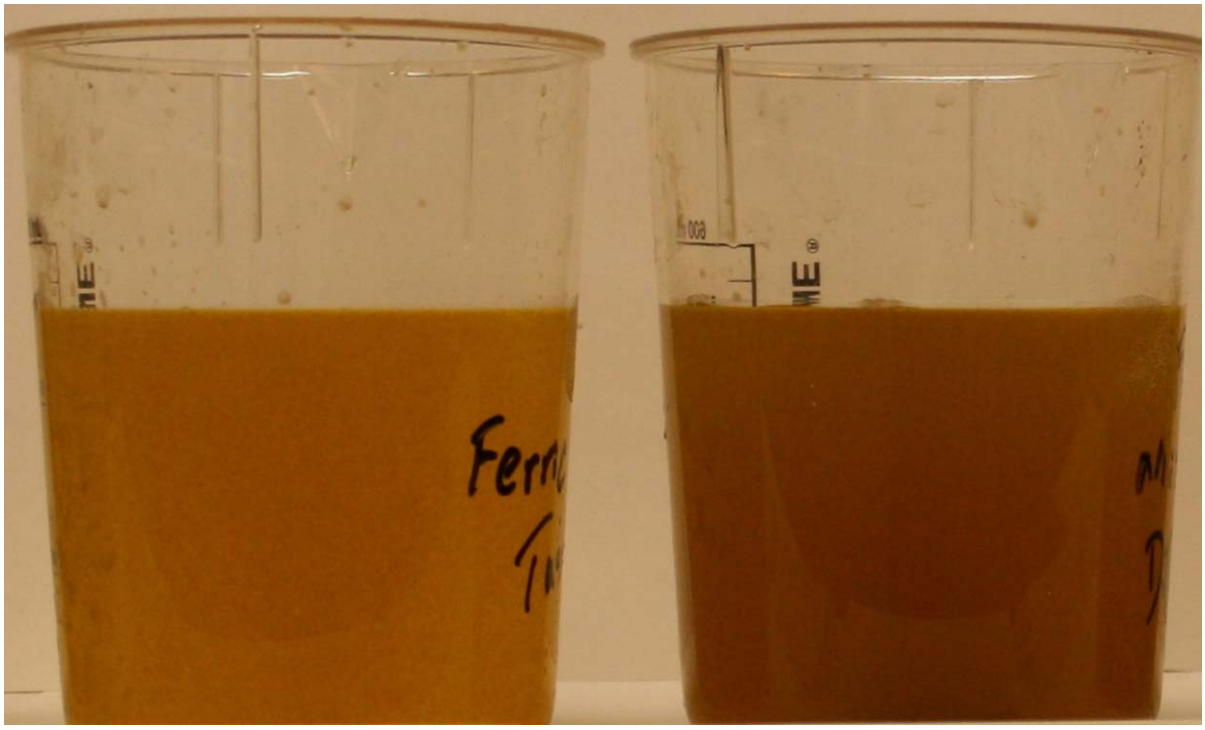


Figure 5-20
Samples from Ferric Chloride Mix Tank Before (left) and After Passing Through Mixer

Particle size and settling characteristics can also be enhanced by recirculating sludge from the clarifier to the ferric mix tank but only if a low-shear pump and flocculator mixers are employed. Otherwise, any recirculated solids will only be sheared to a small size, thereby negating the benefits of recirculation. By using flocculating mixers and positive displacement pumps, one FGD wastewater treatment system has been able to achieve cadmium removal to less than 1 ppb through iron co-precipitation, with sludge that had the characteristics of fine sand.

The iron-coagulated wastewater in Figure 5-20 was subsequently flocculated with a polymer, which resulted in good suspended solids removal by clarification and filtration. However, the clarified effluent still had considerable reddish color and significant mercury in the 0.45- to 5-micron size range, indicating that there is a considerable amount of fines in the water that are not successfully flocculated by the polymer.

Secondary Clarification

Secondary clarifiers should be limited to an overflow rate of approximately 0.33 gpm/sf. Use of lamella clarifiers can reduce the footprint if the clarifier is to be located in a building. Lamella clarifiers have limitations that need to be overcome or accepted if used. Effective overflow rate (compared to conventional clarifier) should be reduced to less than 0.2 gpm/sf due to higher velocity between the plates. Lamella clarifiers tend to be tall, and so all mix tanks need to be elevated with gravity flow in straight pipes between mix tanks to reduce shear. Sludge volume is limited in a sludge hopper, so a larger thickener bottom is recommended to provide adequate sludge volume to have effective sludge recirculation to the iron mix tank. Sludge recirculation

must be optimized and polymer addition minimized to produce a solid that will slide easily down the lamella plates. Otherwise, there can be a tendency of the sludge to stick to the plates, causing sudden breakthrough of solids and a frequent maintenance job of draining the water level below the plates and cleaning them.

Filtration

Media Filters

Filtration is a necessity if metals removal is required. Sand filters can reduce TSS to 1 parts per million, and generally remove solids that are in the 5-micron range and larger. Filters, however, are prone to scaling. Scaling can be reduced, but not eliminated, if hydrochloric acid is used for pH control instead of sulfuric acid. Filters add to the complexity of the process and increase all of the treatment unit sizes because of backwashing. If TSS is greater 100 mg/L, then backwashing becomes so frequent that the plant can become overloaded.

Membrane Filtration

Membrane filtration is being used more frequently for metals removal. However, membranes are more prone to scaling and are also sensitive to polymer usage in the plant. As the pore size decreases, the head loss increases and flux decreases, adding to the size and cost of the technology.

Other Tertiary Treatment Options

Advanced Metals Removal. EPRI is conducting research on advanced metals removal working with facilities to conduct treatability testing of selenate and mercury removal. The results of EPRI treatability testing of a metallic iron cementation approach is summarized in Report 1016191 [10].

Sorption

In addition to organosulfide treatment, some non-FGD wastewaters have been successfully treated with ion exchange resins with sulfide functional groups. Due to the high affinity of mercury for sulfides, these expensive resins (up to $2,000/cubic foot) are not regenerable, and therefore are best used for applications with low-flow wastewaters, such as from dental sinks.

Selenium Removal

Selenium removal is broken into selenite versus selenate treatment. Selenite treatment is difficult but has been shown to work using iron hydroxide sorption. The process is effective over a narrow pH range of 6 to 6.5. Selenate removal for FGD wastewater is more problematic. Three processes have been demonstrated at the pilot level, but these processes need further demonstration on FGD wastewater.

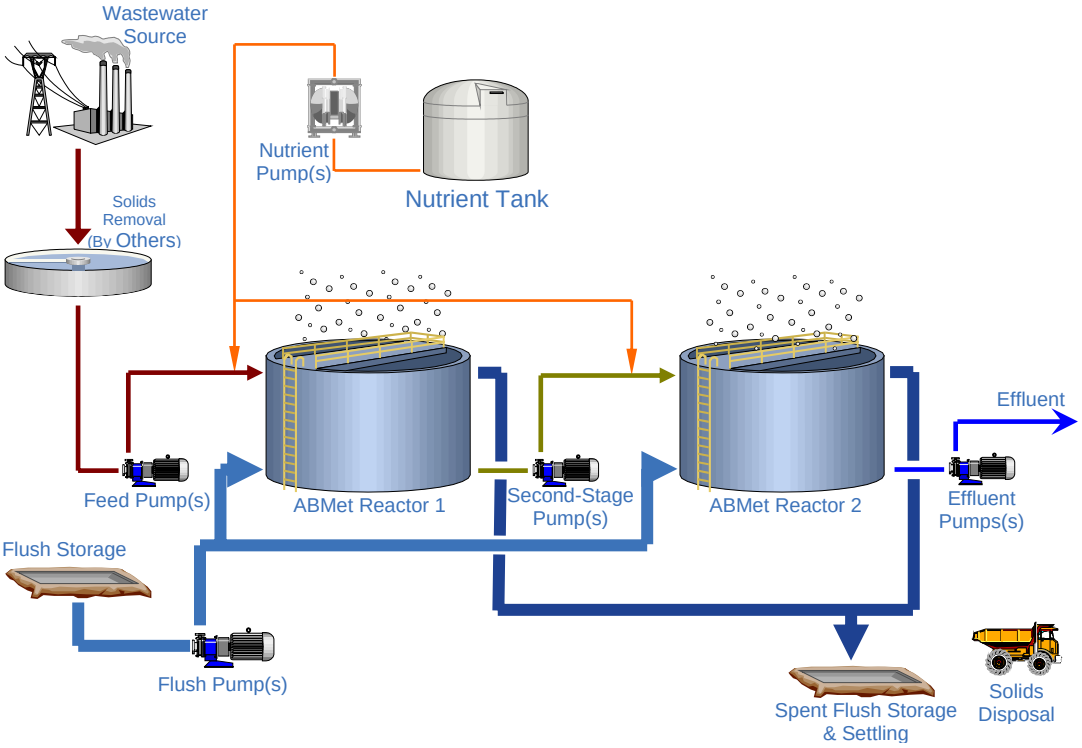


Figure 5-21
ABMet Process Flow Diagram

Figure 5-22
ABMet Pilot Plant

Of the experimental selenium removal processes, the most advanced is the ABMet Process (Figure 5-21) owned by GE Water, which recently was pilot tested with FGD system wastewater over 5 months (Figure 5-22). This pilot plant employed two-stage anoxic reactors. The first reactor was used to denitrify nitrates in the wastewater, as well as reduce some of the selenium to elemental selenium. In the second stage, the remaining selenium was reduced. Results of the test are shown in Figure 5-23.

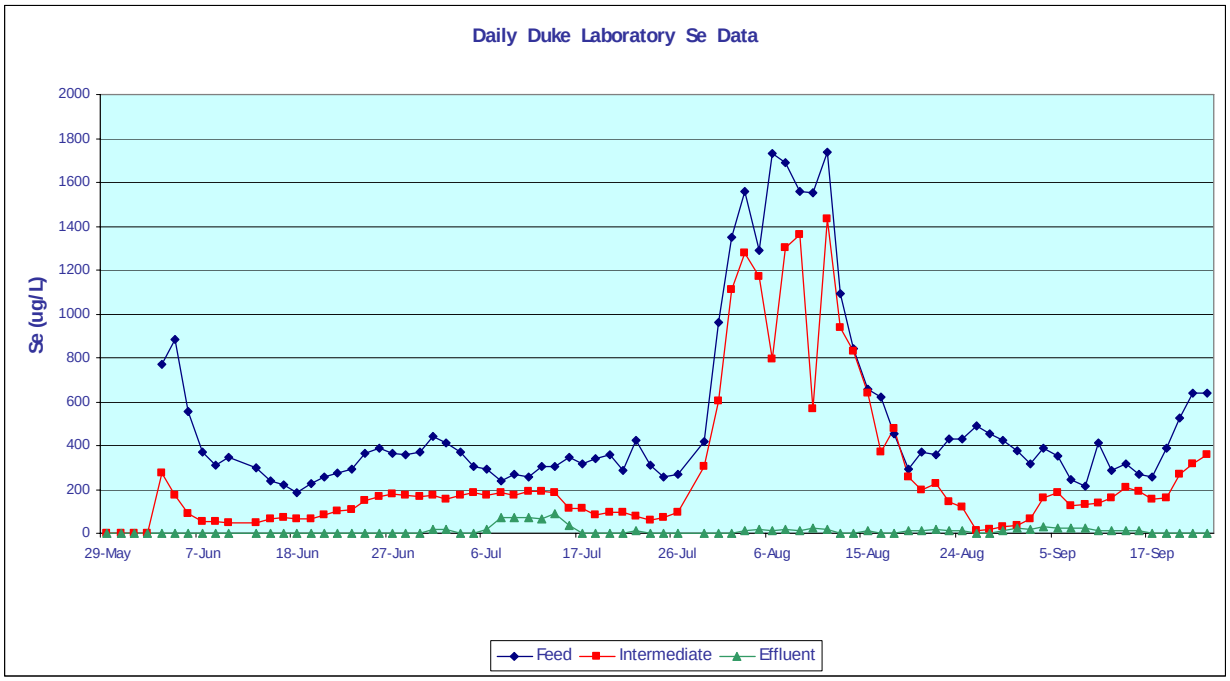


Figure 5-23
Pilot Plant Removal Data for ABMet Treatment of FGD Wastewater

Sludge Dewatering

Sludge is produced in primary and secondary clarification. There are three main technologies for sludge dewatering: centrifuge, belt press, and plate-and-frame press (Figures 5-24, 5-25, and 5-26). While there are three possible technologies, the choice typically falls between a belt press and plate-and-frame press. Centrifuges tend to have excessive wear when treating the typically abrasive power plant solids. Also, centrifuges tend to segregate solids by size, with the centrate returning the fines to the process. This has a result of building fines in the treatment process, with adverse results on performance.

Gypsum solids tend to be thixotropic in the 50 percent solids range, which means the solids tend to take the shape of and stick to the container in transit, thereby making them difficult to remove. Transit by truck also tends to release water from belt press dried sludge, which may be a disposal problem. This can be solved by mixing flash or gypsum with the dewatered cake to soak up free liquids. Initial cost of belt presses is lower than plate-and-frame filter presses, but the former

require more operator attention and polymers, and produce larger volume of dry cake, which makes the plate-and-frame presses less costly in a lifecycle cost analysis (Table 5-2).

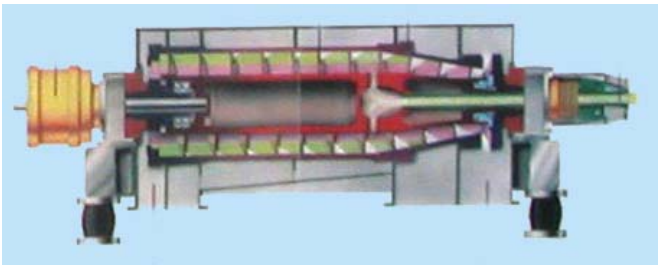


Figure 5-24
Centrifuge

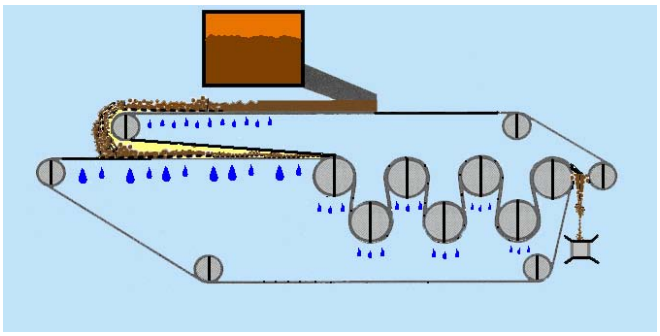


Figure 5-25
Belt Press

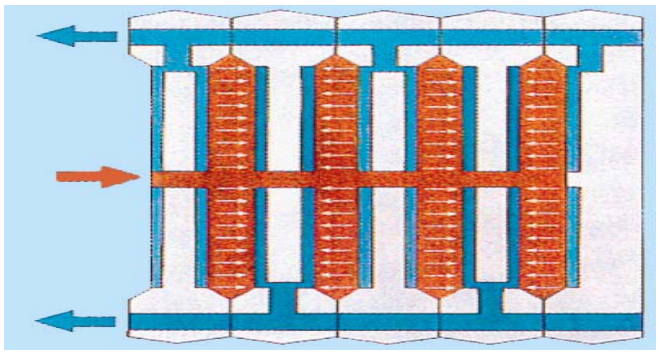


Figure 5-26
Plate and Frame Filter Press

Table 5-2
Comparison of Sludge Dewatering Equipment

Parameter	Centrifuge	Belt	Plate & Frame
Operation	Continuous	Continuous	Batch
Dewatering Pressure (pounds per square inch)	NA	<20	150 - 180
Polymers	Yes	Yes	No
Dry cake (% solids)	< 50%	< 50%	60 – 80 %
Thixotropic Potential	High	High	Low
Free Water Potential	High	High	Low
Capital Cost	Mid	Lowest	Highest
Operation and Maintenance Cost	High	High	Lower

Sludge Pumps

Different positive displacement pumps have been used to achieve the high pressure needed for sludge dewatering. Typically, a centrifugal sludge pump is used for rapid filling of the largest presses. Progressive cavity pumps have been successfully used for other sludges, but the abrasive character of power plant sludges results in excessive wear. Air-operated diaphragm pumps cannot achieve the required pressure for dewatering and are short-lived. Hydraulic membrane pumps have been effective, if preventive maintenance is scrupulously performed. At one plant, a hydraulic membrane pump failed rapidly due to check valve chatter when it was installed with sludge tank high level that was higher than the filter press. The failed pump was replaced with two centrifugal pumps in series (Figure 5-27). When these pumps are operated with variable frequency drive controls, the pumps combine the ability to provide rapid filling at low pressure and can ramp up pressure as the sludge cake forms. Final pressure is achieved by turning on the second pump. One caution is to control speed to achieve required pressure, rather than having pressure used to then adjust speed. The latter can result in rapid oscillations in both pressure and speed.

Figure 5-27
Dual Centrifugal Sludge Pumps in Series

When a sludge is maintained at a good density range (10 to 20 percent solids) through adequate dose of lime and sludge recirculation, and care is taken not to use excessive anionic polymer, then cake will dewater quickly to 60 to 80 percent solids and will drop off the cloth with little if any prodding (Figure 5-28).

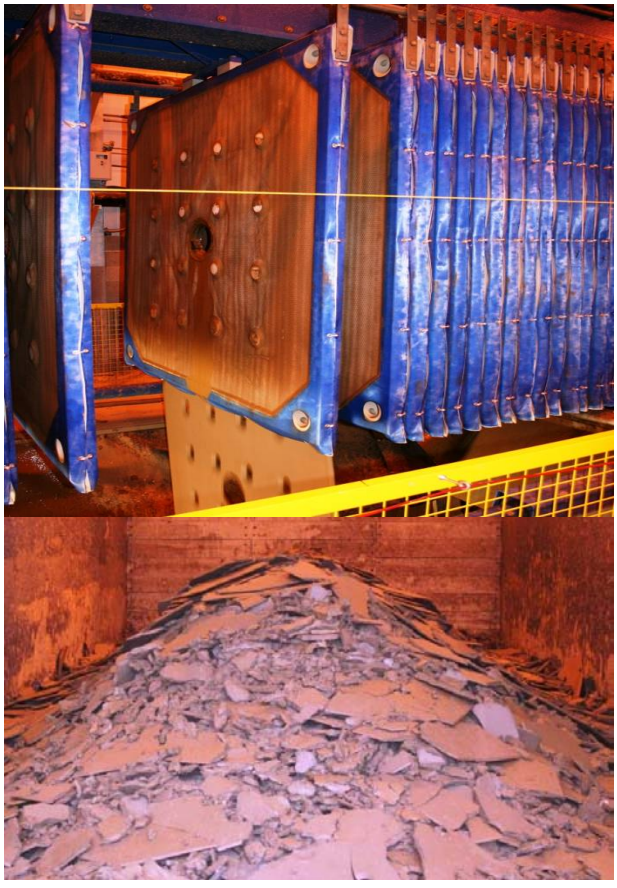


Figure 5-28
Plate and Frame Filter Press and Resulting Dewatered Cake

6
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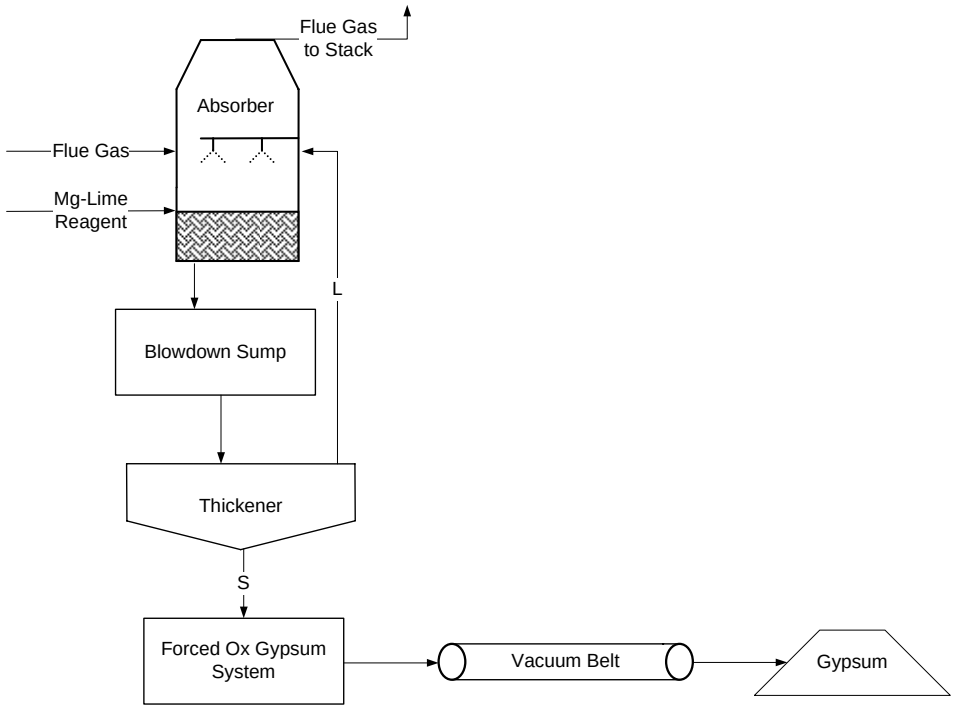
A

FGD SYSTEMS AND FGD WASTEWATER TREATMENT SYSTEM PROCESS FLOW DIAGRAMS FOR SITES USED IN THIS REPORT

This appendix contains simplified process flow diagrams of the FGD systems and wastewater treatment plants (WWTP) included in this report. Chemical addition was included for the wastewater treatment plants. Chemicals used to adjust pH were not included in the diagrams, because this information was not consistently available. When streams are separated, an S is shown on the high-solids stream and an L on the liquid stream (low-solids stream).

Site 1 - FGD



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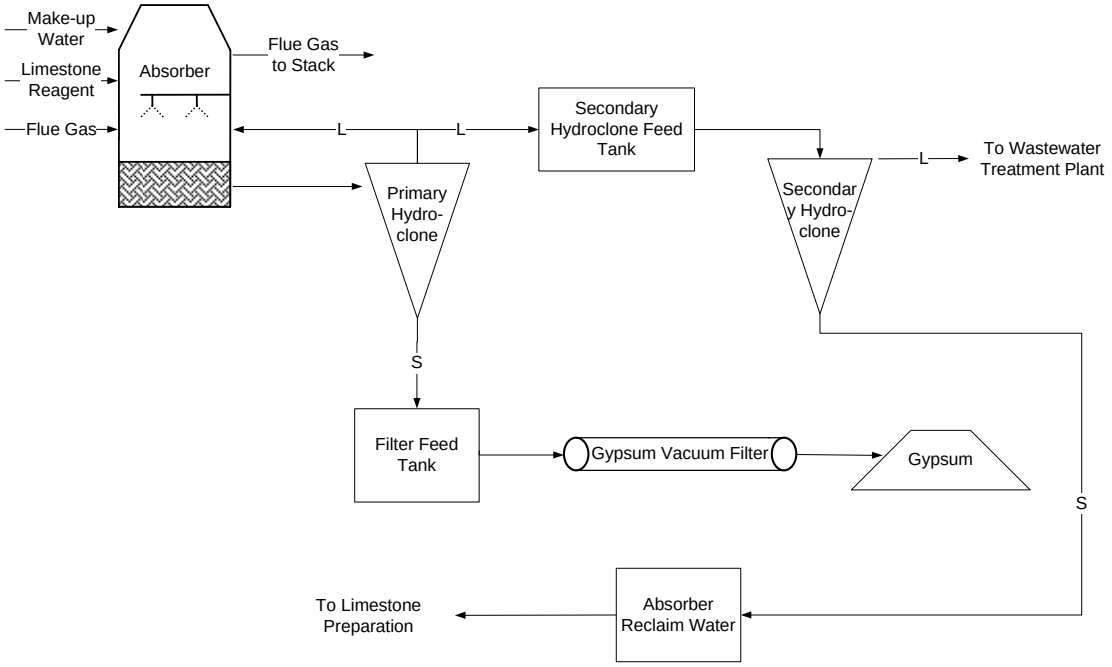

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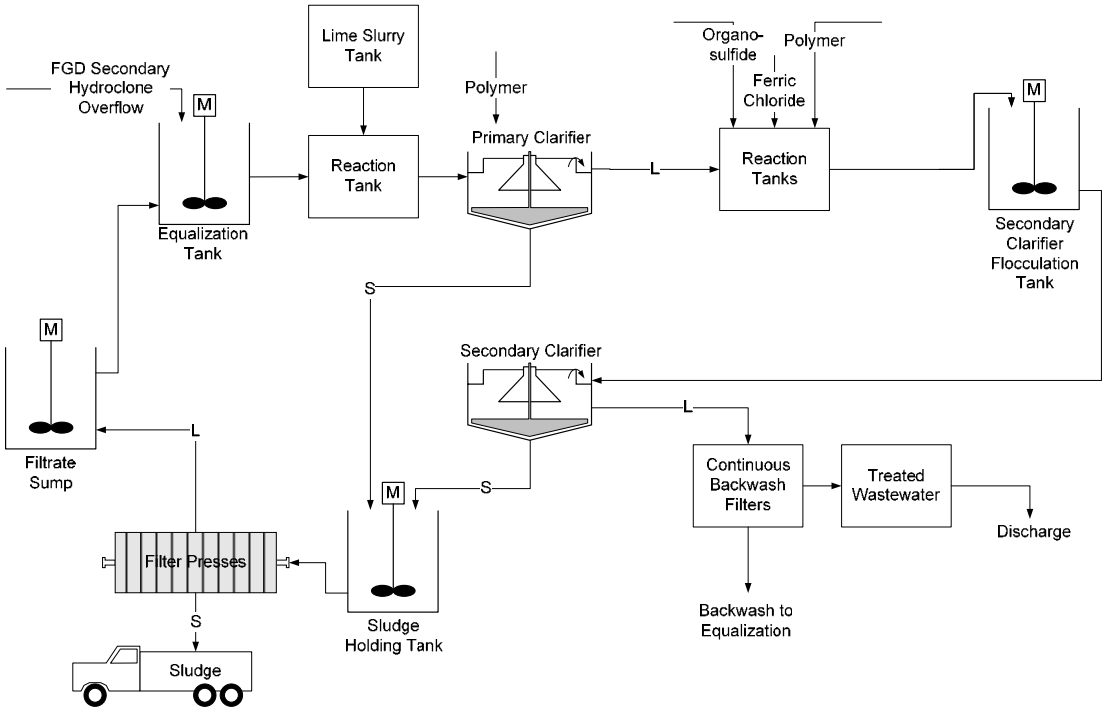

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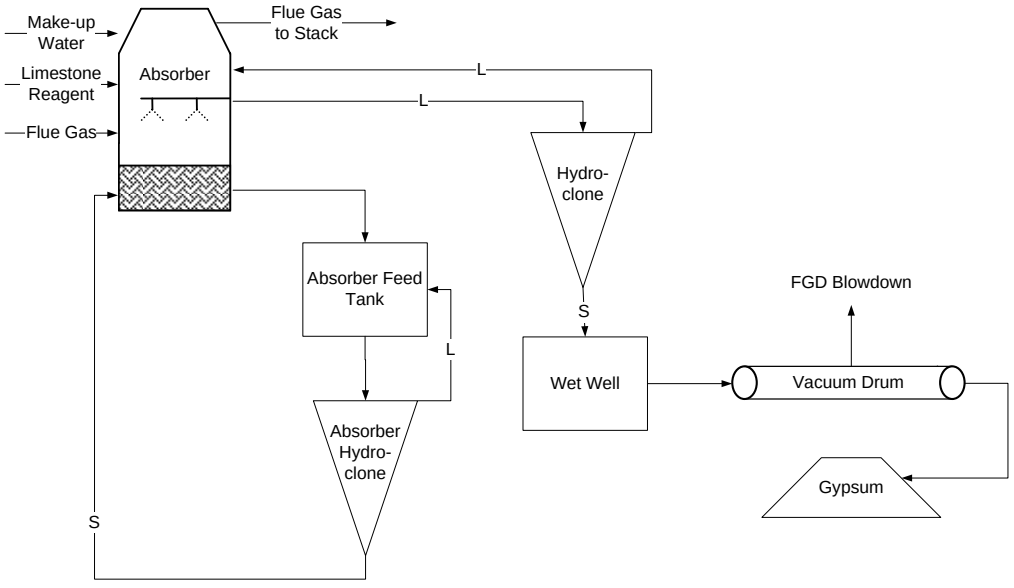
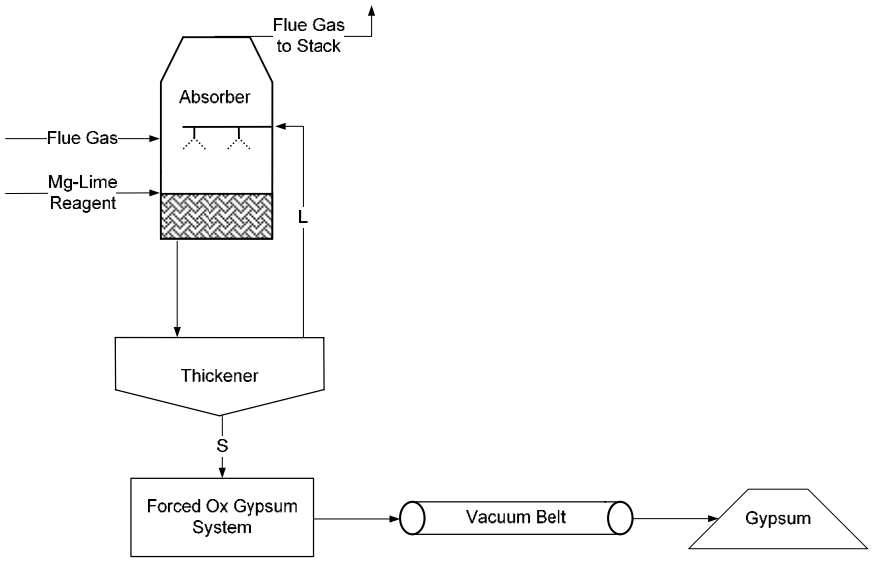
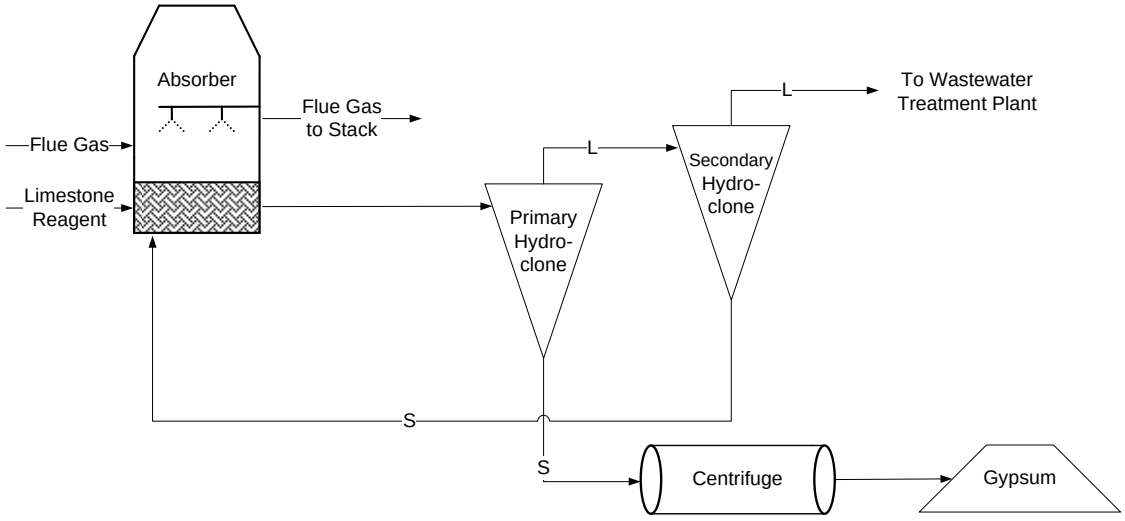


Site 4 - FGD



Site 7 - FGD



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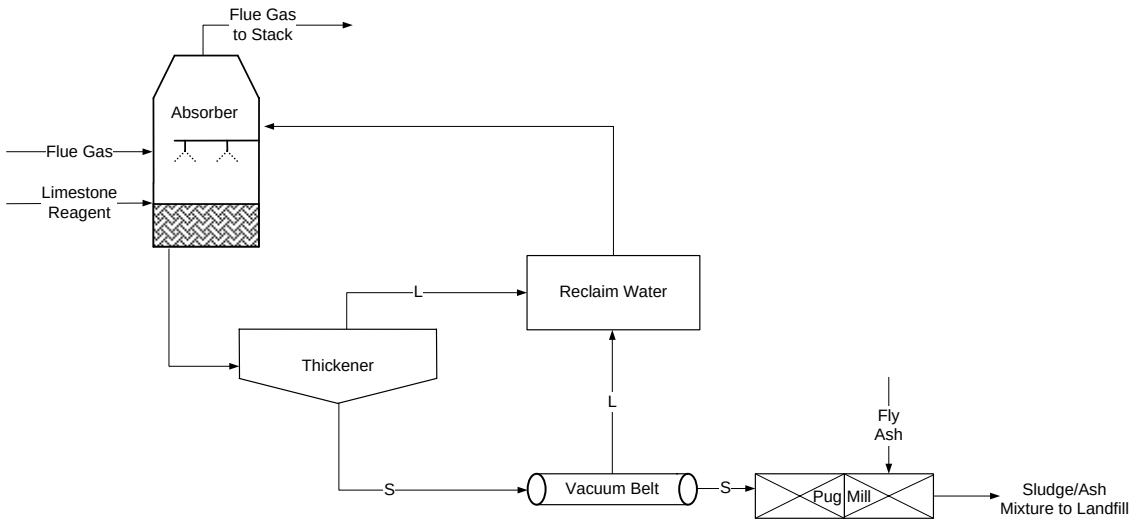
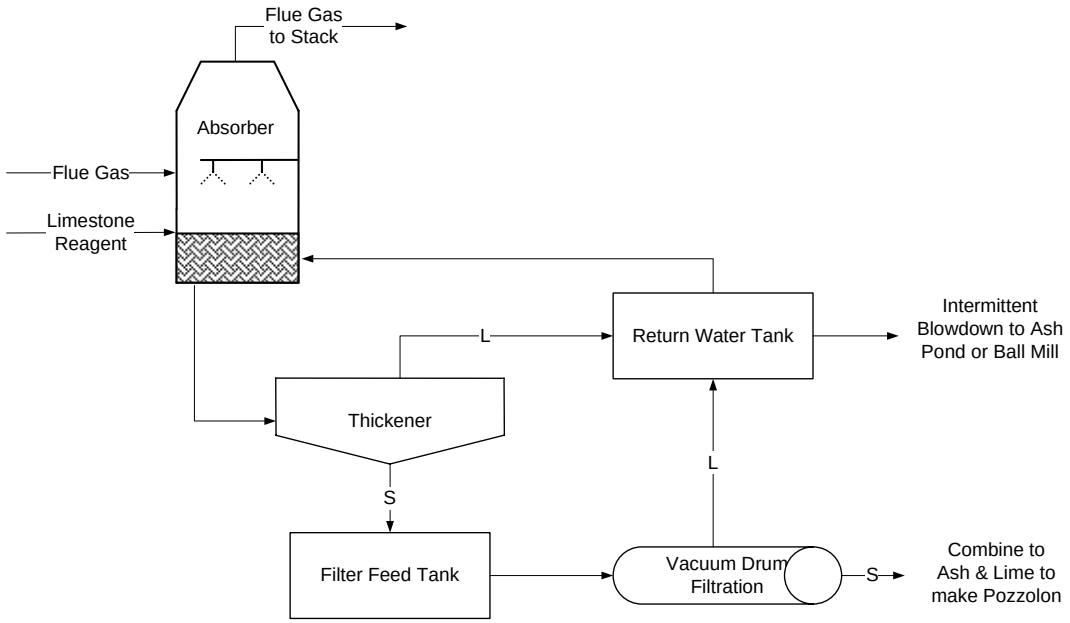
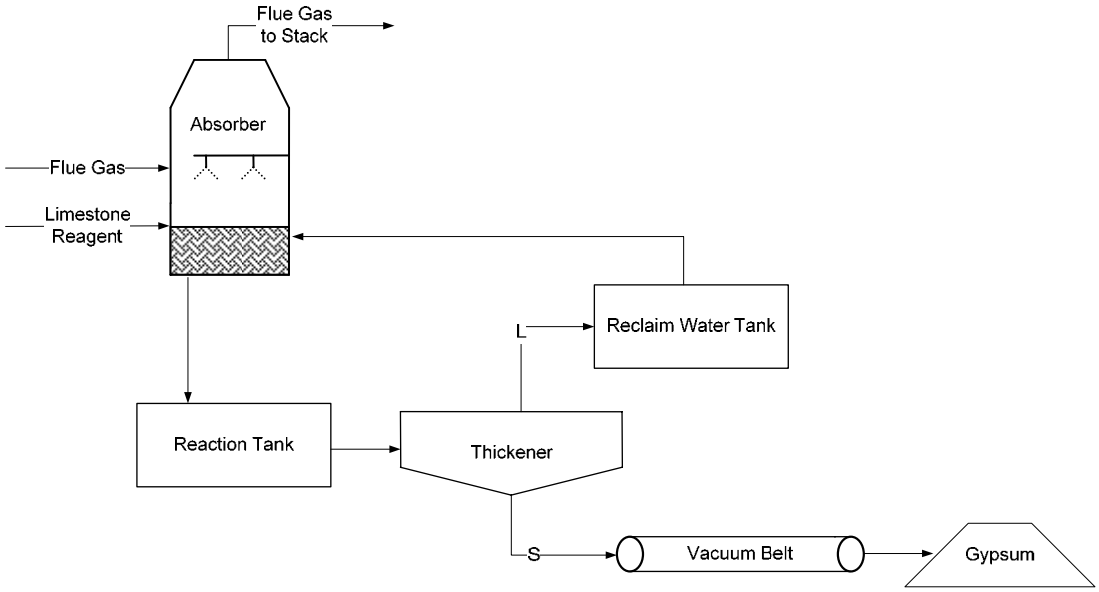


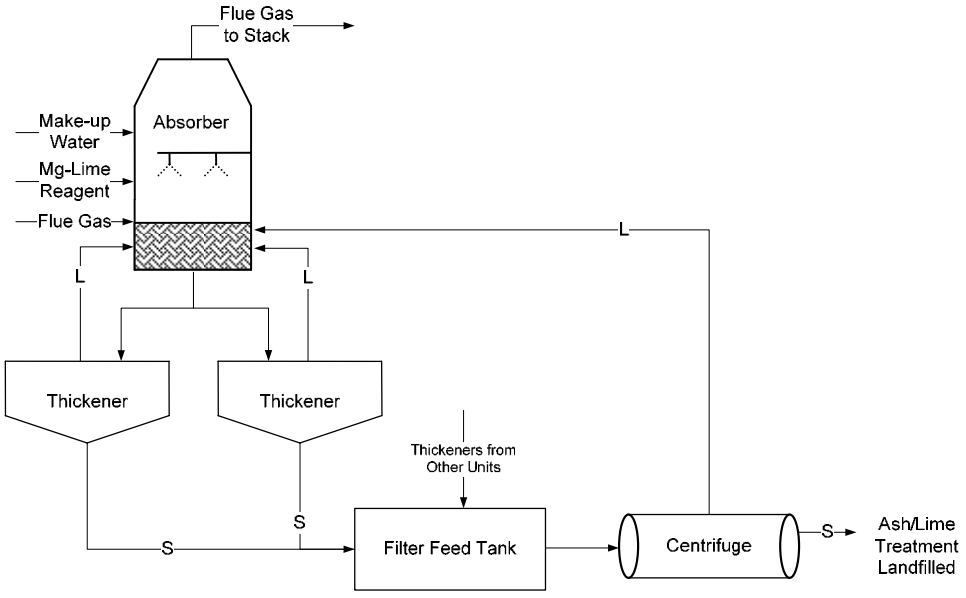
Site 9 - FGD



Site 10 - FGD



Site BLMNO - FGD



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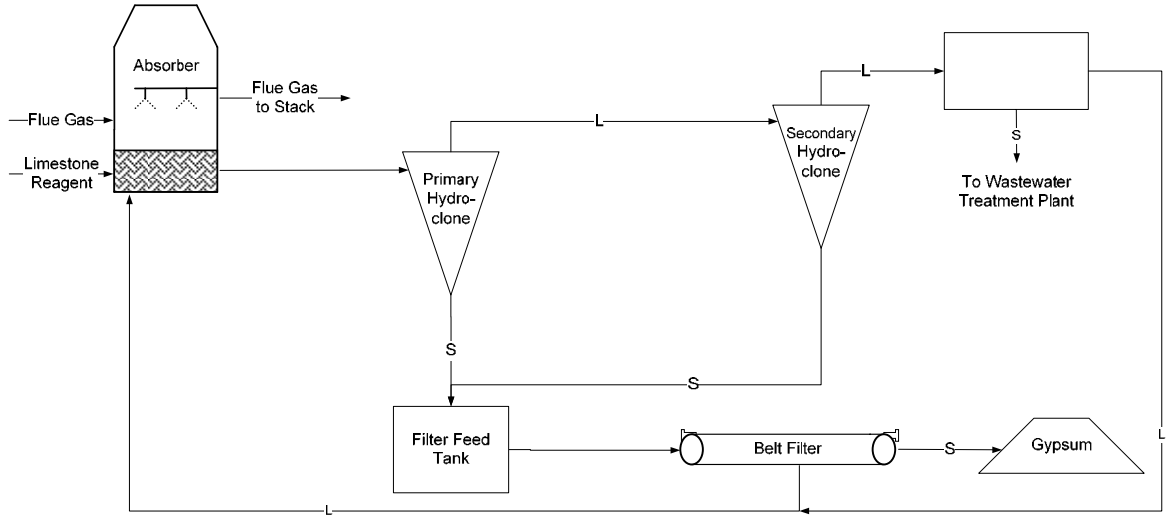
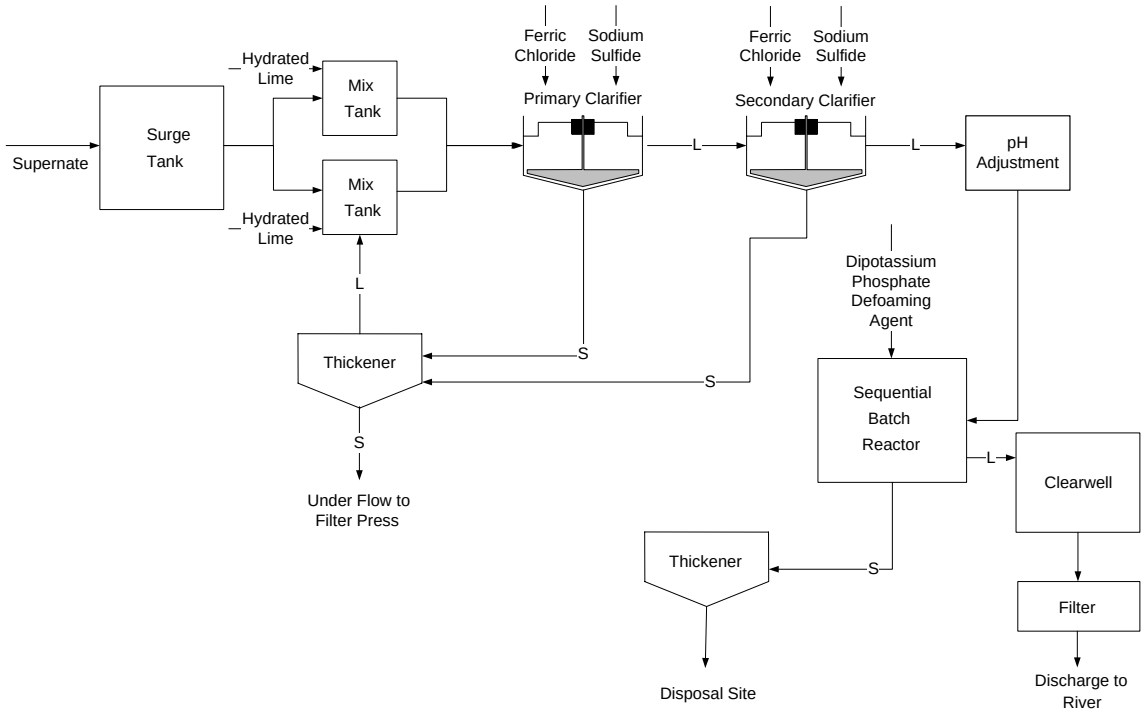
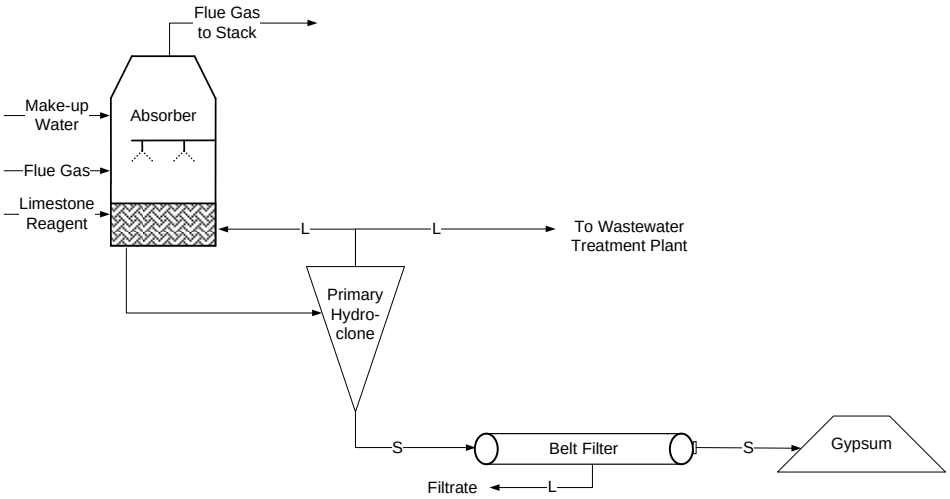


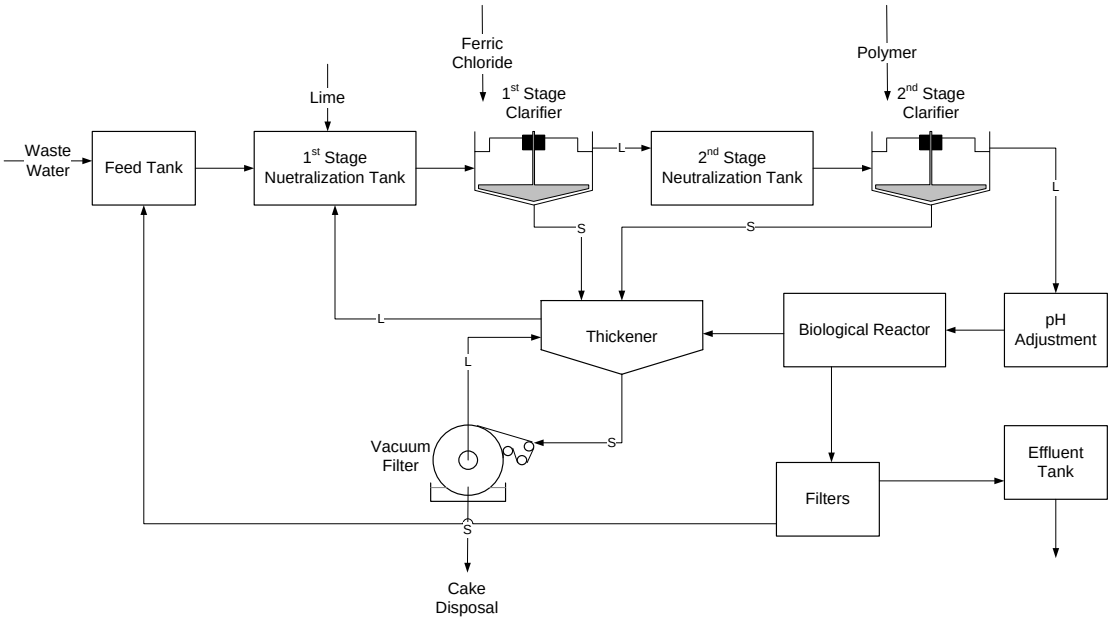
Site BLSF02 – WWTP



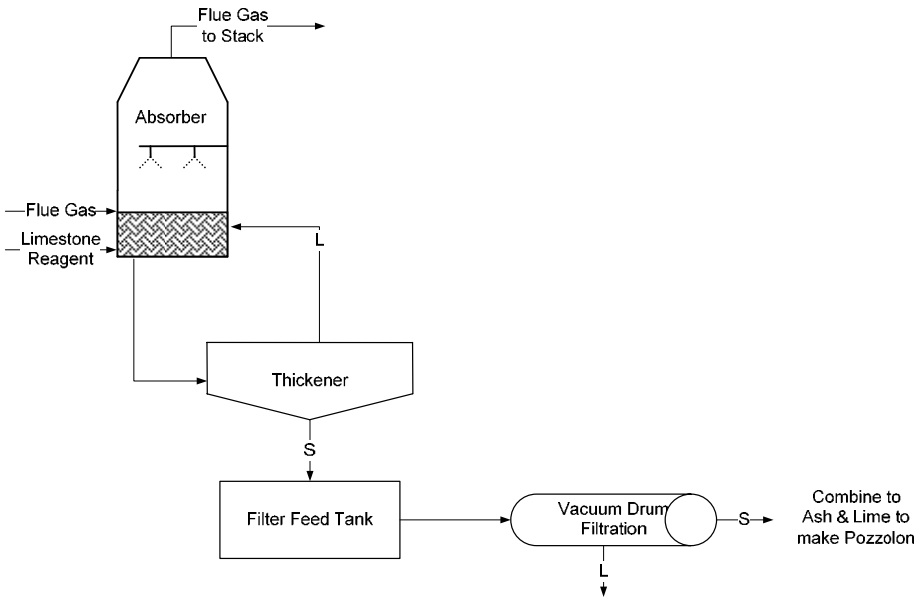
Site BLSFO3 - FGD



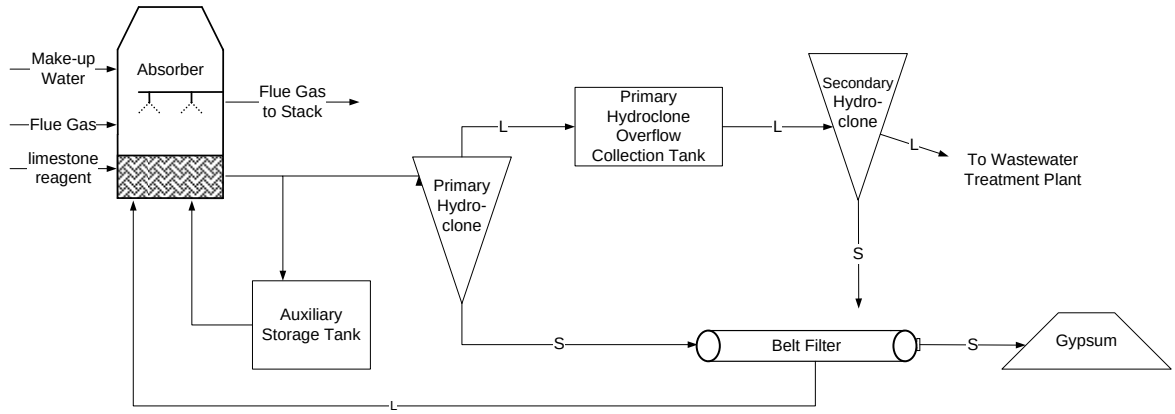
Site BLSF03 - WWTP



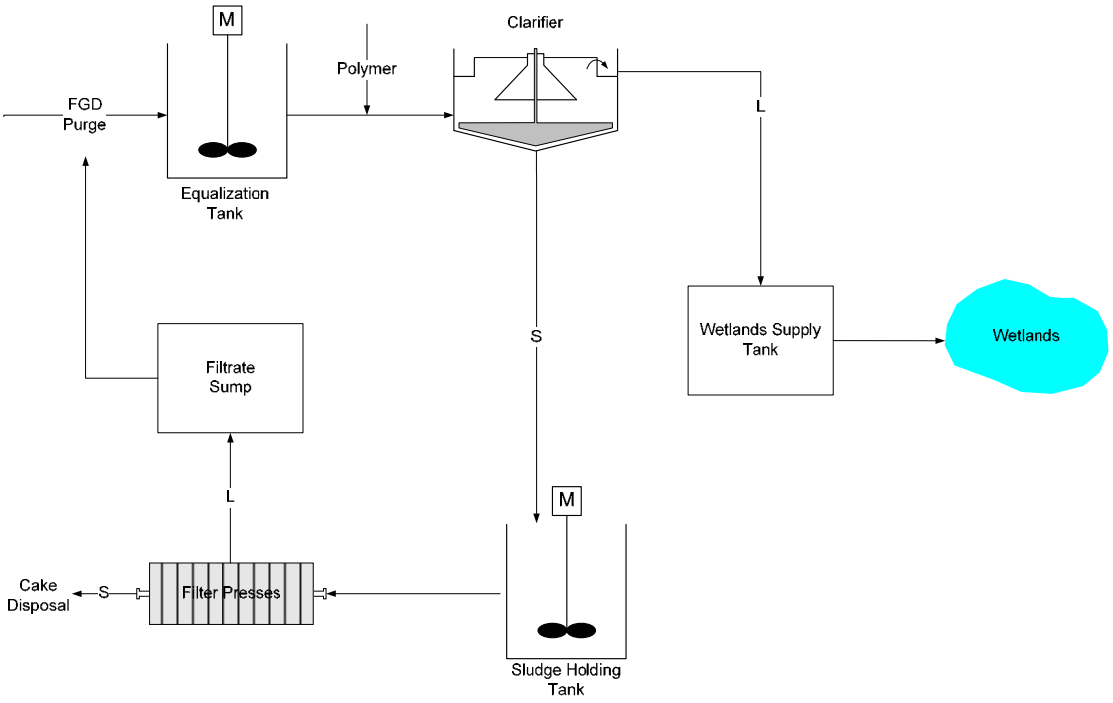
Site BLSIO – FGD



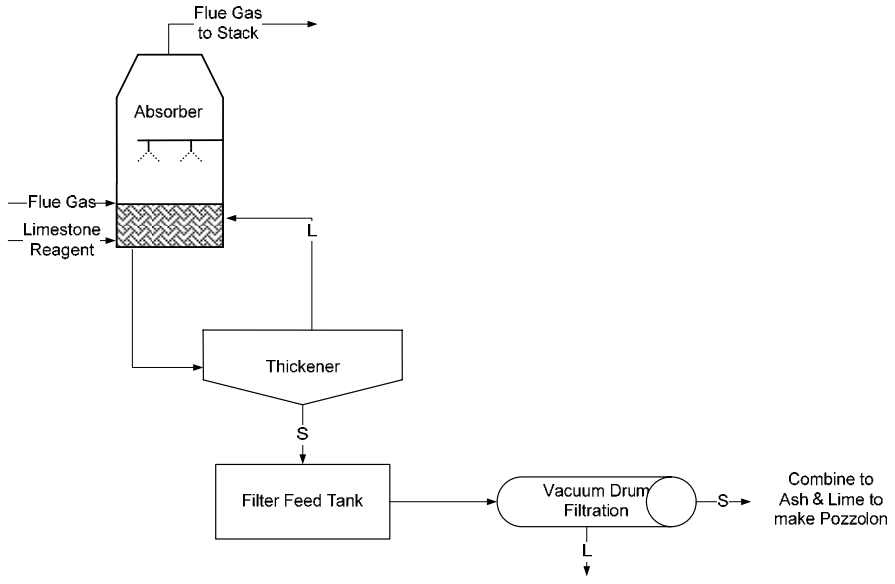
Site L1 - FGD



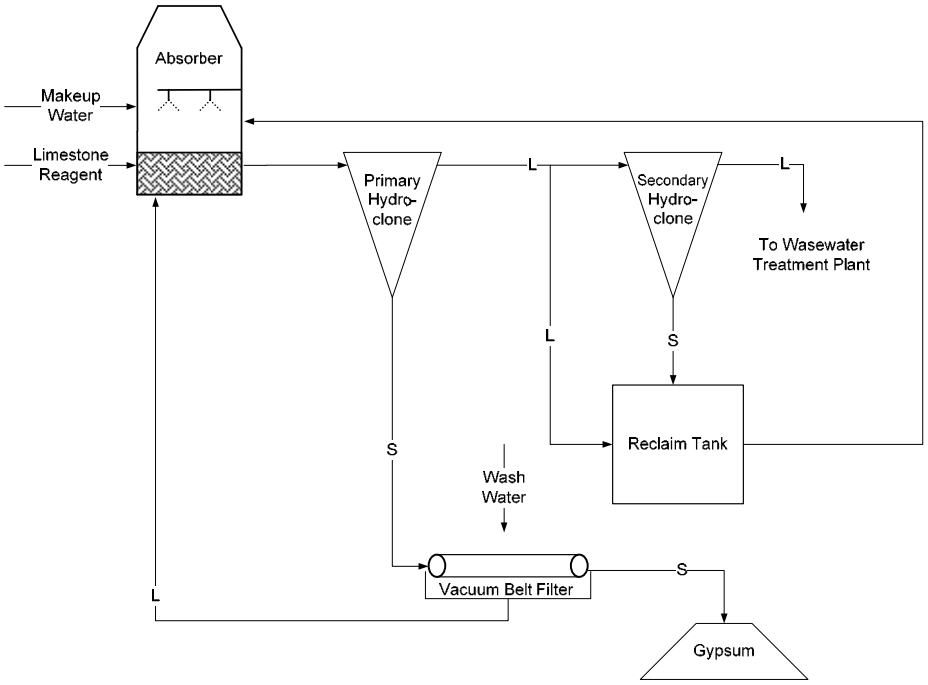
Site L1 - WWTP



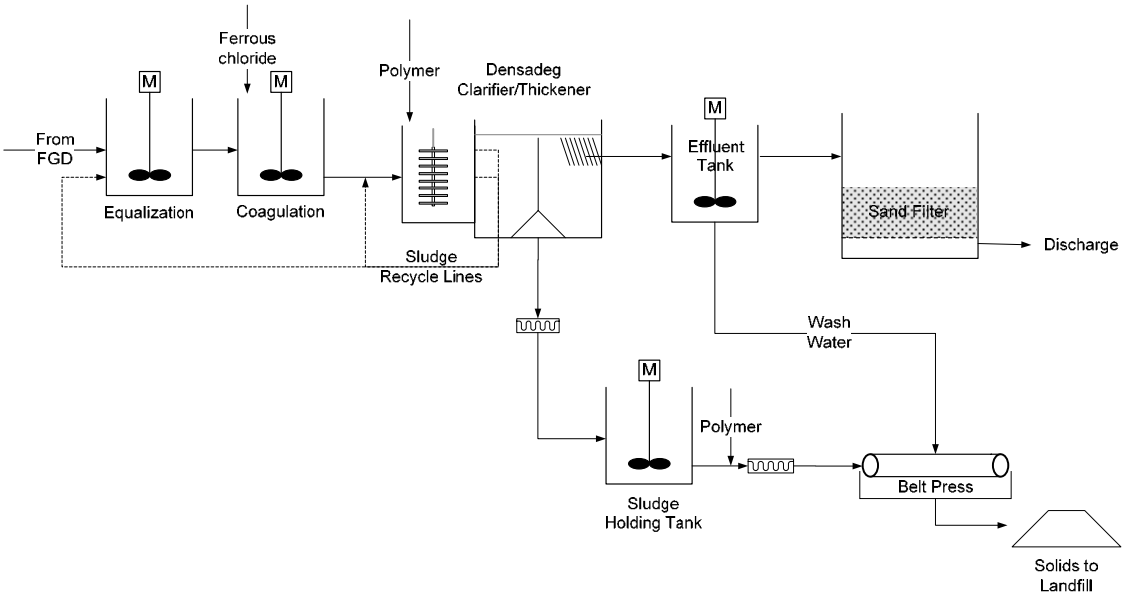
Site L2 – Older Scrubbers FGD



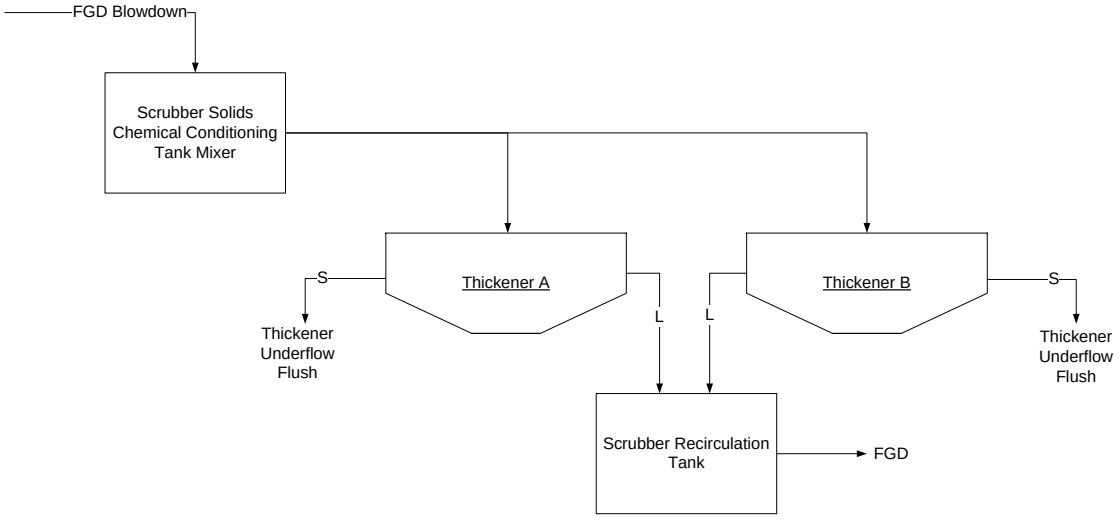
Site L2 – Newer Scrubbers FGD



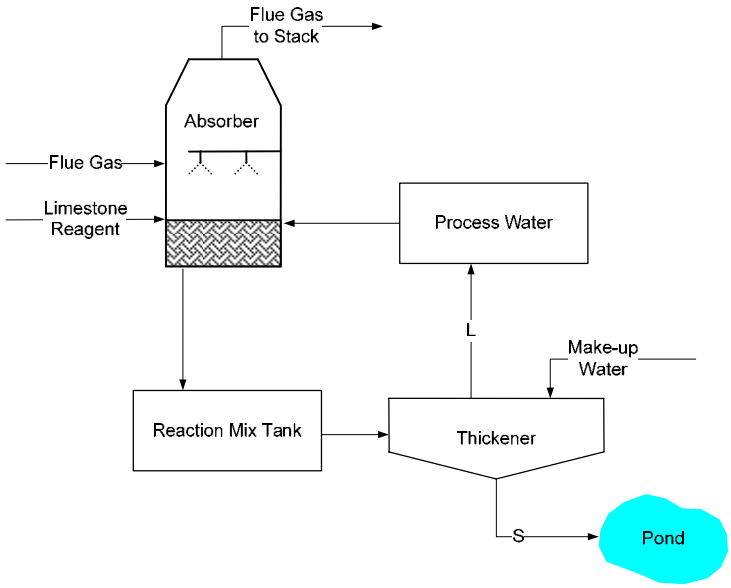
Site L2 – Newer Scrubbers WWTP



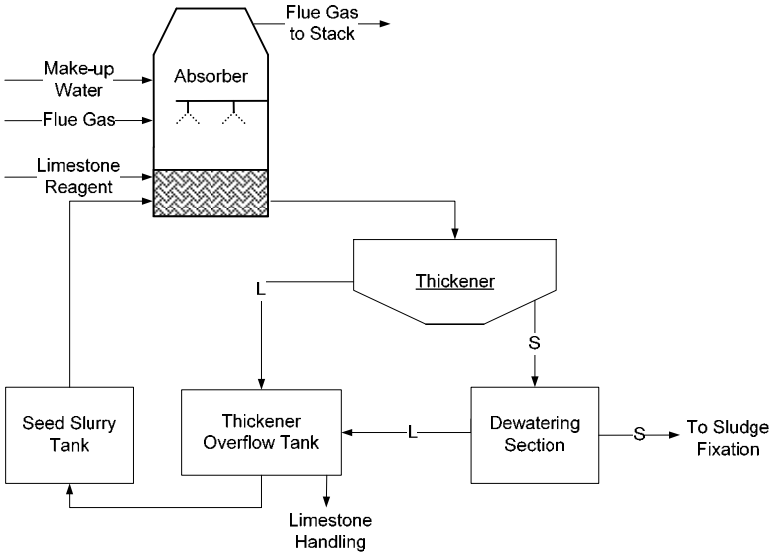
Site P - FGD



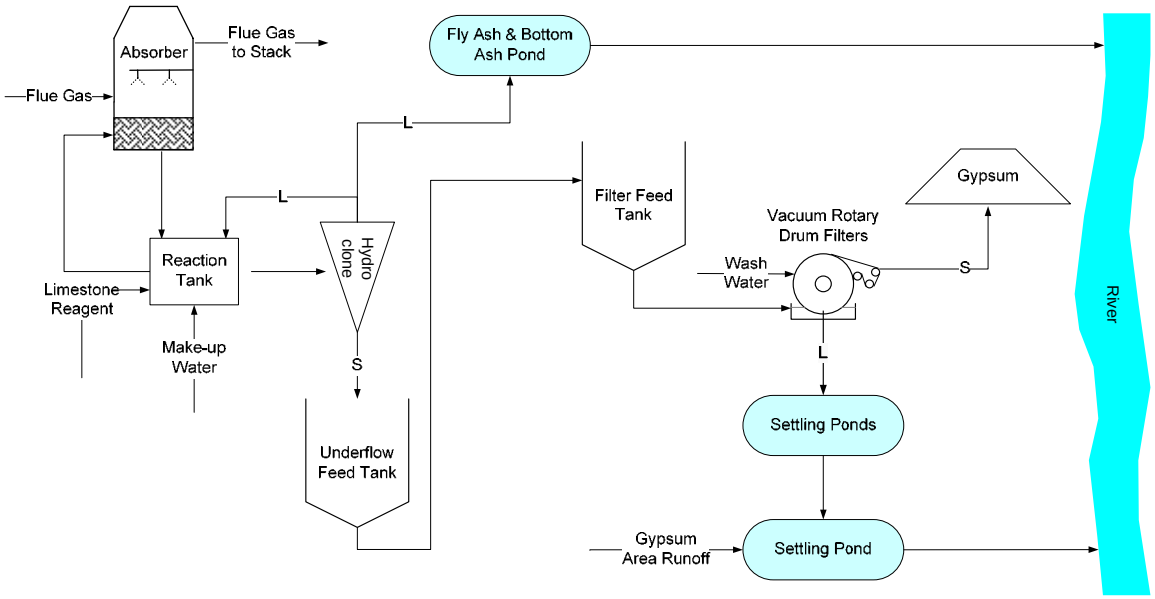
Site PRBLSNO - FGD



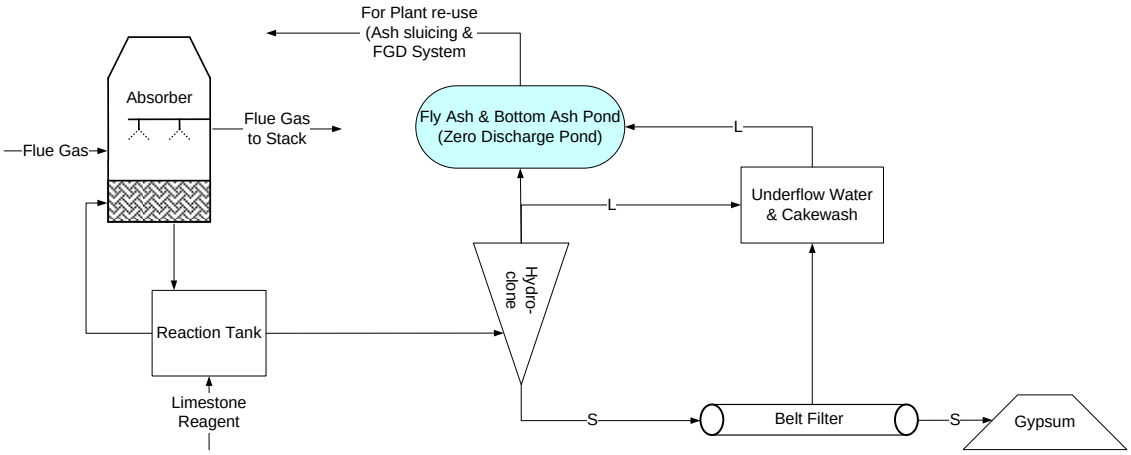
Site R - FGD



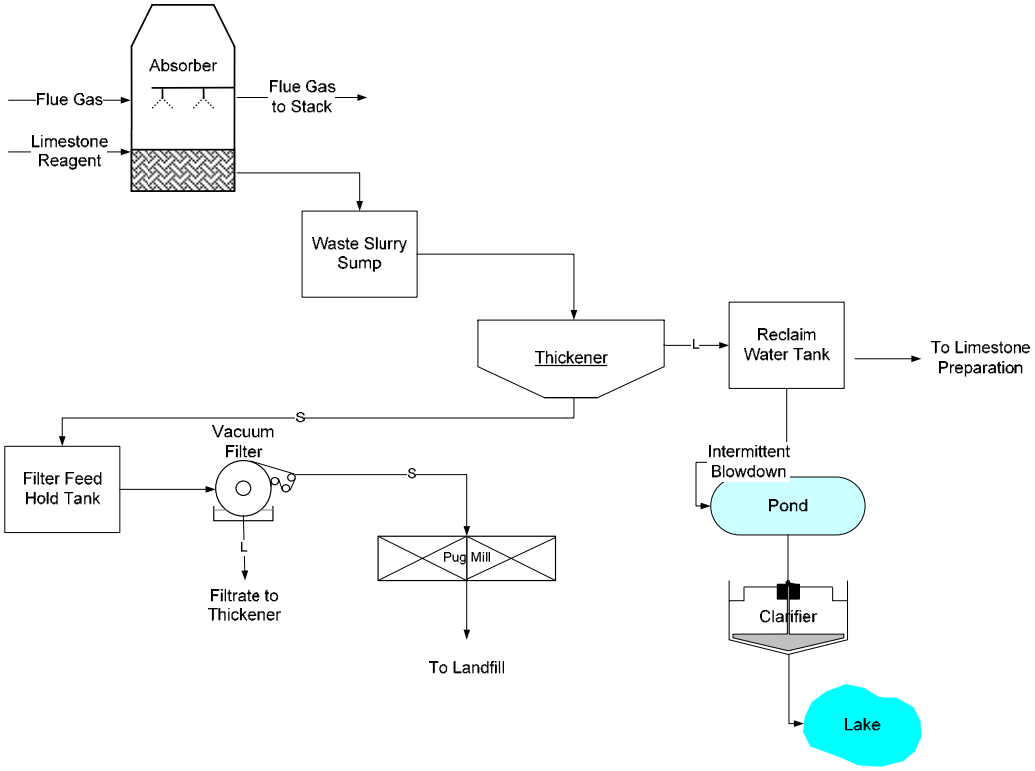
Site S - FGD



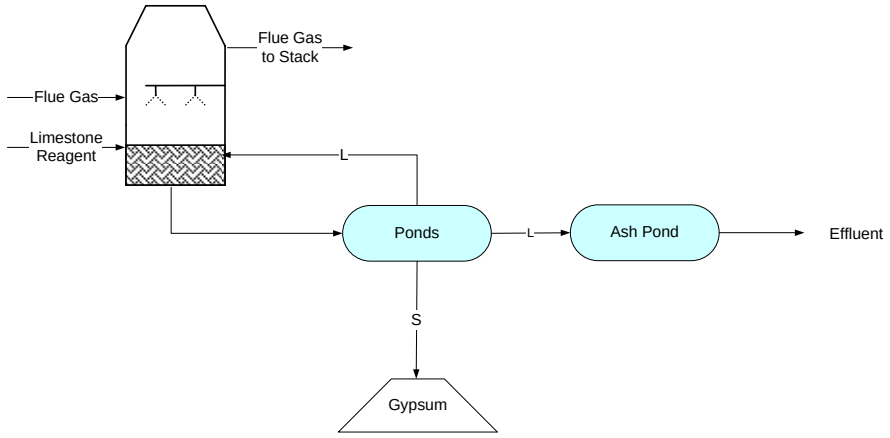
Site T – FGD



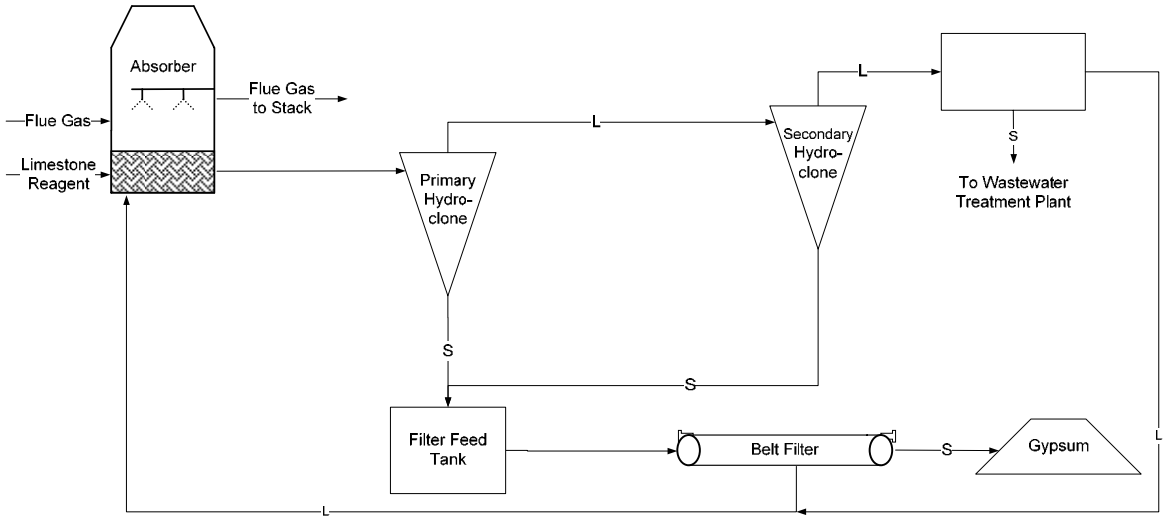
Site U – FGD



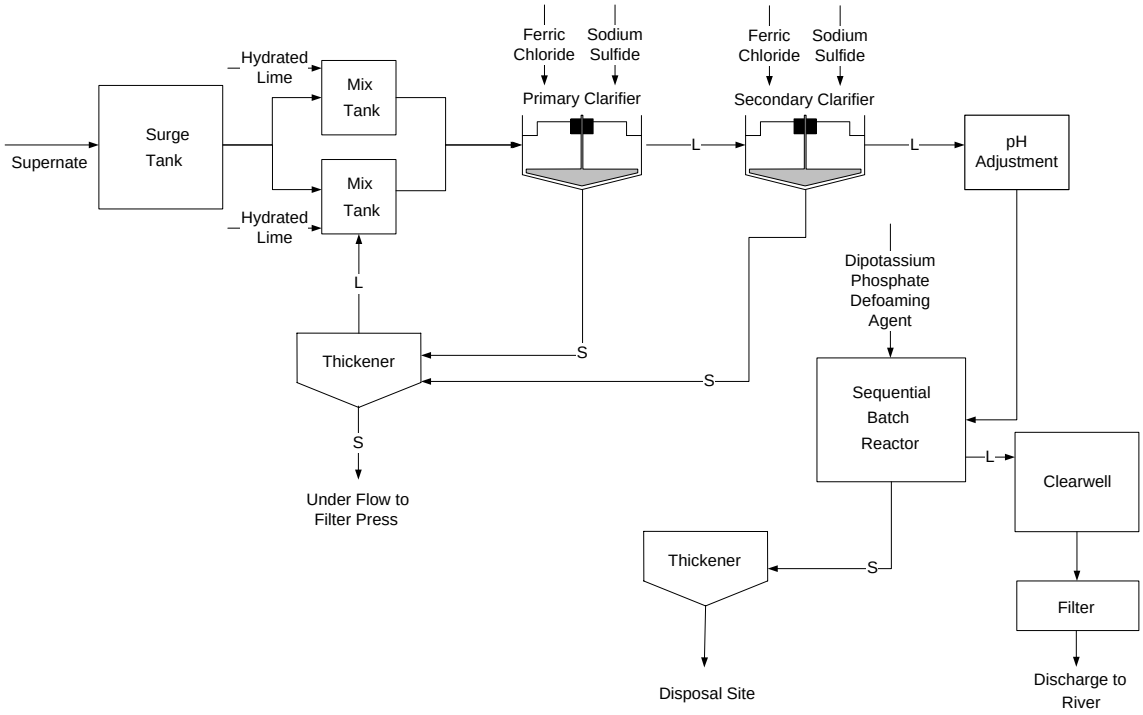
Site Y - FGD



Site Z - FGD



Site Z – WWTP


Ferric Chloride
Sodium Sulfide
Ferric Chloride
Sodium Sulfide
Hydrated Lime
Mix Tank
Primary Clarifier
Secondary Clarifier
Supernate
Surge Tank
L
L
pH Adjustment
Mix Tank
Hydrated Lime
Dipotassium Phosphate Defoaming Agent
L
Thickener
S
S
Sequential Batch Reactor
S
L
Clearwell
Under Flow to Filter Press
Thickener
S
Filter
Disposal Site
Discharge to River

B
FGD SYSTEM WASTEWATER CHARACTERIZATION DATA

FGD System Wastewater Characterization Data

SiteID	Sample Name	Sample Stream Name	Generic Sample Stream Name	Date of Collection
Site L1	L1A001a	FGD wastewater treatment plant influent	Untreated FGD Wastewater	16-Aug-07
Site L1	L1A001aFF	FGD wastewater treatment plant influent	Untreated FGD Wastewater	16-Aug-07
Site L1	L1A001b	FGD wastewater treatment plant influent	Untreated FGD Wastewater	16-Aug-07
Site L1	L1A001c	FGD wastewater treatment plant influent	Untreated FGD Wastewater	16-Aug-07
Site L1	L1A001d	FGD wastewater treatment plant influent	Untreated FGD Wastewater	16-Aug-07
Site L1	L1A002a	FGD wastewater clarifier effluent	Treated FGD Wastewater	16-Aug-07
Site L1	L1A002aFF	FGD wastewater clarifier effluent	Treated FGD Wastewater	16-Aug-07
Site L1	L1A002b	FGD wastewater clarifier effluent	Treated FGD Wastewater	16-Aug-07
Site L1	L1A002c	FGD wastewater clarifier effluent	Treated FGD Wastewater	16-Aug-07
Site L1	L1A002d	FGD wastewater clarifier effluent	Treated FGD Wastewater	16-Aug-07
Site L1	L1A003	FGD absorber	FGD Absorber Liquid	16-Aug-07
Site L1	L1A003FF	FGD absorber	FGD Absorber Liquid	16-Aug-07
Site L1	L1B001a	FGD wastewater treatment plant influent	Untreated FGD Wastewater	23-Aug-07
Site L1	L1B001aFF	FGD wastewater treatment plant influent	Untreated FGD Wastewater	23-Aug-07
Site L1	L1B001b	FGD wastewater treatment plant influent	Untreated FGD Wastewater	23-Aug-07
Site L1	L1B001C	FGD wastewater treatment plant influent	Untreated FGD Wastewater	23-Aug-07
Site L1	L1B001D	FGD wastewater treatment plant influent	Untreated FGD Wastewater	23-Aug-07
Site L1	L1B002a	FGD wastewater clarifier effluent	Treated FGD Wastewater	23-Aug-07
Site L1	L1B002aFF	FGD wastewater clarifier effluent	Treated FGD Wastewater	23-Aug-07
Site L1	L1B002b	FGD wastewater clarifier effluent	Treated FGD Wastewater	23-Aug-07
Site L1	L1B002C	FGD wastewater clarifier effluent	Treated FGD Wastewater	23-Aug-07
Site L1	L1B002D	FGD wastewater clarifier effluent	Treated FGD Wastewater	23-Aug-07
Site L1	L1B003	FGD absorber	FGD Absorber Liquid	23-Aug-07
Site L1	L1B003FF	FGD absorber	FGD Absorber Liquid	23-Aug-07
Site L2	L2A500	FGD reclaim tank blowdown	Untreated FGD Wastewater	31-Mar-98
Site L2	L2A003a	FGD wastewater treatment plant influent	Untreated FGD Wastewater	26-Jul-07
Site L2	L2A003aFF	FGD wastewater treatment plant influent	Untreated FGD Wastewater	26-Jul-07
Site L2	L2A003B	FGD wastewater treatment plant influent	Untreated FGD Wastewater	26-Jul-07
Site L2	L2A003C	FGD wastewater treatment plant influent	Untreated FGD Wastewater	26-Jul-07
Site L2	L2A003d	FGD wastewater treatment plant influent	Untreated FGD Wastewater	26-Jul-07
Site L2	L2A005a	FGD wastewater clarifier effluent	Treated FGD Wastewater	26-Jul-07
Site L2	L2A005aFF	FGD wastewater clarifier effluent	Treated FGD Wastewater	26-Jul-07
Site L2	L2A005B	FGD wastewater clarifier effluent	Treated FGD Wastewater	26-Jul-07
Site L2	L2A005C	FGD wastewater clarifier effluent	Treated FGD Wastewater	26-Jul-07
Site L2	L2A005d	FGD wastewater clarifier effluent	Treated FGD Wastewater	26-Jul-07
Site P	PJA001	FGD blowdown	FGD Absorber Liquid	9-Jun-05
Site P	PJA002	FGD blowdown	FGD Absorber Liquid	9-Jun-05

FGD System Wastewater Characterization Data

SiteID	Sample Name	Sample Stream Name	Generic Sample Stream Name	Date of Collection
Site P	PJA003	FGD blowdown	FGD Absorber Liquid	9-Jun-05
Site R	RJA001	FGD blowdown	FGD Absorber Liquid	9-Jun-05
Site R	RJA002	FGD blowdown	FGD Absorber Liquid	9-Jun-05
Site R	RJA003	FGD blowdown	FGD Absorber Liquid	9-Jun-05
Site S	SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site S	SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site S	SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site T	TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site T	TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site T	TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	Untreated FGD Wastewater	10-Oct-05
Site U	UJA001	FGD Untreated Wastewater (Thickener overflow)	Untreated FGD Wastewater	26-Oct-05
Site U	UJA002	FGD Untreated Wastewater (Thickener overflow)	Untreated FGD Wastewater	26-Oct-05
Site U	UJA003	FGD Untreated Wastewater (Thickener overflow)	Untreated FGD Wastewater	26-Oct-05
Site U	UJA004	FGD treated wastewater	Treated FGD Wastewater	26-Oct-05
Site U	UJA005	FGD treated wastewater	Treated FGD Wastewater	26-Oct-05
Site U	UJA006	FGD treated wastewater	Treated FGD Wastewater	26-Oct-05
Site Y	YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	Untreated FGD Wastewater	1-Dec-05
Site Y	YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	Untreated FGD Wastewater	1-Dec-05
Site Y	YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	Untreated FGD Wastewater	1-Dec-05
Site Z	ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	Untreated FGD Wastewater	28-Jul-05
Site Z	ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	Untreated FGD Wastewater	28-Jul-05
Site 2B	2BA001	FGD Wastewater Equalization Tank Slurry	Untreated FGD Wastewater	27-Apr-07
Site 2B	2BA001FF	FGD Wastewater Equalization Tank Slurry	Untreated FGD Wastewater	27-Apr-07
Site 2B	2BA002FF	FGD Wastewater Equalization Tank Slurry	Untreated FGD Wastewater	27-Apr-07
Site 2B	2BA003	FGD Absorber Slurry	FGD Absorber Liquid	27-Apr-07
Site 2B	2BA003FF	FGD Absorber Slurry	FGD Absorber Liquid	27-Apr-07
Site 2B	2BA004FF	FGD Absorber Slurry	FGD Absorber Liquid	27-Apr-07
Site 2B	2BA005	FGD Wastewater Primary Clarifier Effluent	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA005FF	FGD Wastewater Primary Clarifier Effluent	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA006FF	FGD Wastewater Primary Clarifier Effluent	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA007	FGD Wastewater Secondary Clarifier	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA007FF	FGD Wastewater Secondary Clarifier	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA008FF	FGD Wastewater Secondary Clarifier	Treated FGD Wastewater	27-Apr-07
Site 2B	2BA009	FGD Reagent Water	FGD Reagent Water	24-Apr-07
Site 2B	2BA010	FGD Discharge	Untreated FGD Wastewater	26-Apr-07
Site 2B	2BA011	FGD Discharge	Untreated FGD Wastewater	29-Apr-07
Site 2B	2BA012	FGD Absorber bed reageant water	FGD Reagent Water	29-Apr-07

FGD System Wastewater Characterization Data

SiteID	Sample Name	Sample Stream Name	Generic Sample Stream Name	Date of Collection
Site 2B	2BA013	FGD Slurry	FGD Absorber Liquid	29-Apr-07
Site 2B	2BA014	FGD Slurry	FGD Absorber Liquid	29-Apr-07
Site 2B	2BA015FF	FGD Absorber-Bleed	FGD Absorber Liquid	26-Apr-07
Site 2B	2BA016FF	FGD Absorber-Bleed	FGD Absorber Liquid	29-Apr-07
Site 2C	2CA001	FGD Absorber Feed Tower	FGD Absorber Liquid	7-Jun-07
Site 2C	2CA002	FGD Reagent Feed Tower	FGD Absorber Liquid	7-Jun-07
Site 2C	2CA003	FGD Make-Up Water	FGD Reagent Water	7-Jun-07
Site 2C	2CA004	FGD Absorber Tower, North	FGD Absorber Liquid	7-Jun-07
Site 2C	2CA005	FGD Absorber Tower, South	FGD Absorber Liquid	7-Jun-07
Site 2C	2CA006	FGD Wastewater	Untreated FGD Wastewater	7-Jun-07
Site 2C	2CA007	FGD hydroclone underflow	Untreated FGD Wastewater	7-Jun-07

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	basis	Aluminum (ug/L)	Antimony (ug/L)	Arsenic (ug/L)
L1A001a	FGD wastewater treatment plant influent	Total	224000 M	100 U	250 U
L1A001aFF	FGD wastewater treatment plant influent	Field Filtered	1000 U,M	100 U	250 U
L1A001b	FGD wastewater treatment plant influent	Lab Filtered (Day 1)	1000 U,M	100 U	250 U
L1A001c	FGD wastewater treatment plant influent	Lab Filtered (Day 3 or 4)	1000 U,M	100 U	250 U
L1A001d	FGD wastewater treatment plant influent	Lab Filtered (Day 1, No Ice)	1000 U,M	100 U	250 U
L1A002a	FGD wastewater clarifier effluent	Total	1000 U,M	100 U	250 U
L1A002aFF	FGD wastewater clarifier effluent	Field Filtered	1000 U,M	100 U	250 U
L1A002b	FGD wastewater clarifier effluent	Lab Filtered (Day 1)	1000 U,M	100 U	250 U
L1A002c	FGD wastewater clarifier effluent	Lab Filtered (Day 3 or 4)	1000 U,M	100 U	250 U
L1A002d	FGD wastewater clarifier effluent	Lab Filtered (Day 1, No Ice)	1000 U,M	100 U	250 U
L1A003	FGD absorber	Total	287000 M	1000 U	2500 U
L1A003FF	FGD absorber	Field Filtered	1350 M	100 U	250 U
L1B001a	FGD wastewater treatment plant influent	Total	135000	100 U	250 U
L1B001aFF	FGD wastewater treatment plant influent	Field Filtered	1000 U	100 U	250 U
L1B001b	FGD wastewater treatment plant influent	Lab Filtered (Day 1)	1000 U	100 U	250 U
L1B001C	FGD wastewater treatment plant influent	Lab Filtered (Day 3 or 4)	1000 U	100 U	250 U
L1B001D	FGD wastewater treatment plant influent	Lab Filtered (Day 1, No Ice)	1000 U	100 U	250 U
L1B002a	FGD wastewater clarifier effluent	Total	1000 U	100 U	250 U
L1B002aFF	FGD wastewater clarifier effluent	Field Filtered	1340	100 U	250 U
L1B002b	FGD wastewater clarifier effluent	Lab Filtered (Day 1)	1000 U	100 U	250 U
L1B002C	FGD wastewater clarifier effluent	Lab Filtered (Day 3 or 4)	1000 U	100 U	250 U
L1B002D	FGD wastewater clarifier effluent	Lab Filtered (Day 1, No Ice)	1000 U	100 U	250 U
L1B003	FGD absorber	Total	240000	1000 U	2500 U
L1B003FF	FGD absorber	Field Filtered	1000 U	100 U	250 U
L2A500	FGD reclaim tank blowdown		43122.76	18.66	95.06
L2A003a	FGD wastewater treatment plant influent	Total	625000	203	2440
L2A003aFF	FGD wastewater treatment plant influent	Field Filtered	1270	100 U	250 U
L2A003B	FGD wastewater treatment plant influent	Lab Filtered (Day 1)	1630	100 U	250 U
L2A003C	FGD wastewater treatment plant influent	Lab Filtered (Day 3 or 4)	1660	100 U	250 U
L2A003d	FGD wastewater treatment plant influent	Lab Filtered (Day 1, No Ice)	1000 U	100 U	250 U
L2A005a	FGD wastewater clarifier effluent	Total	2780	100 U	250 U
L2A005aFF	FGD wastewater clarifier effluent	Field Filtered	2860	100 U	250 U
L2A005B	FGD wastewater clarifier effluent	Lab Filtered (Day 1)	2710	100 U	250 U
L2A005C	FGD wastewater clarifier effluent	Lab Filtered (Day 3 or 4)	2670	100 U	250 U
L2A005d	FGD wastewater clarifier effluent	Lab Filtered (Day 1, No Ice)	2750	100 U	250 U
PJA001	FGD blowdown	settled	1000 U	50 U	30 U
PJA002	FGD blowdown	total	26000	500 U	300 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	basis	Aluminum (ug/L)	Antimony (ug/L)	Arsenic (ug/L)
PJA003	FGD blowdown	filtered	1000 U	50 U	30 U
RJA001	FGD blowdown	settled	1000 U	50 U	30 U
RJA002	FGD blowdown	total	102000	500 U	300 U
RJA003	FGD blowdown	filtered	1000 U	50 U	30 U
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	settled	1990	10 U	10 U
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	total	174000	500 U	240
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	filtered	200 U	10 U	10 U
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	settled	1810	50 U	10 U
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	total	170000	500 U	415
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	filtered	1000 U	50 U	10 U
UJA001	FGD Untreated Wastewater (Thickener overflow)	settled	739	10 U	16.3
UJA002	FGD Untreated Wastewater (Thickener overflow)	total	955	10 U	17.3
UJA003	FGD Untreated Wastewater (Thickener overflow)	filtered	403	10 U	15.5
UJA004	FGD treated wastewater	settled	1040	10 U	10.5
UJA005	FGD treated wastewater	total	1180	10 U	10 U
UJA006	FGD treated wastewater	filtered	200 U	10 U	10.9
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	settled	26300	17.7	5.8
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	total	26500	16.4	6.1
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	filtered	25100	14.1	1.6
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	total	34600	50 U	277
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	filtered	1000 U	50 U	150 U
2BA001	FGD Wastewater Equalization Tank Slurry	unfiltered	1010	100 U	250 U
2BA001FF	FGD Wastewater Equalization Tank Slurry	Filtered			
2BA002FF	FGD Wastewater Equalization Tank Slurry	Filtered	1000 U	100 U	250 U
2BA003	FGD Absorber Slurry	unfiltered	2350	100 U	250 U
2BA003FF	FGD Absorber Slurry	Filtered			
2BA004FF	FGD Absorber Slurry	Filtered	1510	100 U	250 U
2BA005	FGD Wastewater Primary Clarifier Effluent	unfiltered	1000 U	100 U	250 U
2BA005FF	FGD Wastewater Primary Clarifier Effluent	Filtered			
2BA006FF	FGD Wastewater Primary Clarifier Effluent	Filtered	1000 U	100 U	250 U
2BA007	FGD Wastewater Secondary Clarifier	unfiltered	1000 U	100 U	250 U
2BA007FF	FGD Wastewater Secondary Clarifier	Filtered			
2BA008FF	FGD Wastewater Secondary Clarifier	Filtered	1000 U	100 U	250 U
2BA009	FGD Reagent Water		100 U	10 U	25 U
2BA010	FGD Discharge		1000 U	100 U	250 U
2BA011	FGD Discharge		2000 U	200 U	500 U
2BA012	FGD Absorber bed reageant water		100 U	10 U	25 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	basis	Aluminum (ug/L)	Antimony (ug/L)	Arsenic (ug/L)
2BA013	FGD Slurry		1000 U	100 U	250 U
2BA014	FGD Slurry		1000 U	100 U	250 U
2BA015FF	FGD Absorber-Bleed	Filtered			
2BA016FF	FGD Absorber-Bleed	Filtered			
2CA001	FGD Absorber Feed Tower		500 U	50 U	125 U
2CA002	FGD Reagent Feed Tower		100 U	10 U	25 U
2CA003	FGD Make-Up Water		100 U	10 U	25 U
2CA004	FGD Absorber Tower, North		500 U	50 U	125 U
2CA005	FGD Absorber Tower, South		500 U	50 U	125 U
2CA006	FGD Wastewater		1000 U	100 U	250 U
2CA007	FGD hydroclone underflow		500 U	50 U	125 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Barium (ug/L)	Beryllium (ug/L)	Boron (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Cobalt (ug/L)	Copper (ug/L)
L1A001a	FGD wastewater treatment plant influent	1900 D	40 U	178000	50 U	285	100 U	194
L1A001aFF	FGD wastewater treatment plant influent	250 U	40 U	151000	50 U	100 U	100 U	100 U
L1A001b	FGD wastewater treatment plant influent	419	40 U		50 U	100 U	100 U	100 U
L1A001c	FGD wastewater treatment plant influent	318	40 U	179000	50 U	100 U	100 U	100 U
L1A001d	FGD wastewater treatment plant influent	437	40 U	171000	50 U	100 U	100 U	100 U
L1A002a	FGD wastewater clarifier effluent	479	40 U	169000	50 U	100 U	100 U	100 U
L1A002aFF	FGD wastewater clarifier effluent	250 U	40 U	149000	50 U	100 U	100 U	100 U
L1A002b	FGD wastewater clarifier effluent	500	40 U	172000	50 U	100 U	100 U	100 U
L1A002c	FGD wastewater clarifier effluent	473	40 U	179000	50 U	100 U	100 U	100 U
L1A002d	FGD wastewater clarifier effluent	501	40 U	172000	50 U	100 U	100 U	100 U
L1A003	FGD absorber	2500 U	400 U	160000	500 U	1000 U	1000 U	1000 U
L1A003FF	FGD absorber	250 U	40 U	174000	50 U	100 U	100 U	100 U
L1B001a	FGD wastewater treatment plant influent	1610	40 U	176000	50 U	198	100 U	188
L1B001aFF	FGD wastewater treatment plant influent	250 U	40 U	174000	50 U	100 U	100 U	100 U
L1B001b	FGD wastewater treatment plant influent	491	40 U	172000	50 U	100 U	100 U	100 U
L1B001C	FGD wastewater treatment plant influent	375	40 U	168000	50 U	100 U	100 U	100 U
L1B001D	FGD wastewater treatment plant influent	510	40 U	165000	50 U	100 U	100 U	100 U
L1B002a	FGD wastewater clarifier effluent	644	40 U	176000	50 U	100 U	100 U	100 U
L1B002aFF	FGD wastewater clarifier effluent	486	40 U	169000	50 U	100 U	100 U	100 U
L1B002b	FGD wastewater clarifier effluent	542	40 U	169000	50 U	100 U	100 U	100 U
L1B002C	FGD wastewater clarifier effluent	565	40 U	172000	50 U	100 U	100 U	100 U
L1B002D	FGD wastewater clarifier effluent	559	40 U	163000	50 U	100 U	100 U	100 U
L1B003	FGD absorber	2500 U	400 U	142000	500 U	1000 U	1000 U	1000 U
L1B003FF	FGD absorber	250 U	40 U	157000	50 U	100 U	100 U	100 U
L2A500	FGD reclaim tank blowdown	302.76	2.72	150178.3	7.68	185	26.5	75.88
L2A003a	FGD wastewater treatment plant influent	3040	62.2	1250000	279	4790	439	1450
L2A003aFF	FGD wastewater treatment plant influent	250 U	40 U	1400000	287	100 U	329	100 U
L2A003B	FGD wastewater treatment plant influent	250 U	40 U	1290000	264	100 U	307	100 U
L2A003C	FGD wastewater treatment plant influent	250 U	40 U	1310000	277	100 U	323	100 U
L2A003d	FGD wastewater treatment plant influent	250 U	40 U	1130000	234	100 U	271	100 U
L2A005a	FGD wastewater clarifier effluent	250 U	40 U	1090000	224	100 U	259	100 U
L2A005aFF	FGD wastewater clarifier effluent	250 U	40 U	1120000	221	100 U	258	100 U
L2A005B	FGD wastewater clarifier effluent	250 U	40 U	1080000	227	100 U	255	100 U
L2A005C	FGD wastewater clarifier effluent	250 U	40 U	1100000	227	100 U	258	100 U
L2A005d	FGD wastewater clarifier effluent	250 U	40 U	1090000	227	100 U	259	100 U
PJA001	FGD blowdown	1060	40 U	261000	50 U	100 U	100 U	100 U
PJA002	FGD blowdown	2500 U	400 U	244000	500 U	1030	1000 U	1000 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Barium (ug/L)	Beryllium (ug/L)	Boron (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Cobalt (ug/L)	Copper (ug/L)
PJA003	FGD blowdown	1030	40 U	255000	50 U	100 U	100 U	100 U
RJA001	FGD blowdown	250 U	40 U	407000	50 U	100 U	100 U	298
RJA002	FGD blowdown	2930	400 U	340000	500 U	1000 U	1000 U	4230
RJA003	FGD blowdown	250 U	40 U	411000	50 U	100 U	100 U	321
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	57.9	8 U	87900	39.6	20 U	57.7	68.6
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	3040	400 U	85200	500 U	1050	1000 U	1530
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	50 U	8 U	88300	37.8	20 U	55.8	47.4
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	250 U	40 U	359000	96.4	100 U	100 U	121
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	2960	400 U	344000	500 U	1000 U	1000 U	1000 U
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	250 U	40 U	360000	96.7	100 U	100 U	100 U
UJA001	FGD Untreated Wastewater (Thickener overflow)	232	8 U	14400	16.3	20 U	20 U	157
UJA002	FGD Untreated Wastewater (Thickener overflow)	254	8 U	15100	12.2	20 U	20 U	152
UJA003	FGD Untreated Wastewater (Thickener overflow)	207	8 U	14900	10 U	20 U	20 U	136
UJA004	FGD treated wastewater	143	8 U	9120	10 U	20 U	20 U	41.8
UJA005	FGD treated wastewater	143	8 U	9150	10 U	20 U	20 U	38.7
UJA006	FGD treated wastewater	148	8 U	9660	10 U	20 U	20 U	45.1
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	158	4 U	17100	21.5	35.9	28	158
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	136	4 U	17500	21.3	37.2	28.2	157
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	225	4 U	14300	21	12	26.7	145
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	1560	40 U	510000	50 U	187		301
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	400	40 U	510000	50 U	100 U		100 U
2BA001	FGD Wastewater Equalization Tank Slurry	250 U	40 U	19400	50 U	100 U	100 U	100 U
2BA001FF	FGD Wastewater Equalization Tank Slurry							
2BA002FF	FGD Wastewater Equalization Tank Slurry	250 U	40 U	19600	50 U	100 U	100 U	100 U
2BA003	FGD Absorber Slurry	250 U	40 U	18000	50 U	100 U	100 U	100 U
2BA003FF	FGD Absorber Slurry							
2BA004FF	FGD Absorber Slurry	250 U	40 U	18500	50 U	100 U	103	100 U
2BA005	FGD Wastewater Primary Clarifier Effluent	250 U	40 U	9280	50 U	100 U	100 U	100 U
2BA005FF	FGD Wastewater Primary Clarifier Effluent							
2BA006FF	FGD Wastewater Primary Clarifier Effluent	250 U	40 U	9140	50 U	100 U	100 U	100 U
2BA007	FGD Wastewater Secondary Clarifier	250 U	40 U	9420	50 U	100 U	100 U	100 U
2BA007FF	FGD Wastewater Secondary Clarifier							
2BA008FF	FGD Wastewater Secondary Clarifier	250 U	40 U	9340	50 U	100 U	100 U	100 U
2BA009	FGD Reagent Water	25 U	4 U	1290	5 U	10 U	10 U	10 U
2BA010	FGD Discharge	250 U	40 U	19900	50 U	100 U	100 U	100 U
2BA011	FGD Discharge	500 U	80 U	18300	100 U	200 U	200 U	200 U
2BA012	FGD Absorber bed reageant water	25 U	4 U	1080	5 U	10 U	10 U	10 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Barium (ug/L)	Beryllium (ug/L)	Boron (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Cobalt (ug/L)	Copper (ug/L)
2BA013	FGD Slurry	250 U	40 U	17800	50 U	100 U	100 U	100 U
2BA014	FGD Slurry	250 U	40 U	22500	50 U	100 U	100 U	100 U
2BA015FF	FGD Absorber-Bleed							
2BA016FF	FGD Absorber-Bleed							
2CA001	FGD Absorber Feed Tower	139	20 U	8810	25 U	50 U	50 U	50 U
2CA002	FGD Reagent Feed Tower	25 U	4 U	153	5 U	10 U	10 U	10 U
2CA003	FGD Make-Up Water	30.6	4 U	100 U	5 U	10 U	10 U	10 U
2CA004	FGD Absorber Tower, North	198	20 U	142000	25 U	50 U	50 U	50 U
2CA005	FGD Absorber Tower, South	225	20 U	154000	25 U	50 U	50 U	50 U
2CA006	FGD Wastewater	492	40 U	527000	50 U	100 U	100 U	100 U
2CA007	FGD hydroclone underflow	203	20 U	135000	25 U	50 U	50 U	50 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Iron (ug/L)	Lead (ug/L)	Mercury (ug/L)	Molybdenum (ug/L)	Nickel (ug/L)	Selenium (ug/L)
L1A001a	FGD wastewater treatment plant influent	170000 M	145	59.1	250 U	332	2060 D
L1A001aFF	FGD wastewater treatment plant influent	1000 U,M	50 U	4.2	250 U	200 U	778
L1A001b	FGD wastewater treatment plant influent	1000 U,M	50 U	3.4	250 U	200 U	752
L1A001c	FGD wastewater treatment plant influent	1000 U,M	50 U	6.4	250 U	200 U	821
L1A001d	FGD wastewater treatment plant influent	1000 U,M	50 U	4.8	250 U	200 U	858
L1A002a	FGD wastewater clarifier effluent	1000 U,M	50 U	7.9	250 U	200 U	834
L1A002aFF	FGD wastewater clarifier effluent	1000 U,M	50 U	6.8	250 U	200 U	866
L1A002b	FGD wastewater clarifier effluent	1000 U,M	50 U	7.2	250 U	200 U	691
L1A002c	FGD wastewater clarifier effluent	1000 U,M	50 U	7.5	250 U	200 U	931
L1A002d	FGD wastewater clarifier effluent	1000 U,M	50 U	6.9	250 U	200 U	855
L1A003	FGD absorber	223000 M	500 U	108	2500 U	2000 U	3950
L1A003FF	FGD absorber	1000 U,M	50 U	1.7	250 U	200 U	556
L1B001a	FGD wastewater treatment plant influent	125000	123	43900	250 U	305	2210
L1B001aFF	FGD wastewater treatment plant influent	1000 U	50 U	0.1 U	250 U	200 U	685 D
L1B001b	FGD wastewater treatment plant influent	1000 U	50 U	0.1 U	250 U	200 U	613
L1B001C	FGD wastewater treatment plant influent	1000 U	50 U	0.27	250 U	200 U	497
L1B001D	FGD wastewater treatment plant influent	1000 U	50 U	0.1 U	250 U	200 U	612
L1B002a	FGD wastewater clarifier effluent	1000 U	50 U	255	250 U	208	564
L1B002aFF	FGD wastewater clarifier effluent	1000 U	50 U	0.1 U	250 U	200 U	674
L1B002b	FGD wastewater clarifier effluent	1000 U	50 U	0.1 U	250 U	200 U	578
L1B002C	FGD wastewater clarifier effluent	1000 U	50 U	0.1 U	250 U	200 U	560
L1B002D	FGD wastewater clarifier effluent	1000 U	50 U	0.1 U	250 U	200 U	639
L1B003	FGD absorber	214000	500 U	83400	2500 U	2000 U	4110
L1B003FF	FGD absorber	1000 U	50 U	0.1 U	250 U	200 U	1120
L2A500	FGD reclaim tank blowdown	41851.68	33.3	18.289	185.06	259.7	924.38
L2A003a	FGD wastewater treatment plant influent	721000	906	496	2210	4290	4710
L2A003aFF	FGD wastewater treatment plant influent	1000 U	50 U	0.52 M	865	3100	1420
L2A003B	FGD wastewater treatment plant influent	1000 U	50 U	0.2 M	822	2860	1240
L2A003C	FGD wastewater treatment plant influent	1000 U	50 U	0.16 M	860	3000	1240
L2A003d	FGD wastewater treatment plant influent	1000 U	50 U	0.27 M	782	2500	1260
L2A005a	FGD wastewater clarifier effluent	1000 U	50 U	7.1	338	2540	792
L2A005aFF	FGD wastewater clarifier effluent	1000 U	50 U	0.27 M	327	2520	741
L2A005B	FGD wastewater clarifier effluent	1000 U	50 U	1.1 M	363	2490	821
L2A005C	FGD wastewater clarifier effluent	1000 U	50 U	0.95 M	336	2520	702
L2A005d	FGD wastewater clarifier effluent	1000 U	50 U	0.24 M	328	2540	798
PJA001	FGD blowdown	1630	50 U	2.3	549	463	1660
PJA002	FGD blowdown	60900	500 U	73.6	2500 U	2000 U	2930

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Iron (ug/L)	Lead (ug/L)	Mercury (ug/L)	Molybdenum (ug/L)	Nickel (ug/L)	Selenium (ug/L)
PJA003	FGD blowdown	1000 U	50 U	0.55	532	447	1610
RJA001	FGD blowdown	1000 U	50 U	6.4	250 U	200 U	1860
RJA002	FGD blowdown	185000	500 U	91.6	2500 U	2000 U	2000 U
RJA003	FGD blowdown	1000 U	50 U	7.4	250 U	200 U	1810
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	1850	10 U	1.2	79.3	263	508
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	257000	500 U	103	2500 U	2000 U	2000 U
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	200 U	10 U	0.1	76.2	258	485
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	2060	50 U	1.4	748	694	1160
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	292000	500 U	78	2500 U	2000 U	2000 U
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	1000 U	50 U	0.44	758	687	1150
UJA001	FGD Untreated Wastewater (Thickener overflow)	657	10 U	7.1	88.7	173	40 U
UJA002	FGD Untreated Wastewater (Thickener overflow)	974	10 U	7.5	89.6	181	40 U
UJA003	FGD Untreated Wastewater (Thickener overflow)	200 U	10 U	3.3	86.6	173	40 U
UJA004	FGD treated wastewater	200 U	10 U	0.21	71.4	40 U	40 U
UJA005	FGD treated wastewater	200 U	10 U	0.19	70.5	40 U	40 U
UJA006	FGD treated wastewater	200 U	10 U	0.13	73.3	47.2	40 U
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	2490	5 U	9.5	34.4	96.2	157
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	2580	5 U	9.5	35.4	94.5	172
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	100 U	5 U	9	25 U	92.1	131
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	63400	50 U	47.85		1460	1460
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	1000 U	50 U	0.1 U		1350	1070
2BA001	FGD Wastewater Equalization Tank Slurry	2210	50 U	20.5	250 U	970	10300
2BA001FF	FGD Wastewater Equalization Tank Slurry			12			
2BA002FF	FGD Wastewater Equalization Tank Slurry	1000 U	50 U		250 U	958	10000
2BA003	FGD Absorber Slurry	2110	50 U	7.2	250 U	994	5400
2BA003FF	FGD Absorber Slurry			1.1			
2BA004FF	FGD Absorber Slurry	1000 U	50 U		250 U	989	5580
2BA005	FGD Wastewater Primary Clarifier Effluent	1000 U	50 U	84	250 U	200 U	9790
2BA005FF	FGD Wastewater Primary Clarifier Effluent			81.9			
2BA006FF	FGD Wastewater Primary Clarifier Effluent	1000 U	50 U		250 U	200 U	9510
2BA007	FGD Wastewater Secondary Clarifier	1010	50 U	4.1	250 U	200 U	9750
2BA007FF	FGD Wastewater Secondary Clarifier			1.7			
2BA008FF	FGD Wastewater Secondary Clarifier	1000 U	50 U		250 U	200 U	9260
2BA009	FGD Reagent Water	100 U	5 U		25.2	25.1	406
2BA010	FGD Discharge	1000 U	50 U		250 U	839	8700
2BA011	FGD Discharge	2000 U	100 U		500 U	766	6430
2BA012	FGD Absorber bed reageant water	100 U	5 U		25 U	23.6	371

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Iron (ug/L)	Lead (ug/L)	Mercury (ug/L)	Molybdenum (ug/L)	Nickel (ug/L)	Selenium (ug/L)
2BA013	FGD Slurry	1000 U	50 U		250 U	764	5420
2BA014	FGD Slurry	1000 U	50 U		250 U	937	14200
2BA015FF	FGD Absorber-Bleed						
2BA016FF	FGD Absorber-Bleed						
2CA001	FGD Absorber Feed Tower	500 U	25 U	0.1 U*	125 U	193	150 U
2CA002	FGD Reagent Feed Tower	100 U	5 U	0.1 U*	25 U	20 U	30 U
2CA003	FGD Make-Up Water	100 U	5 U	0.1 U*	25 U	20 U	30 U
2CA004	FGD Absorber Tower, North	500 U	25 U	11.3	125 U	738	410
2CA005	FGD Absorber Tower, South	500 U	25 U	28.6	125 U	699	354
2CA006	FGD Wastewater	1000 U	50 U	0.17	250 U	928	385
2CA007	FGD hydroclone underflow	500 U	25 U	1.2	125 U	679	306

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Silver (ug/L)	Strontium (ug/L)	Thallium (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Zinc (ug/L)
L1A001a	FGD wastewater treatment plant influent	100 U		100 U	2800	327	494
L1A001aFF	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1A001b	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1A001c	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1A001d	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1A002a	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1A002aFF	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1A002b	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1A002c	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1A002d	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1A003	FGD absorber	1000 U		1000 U	10000 U	2500 U	2000 U
L1A003FF	FGD absorber	100 U		100 U	1000 U	250 U	287
L1B001a	FGD wastewater treatment plant influent	100 U		100 U	2340	251	457
L1B001aFF	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	216
L1B001b	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1B001C	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1B001D	FGD wastewater treatment plant influent	100 U		100 U	1000 U	250 U	200 U
L1B002a	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1B002aFF	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1B002b	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1B002C	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1B002D	FGD wastewater clarifier effluent	100 U		100 U	1000 U	250 U	200 U
L1B003	FGD absorber	1000 U		2340	10000 U	2500 U	2000 U
L1B003FF	FGD absorber	100 U		100 U	1000 U	250 U	272
L2A500	FGD reclaim tank blowdown	-6.2		-18.22	287.62	102.9	406.26
L2A003a	FGD wastewater treatment plant influent	100 U		247	7750	4280	13500
L2A003aFF	FGD wastewater treatment plant influent	100 U		243	1000 U	250 U	6180
L2A003B	FGD wastewater treatment plant influent	100 U		184	1000 U	250 U	6050
L2A003C	FGD wastewater treatment plant influent	100 U		218	1000 U	250 U	6480
L2A003d	FGD wastewater treatment plant influent	100 U		163	1000 U	250 U	4700
L2A005a	FGD wastewater clarifier effluent	100 U		159 D	1000 U	250 U	4870
L2A005aFF	FGD wastewater clarifier effluent	100 U		167	1000 U	250 U	4800
L2A005B	FGD wastewater clarifier effluent	100 U		238	1000 U	250 U	4750
L2A005C	FGD wastewater clarifier effluent	100 U		241	1000 U	250 U	4790
L2A005d	FGD wastewater clarifier effluent	100 U		175	1000 U	250 U	4880
PJA001	FGD blowdown	100 U		100 U	1000 U	250 U	200 U
PJA002	FGD blowdown	1000 U		1000 U	10000 U	2500 U	2000 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Silver (ug/L)	Strontium (ug/L)	Thallium (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Zinc (ug/L)
PJA003	FGD blowdown	100 U		100 U	1000 U	250 U	200 U
RJA001	FGD blowdown	100 U		100 U	1000 U	250 U	200 U
RJA002	FGD blowdown	1000 U		1000 U	10000 U	2500 U	2000 U
RJA003	FGD blowdown	100 U		100 U	1000 U	250 U	200 U
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	20 U		20 U	200 U	50 U	1100
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	1000 U		1000 U	10000 U	2500 U	3440
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	20 U		20 U	200 U	50 U	1080
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	100 U		100 U	1000 U	250 U	3440
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	1000 U		1000 U	10000 U	2500 U	9040
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	100 U		100 U	1000 U	250 U	3480
UJA001	FGD Untreated Wastewater (Thickener overflow)	20 U		20 U	200 U	50 U	54.2
UJA002	FGD Untreated Wastewater (Thickener overflow)	20 U		20 U	200 U	50 U	57.5
UJA003	FGD Untreated Wastewater (Thickener overflow)	20 U		20 U	200 U	50 U	53
UJA004	FGD treated wastewater	20 U		20 U	200 U	50 U	40 U
UJA005	FGD treated wastewater	20 U		20 U	200 U	50 U	40 U
UJA006	FGD treated wastewater	20 U		20 U	200 U	50 U	40 U
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	10 U		14.3	152	25 U	1310
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	10 U		10 U	163	25 U	1310
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	10 U		10 U	100 U	25 U	1290
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	100 U	18000	100 U			1250
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	100 U	14600	100 U			997
2BA001	FGD Wastewater Equalization Tank Slurry	100 U		105	1000 U	250 U	697
2BA001FF	FGD Wastewater Equalization Tank Slurry						
2BA002FF	FGD Wastewater Equalization Tank Slurry	100 U		121	1000 U	250 U	668
2BA003	FGD Absorber Slurry	100 U		147	1000 U	250 U	823
2BA003FF	FGD Absorber Slurry						
2BA004FF	FGD Absorber Slurry	100 U		119	1000 U	250 U	802
2BA005	FGD Wastewater Primary Clarifier Effluent	100 U		100 U	1000 U	250 U	200 U
2BA005FF	FGD Wastewater Primary Clarifier Effluent						
2BA006FF	FGD Wastewater Primary Clarifier Effluent	100 U		100 U	1000 U	250 U	200 U
2BA007	FGD Wastewater Secondary Clarifier	100 U		100 U	1000 U	250 U	200 U
2BA007FF	FGD Wastewater Secondary Clarifier						
2BA008FF	FGD Wastewater Secondary Clarifier	100 U		100 U	1000 U	250 U	200 U
2BA009	FGD Reagent Water	10 U			100 U	25 U	20 U
2BA010	FGD Discharge	100 U			1000 U	250 U	670
2BA011	FGD Discharge	200 U			2000 U	500 U	400 U
2BA012	FGD Absorber bed reageant water	10 U			100 U	25 U	20 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Silver (ug/L)	Strontium (ug/L)	Thallium (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Zinc (ug/L)
2BA013	FGD Slurry	100 U			1000 U	250 U	504
2BA014	FGD Slurry	100 U			1000 U	250 U	1150
2BA015FF	FGD Absorber-Bleed						
2BA016FF	FGD Absorber-Bleed						
2CA001	FGD Absorber Feed Tower	50 U		50 U	500 U	125 U	100 U
2CA002	FGD Reagent Feed Tower	10 U		10 U	100 U	25 U	20 U
2CA003	FGD Make-Up Water	10 U		10 U	100 U	25 U	20 U
2CA004	FGD Absorber Tower, North	50 U		50 U	500 U	125 U	118
2CA005	FGD Absorber Tower, South	50 U		50 U	500 U	125 U	117
2CA006	FGD Wastewater	100 U		100 U	1000 U	250 U	200 U
2CA007	FGD hydroclone underflow	50 U		50 U	500 U	125 U	100 U

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Calcium (ug/L)	Magnesium (ug/L)	Manganese (ug/L)	Potassium (ug/L)	Silicon (ug/L)	Sodium (ug/L)
L1A001a	FGD wastewater treatment plant influent	3820000 D	1540000	7860 D	121000 D		78300
L1A001aFF	FGD wastewater treatment plant influent						
L1A001b	FGD wastewater treatment plant influent			309			
L1A001c	FGD wastewater treatment plant influent						
L1A001d	FGD wastewater treatment plant influent						
L1A002a	FGD wastewater clarifier effluent	2480000	1510000	100 U	30600		68200
L1A002aFF	FGD wastewater clarifier effluent						
L1A002b	FGD wastewater clarifier effluent						
L1A002c	FGD wastewater clarifier effluent						
L1A002d	FGD wastewater clarifier effluent						
L1A003	FGD absorber	34300000	1400000	9060	182000		100000 U
L1A003FF	FGD absorber						
L1B001a	FGD wastewater treatment plant influent	3670000	1240000	8960	100000 U		60900
L1B001aFF	FGD wastewater treatment plant influent						
L1B001b	FGD wastewater treatment plant influent						
L1B001C	FGD wastewater treatment plant influent						
L1B001D	FGD wastewater treatment plant influent						
L1B002a	FGD wastewater clarifier effluent	2770000	1530000	4320	30900		71400
L1B002aFF	FGD wastewater clarifier effluent						
L1B002b	FGD wastewater clarifier effluent						
L1B002C	FGD wastewater clarifier effluent						
L1B002D	FGD wastewater clarifier effluent						
L1B003	FGD absorber	38700000	1280000	9950	145000		100000 U
L1B003FF	FGD absorber						
L2A500	FGD reclaim tank blowdown	2126536.9	1983610.8	1890.7	36110.8	17471.8	99540.2
L2A003a	FGD wastewater treatment plant influent	1980000	7150000	54300	504000		1150000
L2A003aFF	FGD wastewater treatment plant influent						
L2A003B	FGD wastewater treatment plant influent						
L2A003C	FGD wastewater treatment plant influent						
L2A003d	FGD wastewater treatment plant influent						
L2A005a	FGD wastewater clarifier effluent	669000	5850000	45900	198000		938000
L2A005aFF	FGD wastewater clarifier effluent						
L2A005B	FGD wastewater clarifier effluent						
L2A005C	FGD wastewater clarifier effluent						
L2A005d	FGD wastewater clarifier effluent						
PJA001	FGD blowdown	4440000	4710000	6530	1120000		5550000
PJA002	FGD blowdown	30500000	4290000	8410	684000		5340000

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Calcium (ug/L)	Magnesium (ug/L)	Manganese (ug/L)	Potassium (ug/L)	Silicon (ug/L)	Sodium (ug/L)
PJA003	FGD blowdown	4240000	4510000	6390	1060000		5530000
RJA001	FGD blowdown	751000	1150000	1670	27100		950000
RJA002	FGD blowdown	34300000	1050000	14900	70600		867000
RJA003	FGD blowdown	748000	1140000	1650	28000		943000
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	693000	1030000	13800	22700		140000
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	28000000	1040000	14200	98500		112000
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	638000	994000	13900	20600		135000
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	683000	2510000	19000	195000		396000
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	4930000	2680000	23800	241000		323000
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	640000	2550000	19300	202000		389000
UJA001	FGD Untreated Wastewater (Thickener overflow)	650000	838000	5350	309000		2400000
UJA002	FGD Untreated Wastewater (Thickener overflow)	680000	873000	5480	326000		2580000
UJA003	FGD Untreated Wastewater (Thickener overflow)	659000	851000	5380	329000		2540000
UJA004	FGD treated wastewater	558000	526000	303	204000		1470000
UJA005	FGD treated wastewater	560000	531000	307	198000		1500000
UJA006	FGD treated wastewater	570000	564000	871	201000		1710000
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	737000	204000	1840	22300		51600
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	757000	205000	1840	23200		52000
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	725000	199000	1810	21900		51600
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	3580000	4350000	67700			
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	2830000	4220000	65900			
2BA001	FGD Wastewater Equalization Tank Slurry	643000	5250000	21500	159000		1050000
2BA001FF	FGD Wastewater Equalization Tank Slurry						
2BA002FF	FGD Wastewater Equalization Tank Slurry						
2BA003	FGD Absorber Slurry	654000	5840000	58700	197000		1290000
2BA003FF	FGD Absorber Slurry						
2BA004FF	FGD Absorber Slurry						
2BA005	FGD Wastewater Primary Clarifier Effluent	809000	3910000	100 U	142000		933000
2BA005FF	FGD Wastewater Primary Clarifier Effluent						
2BA006FF	FGD Wastewater Primary Clarifier Effluent						
2BA007	FGD Wastewater Secondary Clarifier	815000	4090000	100 U	140000		976000
2BA007FF	FGD Wastewater Secondary Clarifier						
2BA008FF	FGD Wastewater Secondary Clarifier						
2BA009	FGD Reagent Water						
2BA010	FGD Discharge						
2BA011	FGD Discharge						
2BA012	FGD Absorber bed reageant water						

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Calcium (ug/L)	Magnesium (ug/L)	Manganese (ug/L)	Potassium (ug/L)	Silicon (ug/L)	Sodium (ug/L)
2BA013	FGD Slurry						
2BA014	FGD Slurry						
2BA015FF	FGD Absorber-Bleed						
2BA016FF	FGD Absorber-Bleed						
2CA001	FGD Absorber Feed Tower	1460000	255000	6180	10000 U		29600
2CA002	FGD Reagent Feed Tower	62300	9630	10 U	5530		17400
2CA003	FGD Make-Up Water	22200	13500	10 U	1910		6710
2CA004	FGD Absorber Tower, North	2070000	278000	12500	11000		38800
2CA005	FGD Absorber Tower, South	2260000	331000	16200	12000		43400
2CA006	FGD Wastewater	3730000	625000	37200	26400		80100
2CA007	FGD hydroclone underflow	2220000	316000	12100	11900		41800

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Sulfate (mg/L)	Acidity as CaCO3 (mg/L)
L1A001a	FGD wastewater treatment plant influent		7920	6.6			1650	202
L1A001aFF	FGD wastewater treatment plant influent							
L1A001b	FGD wastewater treatment plant influent							
L1A001c	FGD wastewater treatment plant influent							
L1A001d	FGD wastewater treatment plant influent							
L1A002a	FGD wastewater clarifier effluent		7380	6.2			1780	253
L1A002aFF	FGD wastewater clarifier effluent							
L1A002b	FGD wastewater clarifier effluent							
L1A002c	FGD wastewater clarifier effluent							
L1A002d	FGD wastewater clarifier effluent							
L1A003	FGD absorber		7670	6.5			1560	215
L1A003FF	FGD absorber							
L1B001a	FGD wastewater treatment plant influent		7980	6.9			1540	225
L1B001aFF	FGD wastewater treatment plant influent							
L1B001b	FGD wastewater treatment plant influent							
L1B001C	FGD wastewater treatment plant influent							
L1B001D	FGD wastewater treatment plant influent							
L1B002a	FGD wastewater clarifier effluent		7990	6.1			1580	225
L1B002aFF	FGD wastewater clarifier effluent							
L1B002b	FGD wastewater clarifier effluent							
L1B002C	FGD wastewater clarifier effluent							
L1B002D	FGD wastewater clarifier effluent							
L1B003	FGD absorber		6640	7.1			1370	250
L1B003FF	FGD absorber							
L2A500	FGD reclaim tank blowdown	3 U	384	41.1	5.91	0.05 U	9500	586
L2A003a	FGD wastewater treatment plant influent		8230	108			15600	2630
L2A003aFF	FGD wastewater treatment plant influent							
L2A003B	FGD wastewater treatment plant influent							
L2A003C	FGD wastewater treatment plant influent							
L2A003d	FGD wastewater treatment plant influent							
L2A005a	FGD wastewater clarifier effluent		6900	57.2			13400	2000
L2A005aFF	FGD wastewater clarifier effluent							
L2A005B	FGD wastewater clarifier effluent							
L2A005C	FGD wastewater clarifier effluent							
L2A005d	FGD wastewater clarifier effluent							
PJA001	FGD blowdown		29200	5.4			2280	780
PJA002	FGD blowdown		28800	5.7			2260	950

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Sulfate (mg/L)	Acidity as CaCO3 (mg/L)
PJA003	FGD blowdown		29200	5.8			2180	800
RJA001	FGD blowdown		963	12.4			4760	397
RJA002	FGD blowdown		979	13.4			4450	470
RJA003	FGD blowdown		982	12.9			4750	400
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)		1150	16.3			3240	50
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)		1180					70
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)		1120					54
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)		3750	48.6			6090	232
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)		3650					274
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)		3850					268
UJA001	FGD Untreated Wastewater (Thickener overflow)		3650	7.6			4490	45
UJA002	FGD Untreated Wastewater (Thickener overflow)		3610	8.5			4430	44.2
UJA003	FGD Untreated Wastewater (Thickener overflow)		3610	8.2			4340	42.2
UJA004	FGD treated wastewater		2100	4.8			3120	19.2
UJA005	FGD treated wastewater		2090	5			3100	20.2
UJA006	FGD treated wastewater		2100	6			3110	21
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)		589	49.8			1450	124
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)		592	51.1			1470	122
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)		584	51.6			1480	128
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)							15000
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)		19100	15			2200	15000
2BA001	FGD Wastewater Equalization Tank Slurry		5550	100			17100	114
2BA001FF	FGD Wastewater Equalization Tank Slurry							
2BA002FF	FGD Wastewater Equalization Tank Slurry							
2BA003	FGD Absorber Slurry		6150	137			19600	163
2BA003FF	FGD Absorber Slurry							
2BA004FF	FGD Absorber Slurry							
2BA005	FGD Wastewater Primary Clarifier Effluent		5550	27.2			16000	10 U
2BA005FF	FGD Wastewater Primary Clarifier Effluent							
2BA006FF	FGD Wastewater Primary Clarifier Effluent							
2BA007	FGD Wastewater Secondary Clarifier		4740	24.7			13400	50.6
2BA007FF	FGD Wastewater Secondary Clarifier							
2BA008FF	FGD Wastewater Secondary Clarifier							
2BA009	FGD Reagent Water							
2BA010	FGD Discharge							
2BA011	FGD Discharge							
2BA012	FGD Absorber bed reageant water							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Sulfate (mg/L)	Acidity as CaCO3 (mg/L)
2BA013	FGD Slurry							
2BA014	FGD Slurry							
2BA015FF	FGD Absorber-Bleed							
2BA016FF	FGD Absorber-Bleed							
2CA001	FGD Absorber Feed Tower							
2CA002	FGD Reagent Feed Tower							
2CA003	FGD Make-Up Water							
2CA004	FGD Absorber Tower, North							
2CA005	FGD Absorber Tower, South							
2CA006	FGD Wastewater							
2CA007	FGD hydroclone underflow							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Alkalinity as CaCO3 (mg/L)	Alkalinity, Carbonate as CaCO3 (mg/L)	Chemical Oxygen Demand (mg/L)	Hardness as CaCO3 (mg/L)	Oil and Grease (mg/L)	pH (pH Units)	Conductivity
L1A001a	FGD wastewater treatment plant influent	68	5 U		15900		6.8	19300
L1A001aFF	FGD wastewater treatment plant influent							
L1A001b	FGD wastewater treatment plant influent							
L1A001c	FGD wastewater treatment plant influent							
L1A001d	FGD wastewater treatment plant influent							
L1A002a	FGD wastewater clarifier effluent	40	5 U		12400		6.9	15000
L1A002aFF	FGD wastewater clarifier effluent							
L1A002b	FGD wastewater clarifier effluent							
L1A002c	FGD wastewater clarifier effluent							
L1A002d	FGD wastewater clarifier effluent							
L1A003	FGD absorber	232	5 U		5310		6.4	21200
L1A003FF	FGD absorber							
L1B001a	FGD wastewater treatment plant influent	210	5 U		14300		6.9	16400
L1B001aFF	FGD wastewater treatment plant influent							
L1B001b	FGD wastewater treatment plant influent							
L1B001C	FGD wastewater treatment plant influent							
L1B001D	FGD wastewater treatment plant influent							
L1B002a	FGD wastewater clarifier effluent	120	5 U		13200		6.9	16400
L1B002aFF	FGD wastewater clarifier effluent							
L1B002b	FGD wastewater clarifier effluent							
L1B002C	FGD wastewater clarifier effluent							
L1B002D	FGD wastewater clarifier effluent							
L1B003	FGD absorber	740	5 U		102000		6.5	13800
L1B003FF	FGD absorber							
L2A500	FGD reclaim tank blowdown	102		1900	30100	1 U	6.41	
L2A003a	FGD wastewater treatment plant influent	271	5 U				6.6	33200
L2A003aFF	FGD wastewater treatment plant influent							
L2A003B	FGD wastewater treatment plant influent							
L2A003C	FGD wastewater treatment plant influent							
L2A003d	FGD wastewater treatment plant influent							
L2A005a	FGD wastewater clarifier effluent	22	5 U				5.7	28400
L2A005aFF	FGD wastewater clarifier effluent							
L2A005B	FGD wastewater clarifier effluent							
L2A005C	FGD wastewater clarifier effluent							
L2A005d	FGD wastewater clarifier effluent							
PJA001	FGD blowdown	170					6.7	80700
PJA002	FGD blowdown	3200					6.7	85000

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Alkalinity as CaCO3 (mg/L)	Alkalinity, Carbonate as CaCO3 (mg/L)	Chemical Oxygen Demand (mg/L)	Hardness as CaCO3 (mg/L)	Oil and Grease (mg/L)	pH (pH Units)	Conductivity
PJA003	FGD blowdown	155					6.7	79000
RJA001	FGD blowdown	620					7.2	8520
RJA002	FGD blowdown	5040					7.1	7690
RJA003	FGD blowdown	625					7.3	8570
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	200					7.1	6390
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	250					7.1	5990
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	202					7.3	6360
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	136					7.2	11500
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	2100					7.2	11400
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	200					7.2	11800
UJA001	FGD Untreated Wastewater (Thickener overflow)	74			5500		7.2	13400
UJA002	FGD Untreated Wastewater (Thickener overflow)	75			5700		7.3	13400
UJA003	FGD Untreated Wastewater (Thickener overflow)	76			5450		7.3	13300
UJA004	FGD treated wastewater	46			3800		7.7	9450
UJA005	FGD treated wastewater	46			3800		7.7	9470
UJA006	FGD treated wastewater	45			40000		7.6	9910
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	8	5 U		2800		5.8	3620
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	12	5 U		2860		5.9	3590
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	8	5 U		2860		6	3620
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)						6.49	
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)							
2BA001	FGD Wastewater Equalization Tank Slurry	29					6.3	23400
2BA001FF	FGD Wastewater Equalization Tank Slurry							
2BA002FF	FGD Wastewater Equalization Tank Slurry							
2BA003	FGD Absorber Slurry	53					6.4	25800
2BA003FF	FGD Absorber Slurry							
2BA004FF	FGD Absorber Slurry							
2BA005	FGD Wastewater Primary Clarifier Effluent	200					8.9	20800
2BA005FF	FGD Wastewater Primary Clarifier Effluent							
2BA006FF	FGD Wastewater Primary Clarifier Effluent							
2BA007	FGD Wastewater Secondary Clarifier	68					7.7	20700
2BA007FF	FGD Wastewater Secondary Clarifier							
2BA008FF	FGD Wastewater Secondary Clarifier							
2BA009	FGD Reagent Water							
2BA010	FGD Discharge							
2BA011	FGD Discharge							
2BA012	FGD Absorber bed reageant water							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Alkalinity as CaCO3 (mg/L)	Alkalinity, Carbonate as CaCO3 (mg/L)	Chemical Oxygen Demand (mg/L)	Hardness as CaCO3 (mg/L)	Oil and Grease (mg/L)	pH (pH Units)	Conductivity
2BA013	FGD Slurry							
2BA014	FGD Slurry							
2BA015FF	FGD Absorber-Bleed							
2BA016FF	FGD Absorber-Bleed							
2CA001	FGD Absorber Feed Tower						7.8	6230
2CA002	FGD Reagent Feed Tower						8.2	485
2CA003	FGD Make-Up Water						8.5	433
2CA004	FGD Absorber Tower, North						5.3	9300
2CA005	FGD Absorber Tower, South						5.4	10900
2CA006	FGD Wastewater						7.1	17600
2CA007	FGD hydroclone underflow						7.3	9830

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Dissolved Solids (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)	Ammonia-N (mg/L)	BOD, 5 Day (mg/L)	Phosphorous-P, Total (mg/L)	Orthophosphate-P, Total (mg/L)
L1A001a	FGD wastewater treatment plant influent	19600		7700				
L1A001aFF	FGD wastewater treatment plant influent							
L1A001b	FGD wastewater treatment plant influent							
L1A001c	FGD wastewater treatment plant influent							
L1A001d	FGD wastewater treatment plant influent							
L1A002a	FGD wastewater clarifier effluent	18300		13				
L1A002aFF	FGD wastewater clarifier effluent							
L1A002b	FGD wastewater clarifier effluent							
L1A002c	FGD wastewater clarifier effluent							
L1A002d	FGD wastewater clarifier effluent							
L1A003	FGD absorber	20400		174000				
L1A003FF	FGD absorber							
L1B001a	FGD wastewater treatment plant influent	19600		7100				
L1B001aFF	FGD wastewater treatment plant influent							
L1B001b	FGD wastewater treatment plant influent							
L1B001C	FGD wastewater treatment plant influent							
L1B001D	FGD wastewater treatment plant influent							
L1B002a	FGD wastewater clarifier effluent	17100		27				
L1B002aFF	FGD wastewater clarifier effluent							
L1B002b	FGD wastewater clarifier effluent							
L1B002C	FGD wastewater clarifier effluent							
L1B002D	FGD wastewater clarifier effluent							
L1B003	FGD absorber	26700		155000				
L1B003FF	FGD absorber							
L2A500	FGD reclaim tank blowdown	15300	8.8	12400	0.3	74 >	2.45	0.02 U
L2A003a	FGD wastewater treatment plant influent	48800		25900				
L2A003aFF	FGD wastewater treatment plant influent							
L2A003B	FGD wastewater treatment plant influent							
L2A003C	FGD wastewater treatment plant influent							
L2A003d	FGD wastewater treatment plant influent							
L2A005a	FGD wastewater clarifier effluent	38600		25 D				
L2A005aFF	FGD wastewater clarifier effluent							
L2A005B	FGD wastewater clarifier effluent							
L2A005C	FGD wastewater clarifier effluent							
L2A005d	FGD wastewater clarifier effluent							
PJA001	FGD blowdown	48100		91.2				
PJA002	FGD blowdown	57700		94900				

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Dissolved Solids (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)	Ammonia-N (mg/L)	BOD, 5 Day (mg/L)	Phosphorous-P, Total (mg/L)	Orthophosphate-P, Total (mg/L)
PJA003	FGD blowdown	48400		8				
RJA001	FGD blowdown	12800		2 U				
RJA002	FGD blowdown	14200		170000				
RJA003	FGD blowdown	12600		2 U				
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	8170		24				
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	9770		87600				
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)							
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	16400		231				
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	155		13700				
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)							
UJA001	FGD Untreated Wastewater (Thickener overflow)	14400		18				
UJA002	FGD Untreated Wastewater (Thickener overflow)	14600		32				
UJA003	FGD Untreated Wastewater (Thickener overflow)	14300		3.3 U				
UJA004	FGD treated wastewater	9390		39.5				
UJA005	FGD treated wastewater	9500		26.5				
UJA006	FGD treated wastewater	10000		7				
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	4370		29				
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	4350		35				
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	4360		5 U				
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)			5100				
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	50500						
2BA001	FGD Wastewater Equalization Tank Slurry	33900		23.2				
2BA001FF	FGD Wastewater Equalization Tank Slurry							
2BA002FF	FGD Wastewater Equalization Tank Slurry							
2BA003	FGD Absorber Slurry	37300		16				
2BA003FF	FGD Absorber Slurry							
2BA004FF	FGD Absorber Slurry							
2BA005	FGD Wastewater Primary Clarifier Effluent	28400		16.4				
2BA005FF	FGD Wastewater Primary Clarifier Effluent							
2BA006FF	FGD Wastewater Primary Clarifier Effluent							
2BA007	FGD Wastewater Secondary Clarifier	27000		54.8				
2BA007FF	FGD Wastewater Secondary Clarifier							
2BA008FF	FGD Wastewater Secondary Clarifier							
2BA009	FGD Reagent Water							
2BA010	FGD Discharge							
2BA011	FGD Discharge							
2BA012	FGD Absorber bed reageant water							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Dissolved Solids (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)	Ammonia-N (mg/L)	BOD, 5 Day (mg/L)	Phosphorous-P, Total (mg/L)	Orthophosphate-P, Total (mg/L)
2BA013	FGD Slurry							
2BA014	FGD Slurry							
2BA015FF	FGD Absorber-Bleed							
2BA016FF	FGD Absorber-Bleed							
2CA001	FGD Absorber Feed Tower							
2CA002	FGD Reagent Feed Tower							
2CA003	FGD Make-Up Water							
2CA004	FGD Absorber Tower, North							
2CA005	FGD Absorber Tower, South							
2CA006	FGD Wastewater							
2CA007	FGD hydroclone underflow							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Percent Moisture (Percent)	Arsenic III (ug/L)	Arsenic V (ug/L)	Chromium VI (ug/L)	Selenium IV (ug/L)	Selenium VI (ug/L)	Selenium Cyanide
L1A001a	FGD wastewater treatment plant influent							
L1A001aFF	FGD wastewater treatment plant influent							
L1A001b	FGD wastewater treatment plant influent							
L1A001c	FGD wastewater treatment plant influent							
L1A001d	FGD wastewater treatment plant influent							
L1A002a	FGD wastewater clarifier effluent							
L1A002aFF	FGD wastewater clarifier effluent							
L1A002b	FGD wastewater clarifier effluent							
L1A002c	FGD wastewater clarifier effluent							
L1A002d	FGD wastewater clarifier effluent							
L1A003	FGD absorber							
L1A003FF	FGD absorber							
L1B001a	FGD wastewater treatment plant influent							
L1B001aFF	FGD wastewater treatment plant influent							
L1B001b	FGD wastewater treatment plant influent							
L1B001C	FGD wastewater treatment plant influent							
L1B001D	FGD wastewater treatment plant influent							
L1B002a	FGD wastewater clarifier effluent							
L1B002aFF	FGD wastewater clarifier effluent							
L1B002b	FGD wastewater clarifier effluent							
L1B002C	FGD wastewater clarifier effluent							
L1B002D	FGD wastewater clarifier effluent							
L1B003	FGD absorber							
L1B003FF	FGD absorber							
L2A500	FGD reclaim tank blowdown							
L2A003a	FGD wastewater treatment plant influent							
L2A003aFF	FGD wastewater treatment plant influent							
L2A003B	FGD wastewater treatment plant influent							
L2A003C	FGD wastewater treatment plant influent							
L2A003d	FGD wastewater treatment plant influent							
L2A005a	FGD wastewater clarifier effluent							
L2A005aFF	FGD wastewater clarifier effluent							
L2A005B	FGD wastewater clarifier effluent							
L2A005C	FGD wastewater clarifier effluent							
L2A005d	FGD wastewater clarifier effluent							
PJA001	FGD blowdown							
PJA002	FGD blowdown							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Percent Moisture (Percent)	Arsenic III (ug/L)	Arsenic V (ug/L)	Chromium VI (ug/L)	Selenium IV (ug/L)	Selenium VI (ug/L)	Selenium Cyanide
PJA003	FGD blowdown							
RJA001	FGD blowdown							
RJA002	FGD blowdown							
RJA003	FGD blowdown		4.02	3.51		414	4	
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)							
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)							
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)							
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)							
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)							
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)							
UJA001	FGD Untreated Wastewater (Thickener overflow)							
UJA002	FGD Untreated Wastewater (Thickener overflow)							
UJA003	FGD Untreated Wastewater (Thickener overflow)		0.211	0.61 U		4.34	6	
UJA004	FGD treated wastewater							
UJA005	FGD treated wastewater							
UJA006	FGD treated wastewater		0.179	0.61 U		1.04	4.4	
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)							
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)							
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)							
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)							
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)				0.2 U	72	1340	
2BA001	FGD Wastewater Equalization Tank Slurry							
2BA001FF	FGD Wastewater Equalization Tank Slurry		1.1 U	4.9		238	7300	4.2 U
2BA002FF	FGD Wastewater Equalization Tank Slurry							
2BA003	FGD Absorber Slurry							
2BA003FF	FGD Absorber Slurry		1.1 U	4.7		575	3820	4.2 U
2BA004FF	FGD Absorber Slurry							
2BA005	FGD Wastewater Primary Clarifier Effluent							
2BA005FF	FGD Wastewater Primary Clarifier Effluent		1.1 U	4.6		540	6950	4.2 U
2BA006FF	FGD Wastewater Primary Clarifier Effluent							
2BA007	FGD Wastewater Secondary Clarifier							
2BA007FF	FGD Wastewater Secondary Clarifier		1.1 U	4		194	7900	4.2 U
2BA008FF	FGD Wastewater Secondary Clarifier							
2BA009	FGD Reagent Water							
2BA010	FGD Discharge							
2BA011	FGD Discharge							
2BA012	FGD Absorber bed reageant water							

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Percent Moisture (Percent)	Arsenic III (ug/L)	Arsenic V (ug/L)	Chromium VI (ug/L)	Selenium IV (ug/L)	Selenium VI (ug/L)	Selenium Cyanide
2BA013	FGD Slurry							
2BA014	FGD Slurry							
2BA015FF	FGD Absorber-Bleed		0.92	0.32 U		511	2320	6.6
2BA016FF	FGD Absorber-Bleed		0.23	1.21		22.6	11100	5 U
2CA001	FGD Absorber Feed Tower							
2CA002	FGD Reagent Feed Tower							
2CA003	FGD Make-Up Water							
2CA004	FGD Absorber Tower, North							
2CA005	FGD Absorber Tower, South							
2CA006	FGD Wastewater							
2CA007	FGD hydroclone underflow							

Notes:
Mercury was analyzed by method SW7470A or EPA Method 1631 (samples ALB###).
Other metals were analyzed by EPA Method 200.7 (ICP/AES).
Filtered samples were filtered with a 0.45-micron filter.

U = Non-detect, value shown is the method reporting limit (MRL).
M = Matrix spike in associated FGD wastewater sample batch was outside target criteria (75-125% recovery).
D = Field duplicate result was outside target criteria (<25% relative percent difference).
Sites P, R, S, T, U, Y and Z did not have MS/MSD so could not quantify accuracy of results.

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Kjeldahl Nitrogen (mg/L)
L1A001a	FGD wastewater treatment plant influent	6.9
L1A001aFF	FGD wastewater treatment plant influent	
L1A001b	FGD wastewater treatment plant influent	
L1A001c	FGD wastewater treatment plant influent	
L1A001d	FGD wastewater treatment plant influent	
L1A002a	FGD wastewater clarifier effluent	3.2
L1A002aFF	FGD wastewater clarifier effluent	
L1A002b	FGD wastewater clarifier effluent	
L1A002c	FGD wastewater clarifier effluent	
L1A002d	FGD wastewater clarifier effluent	
L1A003	FGD absorber	10.8
L1A003FF	FGD absorber	
L1B001a	FGD wastewater treatment plant influent	5.8 D
L1B001aFF	FGD wastewater treatment plant influent	
L1B001b	FGD wastewater treatment plant influent	
L1B001C	FGD wastewater treatment plant influent	
L1B001D	FGD wastewater treatment plant influent	
L1B002a	FGD wastewater clarifier effluent	4.3
L1B002aFF	FGD wastewater clarifier effluent	
L1B002b	FGD wastewater clarifier effluent	
L1B002C	FGD wastewater clarifier effluent	
L1B002D	FGD wastewater clarifier effluent	
L1B003	FGD absorber	11.2
L1B003FF	FGD absorber	
L2A500	FGD reclaim tank blowdown	
L2A003a	FGD wastewater treatment plant influent	49.4
L2A003aFF	FGD wastewater treatment plant influent	
L2A003B	FGD wastewater treatment plant influent	
L2A003C	FGD wastewater treatment plant influent	
L2A003d	FGD wastewater treatment plant influent	
L2A005a	FGD wastewater clarifier effluent	17.9
L2A005aFF	FGD wastewater clarifier effluent	
L2A005B	FGD wastewater clarifier effluent	
L2A005C	FGD wastewater clarifier effluent	
L2A005d	FGD wastewater clarifier effluent	
PJA001	FGD blowdown	79
PJA002	FGD blowdown	97.3

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Kjeldahl Nitrogen (mg/L)
PJA003	FGD blowdown	63.9
RJA001	FGD blowdown	31
RJA002	FGD blowdown	45.9
RJA003	FGD blowdown	33.5
SJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	2.4
SJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	2 U
SJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	2.9
TJA001	FGD Untreated Wastewater (Primary Hydroclone overflow)	11.8
TJA002	FGD Untreated Wastewater (Primary Hydroclone overflow)	11.4
TJA003	FGD Untreated Wastewater (Primary Hydroclone overflow)	13.8
UJA001	FGD Untreated Wastewater (Thickener overflow)	32.5
UJA002	FGD Untreated Wastewater (Thickener overflow)	37.1
UJA003	FGD Untreated Wastewater (Thickener overflow)	39.8
UJA004	FGD treated wastewater	30.3
UJA005	FGD treated wastewater	26.1
UJA006	FGD treated wastewater	15.9
YJA001	FGD Untreated Wastewater (Stacking Pond effluent)	2.5
YJA002	FGD Untreated Wastewater (Stacking Pond effluent)	2.5
YJA003	FGD Untreated Wastewater (Stacking Pond effluent)	2.2
ZJA001	FGD Untreated Wastewater (Secondary Hydroclone overflow)	
ZJA003	FGD Untreated Wastewater (Secondary Hydroclone overflow)	
2BA001	FGD Wastewater Equalization Tank Slurry	22.5
2BA001FF	FGD Wastewater Equalization Tank Slurry	
2BA002FF	FGD Wastewater Equalization Tank Slurry	
2BA003	FGD Absorber Slurry	34.7
2BA003FF	FGD Absorber Slurry	
2BA004FF	FGD Absorber Slurry	
2BA005	FGD Wastewater Primary Clarifier Effluent	15.9
2BA005FF	FGD Wastewater Primary Clarifier Effluent	
2BA006FF	FGD Wastewater Primary Clarifier Effluent	
2BA007	FGD Wastewater Secondary Clarifier	23.9
2BA007FF	FGD Wastewater Secondary Clarifier	
2BA008FF	FGD Wastewater Secondary Clarifier	
2BA009	FGD Reagent Water	
2BA010	FGD Discharge	
2BA011	FGD Discharge	
2BA012	FGD Absorber bed reageant water	

FGD System Wastewater Characterization Data

Sample Name	Sample Stream Name	Total Kjeldahl Nitrogen (mg/L)
2BA013	FGD Slurry	
2BA014	FGD Slurry	
2BA015FF	FGD Absorber-Bleed	
2BA016FF	FGD Absorber-Bleed	
2CA001	FGD Absorber Feed Tower	
2CA002	FGD Reagent Feed Tower	
2CA003	FGD Make-Up Water	
2CA004	FGD Absorber Tower, North	
2CA005	FGD Absorber Tower, South	
2CA006	FGD Wastewater	
2CA007	FGD hydroclone underflow	

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