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United States Environmental Protection Agency

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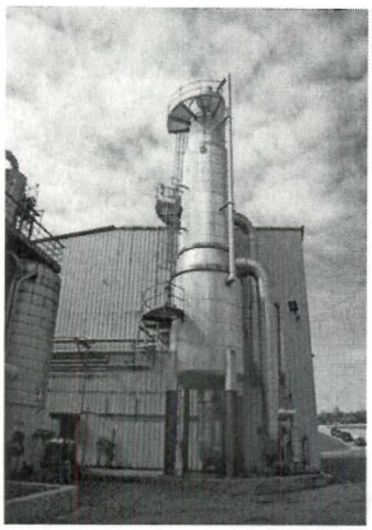
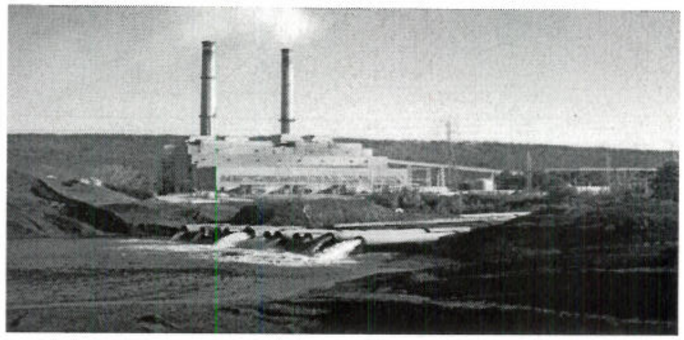
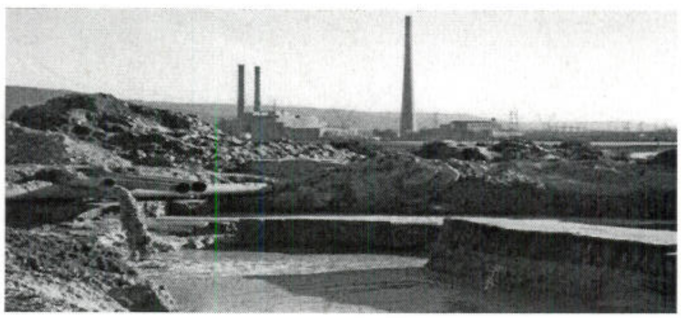
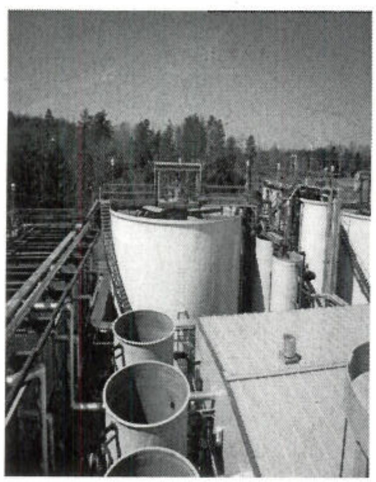
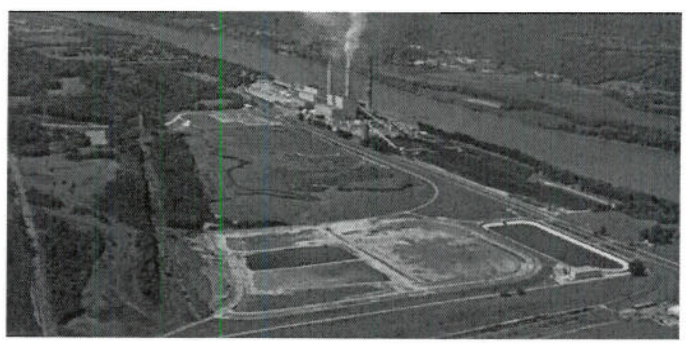
Steam Electric Power Generating Point Source Category: Final Detailed Study Report

October 2009

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4. FLUE GAS DESULFURIZATION SYSTEMS

This chapter presents an overview of flue gas desulfurization (FGD) systems at coal-fired power plants within the steam electric industry, with particular emphasis on FGD wastewater characteristics and treatment. This chapter also presents a profile of the current and projected future use of FGD systems within the industry.

Power plants use FGD systems to control SO_2 emissions from the flue gas generated in the plants' boilers. Wet FGD scrubbers are the most common type of FGD system; however, approximately 20 percent of electric generating units serviced by SO_2 scrubbers are serviced by dry FGD systems [U.S. DOE, 2005b]. There are several variations of wet FGD systems, but this section focuses on the limestone forced oxidation system and the lime or limestone inhibited oxidation system, which are the designs predominantly used in the industry today. This section also presents some information about other types of FGD systems used at coal-fired power plants, including dry scrubbers, which do not generate wastewaters.

EPA has compiled information on the current and projected use of FGD systems at coal-fired power plants using information collected from the 2005 Form EIA-767 [U.S. DOE, 2005b], the 2005 Form EIA-860 [U.S. DOE, 2005a], EPA's site visit and sampling data, EPA's data request information [U.S. EPA, 2008a], EPA's National Electric Energy Data System (NEEDS) 2006 database [U.S. EPA, 2006h], the Integrated Planning Model [U.S. EPA, 2006b] developed by ICF Consulting, Inc., and other publicly available information (e.g., company websites, vendor news releases). The collective data from these data sources are referred to in this report as the "combined data set[12]." See Chapter 2 for additional information about EPA's data collection activities.

4.1 Coal-Fired FGD System Statistics

This section presents statistics on the number and characteristics of coal-fired power plants that currently operate wet or dry FGD systems, or are expected to install an FGD system in the next decade. Also included in this section are estimates of the coal-fired steam electric industry's current and projected total generating capacity and scrubbed capacity.

4.1.1 Current Coal-Fired FGD System Profile

The current coal-fired FGD system profile presents a picture of the coal-fired steam electric industry as of June 2008, including the number of coal-fired power plants with FGD systems, the associated scrubbed capacity, and plant characteristics. EPA used information from the combined data set to generate the profile.

Wet FGD systems are in operation at 108 plants, treating the flue gases from 223 generating units. These 223 electric generating units represent the number of electric generating units scrubbed and is not exactly equal to the number of FGD systems. The two numbers are similar; however, EPA is aware of several plants that use a single FGD scrubber to service more than one electric generating unit. The combined generating capacity of the wet-scrubbed generating units represents approximately 33 percent of the total nationwide coal-fired steam

[12] Due to the limited time available upon receiving the surface impoundment data collected by EPA's ORCR, the ORCR data are not included in the combined data set.

electric power generating capacity. EPA expects that percentage to increase significantly over the next decade, as discussed in Section 4.1.2. Table 4-1 presents statistics on the current coal-fired steam electric power generation associated with FGD systems, relative to total industry coal-fired and fossil-fueled steam electric power generation.

Table 4-1. Scrubbed Coal-Fired Steam Electric Power Generation as of June 2008

Industry Category	Number of Plants [a]	Number of Electric Generating Units [a,b]	Capacity (MW) [a,c]
Fossil-Fueled Steam Electric Power Generation [d, e, f]	1,120	2,450	657,000
Coal-Fired Steam Electric Power Generation [d, f]	488	1,180	330,000
Coal-Fired Steam Electric Power Generation with Any FGD System (Wet or Dry) [g]	146	280	123,000 [i]
Coal-Fired Steam Electric Power Generation with a Wet FGD System [g, h]	108	223	108,000 [i]
Coal-Fired Steam Electric Power Generation with a Dry FGD System [g, h]	41	57	14,900 [i]

a – The numbers presented have been rounded to three significant figures.
b – The number of electric generating units represents the number of electric generating units scrubbed and does not represent the number of FGD systems. The two numbers are similar, but several plants use a single FGD scrubber for more than one electric generating unit.
c – The capacities presented represent the nameplate capacity for the electric generating unit.
d – Source: 2005 EIA-860 [U.S. DOE, 2005a].
e – Fossil-fueled generation includes coal, oil, and natural gas. It does not include nuclear generation.
f – The table includes the stand-alone steam electric and all combined cycle turbines (i.e., combined cycle steam turbine, combined cycle single shaft, and combined cycle combustion turbine).
g – Source: Combined data set (2005 EIA-767 [U.S. DOE, 2005b], UWAG-provided data [ERG, 2008g], data request information [U.S. EPA, 2008a], and site visit and sampling information).
h – The wet and dry FGD system information is a subset of the information for "Any FGD System." Note that several plants operate both wet and dry FGD systems. Thus, there is overlap between the number of plants with wet FGD systems and the number of plants with dry FGD systems.
i – Includes only the capacity for the scrubbed electric generating units.

The majority of the plants in the combined data set with wet FGD systems (46 percent) use eastern bituminous coal as the primary fuel source. This is to be expected because eastern bituminous coal typically contains a higher sulfur content than other coal types, thus producing higher SO_2 emissions than other types of coal. Other coals reported to be used in wet-scrubbed units include subbituminous (24 percent of plants), lignite (9 percent of plants), and other bituminous coal (20 percent of plants). Table 4-2 summarizes plant characteristics for the currently operating wet scrubbed electric generating units included in the combined data set.

Table 4-2. Characteristics of Coal-Fired Power Plants with Wet FGD Systems

	Combined Data Set [a]		
	Number of Plants with Wet FGD Systems	**Number of Wet Scrubbed Electric Generating Units**	**Wet Scrubbed Capacity [b] (MW)**
Total	**108**	**223**	**108,000**
Primary Coal Type [c]			
Bituminous	72	161	76,300
Subbituminous	26	48	22,700
Lignite	10	14	9,060
Type of Oxidation System			
Forced Oxidation	50	111	61,600
Inhibited or Natural Oxidation	36	62	30,000
No Information	26	50	16,700
Sorbent			
Limestone	74	151	78,200
Limestone & Fly Ash	1	1	50
Lime	17	33	11,800
Lime & Fly Ash	2	5	2,750
Magnesium-Enhanced Lime	3	8	7,390
Magnesium Oxide	2	3	896
Fly Ash	3	6	2,360
Soda Ash	1	2	530
Soda Liquor	1	4	2,320
Sodium Carbonate	2	5	938
No Information	3	4	800
NOx Controls			
SCR [d]	40	79	47,000
SNCR	7	15	4,700
None/Other (no SCR/SNCR)	44	80	35,600
No Information	25	49	20,900

Note: All 108 plants are included in the each of the categories presented in this table. Because a plant may operate multiple electric generating units that may represent more than one type of operation in each specific category, the sum of the plants for each category may be greater than 108 plants.

a – Source: Combined Data Set (2005 Form EIA-767 [U.S. DOE, 2005b], the 2005 Form EIA-860 [U.S. DOE, 2005a], EPA's site visit and sampling data, EPA's data request information [U.S. EPA, 2008a], EPA's NEEDS 2006 database [U.S. EPA, 2006h], and other publicly available information (e.g., company web sites, vendor news releases)).

b – The capacities represent the reported nameplate capacity. The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities.

c – Some plants/electric generating units use a blend of more than one coal in the electric generating units. This table presents information for only the primary type of coal burned in the electric generating unit.

d – Some of the SCRs included in the table are planned/under construction.

Of these wet scrubbed electric generating units, 111 (50 percent) are serviced by forced oxidation systems and 62 (28 percent) are serviced by natural or inhibited oxidation systems. EPA does not have information regarding the type of oxidation system for the FGD systems servicing the remaining 50 electric generating units (22 percent).

Wet FGD systems use a sorbent to transfer pollutants from the flue gas to the liquid stream. Limestone is by far the predominant sorbent used in wet FGD systems (68 percent of the currently operating electric generating units), followed by lime (17 percent of electric generating units), and magnesium-enhanced lime (4 percent of electric generating units). Magnesium oxide, fly ash, soda ash, soda liquor, or sodium carbonate sorbents collectively are used in FGD systems servicing 9 percent of electric generating units. EPA does not have sufficient information to determine the type of sorbent used for the remaining 2 percent of electric generating units.

Nearly one-third of the plants reported using additives in their FGD systems. Some plants add organic acids, such as dibasic acid (DBA) or formic acid, to improve the sulfur dioxide removal efficiency. Inhibited oxidation plants typically will add emulsified sulfur or a similar compound to prevent oxidation of the calcium sulfite by-product so that calcium sulfate (gypsum) will not be formed.

Over 40 percent of the wet-scrubbed electric generating units in the combined data set operate either a SCR or SNCR system to reduce NO_x emissions (35 percent SCR; 7 percent SNCR). See Section 3.2 for details regarding the operation of NO_x control systems at power plants.

No plants in the combined data set were identified as currently operating advanced flue gas mercury controls; however, according to the DOE, more than 130 full-scale activated carbon injection systems have been ordered by coal-fired plants [Feeley, 2009]. One outcome of litigation surrounding the Clean Air Mercury Rule has been that in the absence of a specific regulatory requirement, plants are refraining from operating the mercury control systems that have been installed.

4.1.2 Projected Use of FGD Systems at Coal-Fired Plants

EPA used information from EPA's NEEDS 2006 database [U.S. EPA, 2006h], and the IPM [U.S. EPA, 2006b] to evaluate the expected trends in the number and capacity of units that will be scrubbed in the future.

The use of FGD systems has increased substantially since the effluent guidelines were last revised in 1982. Power plants are expected to continue installing new FGD systems in substantial numbers until at least 2025.[13] Table 4-3 presents the projected use of wet and dry FGD systems, from 2009 through 2025, and compares the projected scrubbed capacity to the projected total coal-fired capacity.[14] EPA models have predicted that over 60 percent of coal-fired capacity will be wet scrubbed by 2020. EPA predicts that the industry's dry scrubbed capacity will increase only slightly into the future and that most new FGD systems will be wet scrubbers [ERG, 2008f].

[13] EPA projected future generating capacity with FGD systems using IPM Base Case 2006 (v.3.0), which reflects the CAMR mercury reduction requirements and the CAIR NOx and SO_2 emission reduction requirements for power plants.

[14] The data presented in Table 4-3 is based on the NEEDS 2006 database and IPM Base Case 2006 (v. 3.0). The 2020 capacity presented is the basis for the future FGD wastewater treatment industry profile presented in Section 4.6.1; however, the two data sets are not identical because the future FGD wastewater treatment industry profile does not include the "NEW" plants from the IPM data set and EPA's Office of Water made additional corrections to the IPM data set in some instances for the purpose of the detailed study. The data set corrections were necessary to address conflicting information. For more information about the future FGD wastewater treatment industry profile, see Section 4.6.1 or the memorandum entitled "Development of the Current and Future Industry Profile for the Steam Electric Detailed Study," dated October 9, 2009 [ERG, 2009r].

Table 4-3. Projected Future Use of FGD Systems at Coal-Fired Power Plants

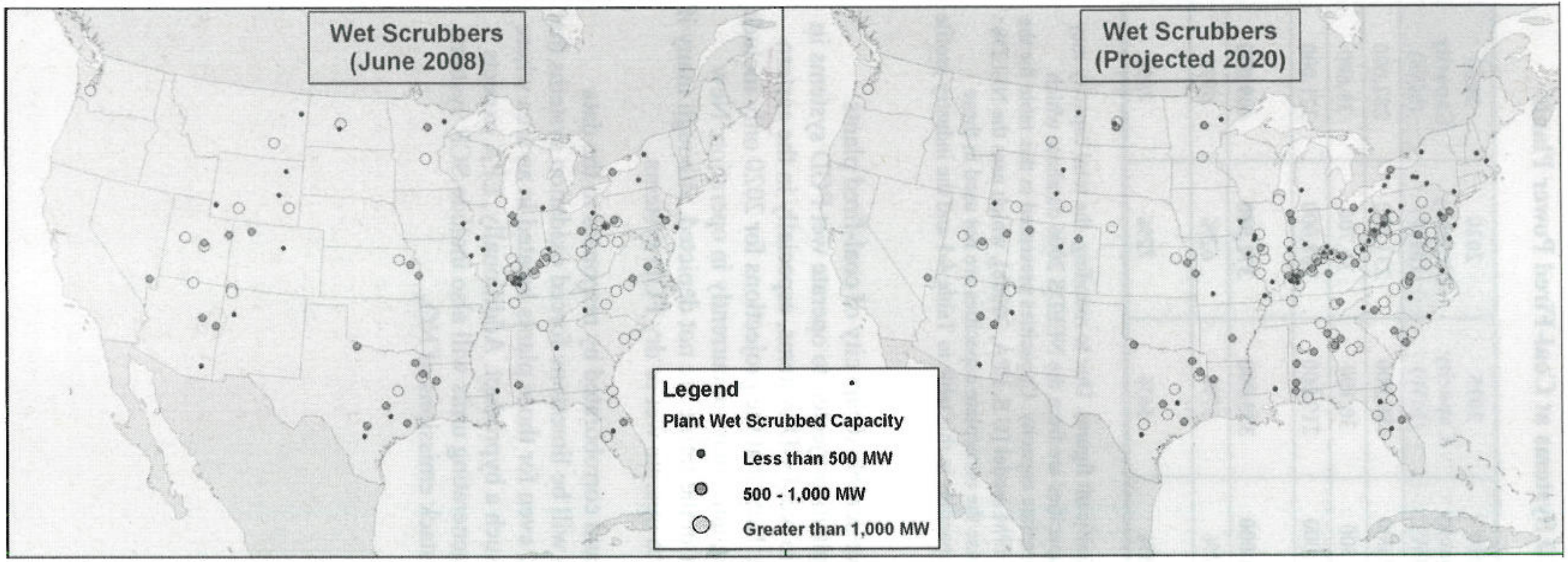
	2009 Capacity (MW)	2010 Capacity (MW)	2015 Capacity (MW)	2020 Capacity (MW)	2025 Capacity (MW)
Wet Scrubbed [a]	136,000	162,000	189,000	231,000	282,000
Dry Scrubbed [a]	21,000	21,500	30,100	36,700	38,600
Total Scrubbed [a]	157,000	184,000	219,000	268,000	321,000
Total Coal-Fired Generating Capacity [a]	**316,000**	**318,000**	**333,000**	**371,000**	**409,000**
Percent Wet Scrubbed	*43%*	*51%*	*57%*	*62%*	*69%*
Percent Scrubbed (Wet & Dry Combined)	*50%*	*58%*	*66%*	*72%*	*78%*

Source: [ERG, 2008f].

a – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The 2009 capacities are from the NEEDS 2006 database which preferentially uses summer and winter capacity before nameplate capacity. Capacities presented in this table for the period 2010 through 2025 are from estimates based on the IPM model [U.S. EPA, 2006b], which uses the NEEDS 2006 database [U.S. EPA, 2006h] as a starting point. Because the nameplate capacities are not used in these projections, caution should be used when comparing the capacities in this table to Table 4-1 and the industry profile tables presented in Chapter 3.

Figure 4-1 shows the locations and relative scrubbed capacity of coal-fired plants currently operating wet FGD systems and those plants projected to operate wet FGD systems in 2020. The figure illustrates the expected growth in wet FGD systems, especially in the eastern United States due to the use of higher sulfur coal. Note that the projections for 2020 only include FGD installations for power plants and generating units that are currently in operation. New generating units or power plants that will be built in the future are not depicted, although many if not all new coal-fired generating units are likely to operate wet or dry FGD systems.

Based on communications with industry and corroborated by responses to the data request, EPA expects that new wet FGD systems will be limestone forced oxidation systems that produce a commercial-grade gypsum by-product, even for those plants located in an area where there may be no market available for the sale of such a byproduct. Additionally, EPA expects that the majority of wet scrubbed steam electric generating units will also include SCR systems to meet state and federal requirements to reduce stack emissions of NO_x.



Source: [ERG, 2008b; ERG, 2008c; ERG, 2008g; ERG, 2009s; ERG, 2009w].

Note: The capacities in the figures represent the plant-level wet scrubbed capacity for the entire plant; they do not represent the plant's total coal-fired or total generating capacity. The capacities in June 2008 figure represent the reported nameplate capacity. The capacities in Projected 2020 figure are from estimates based on the IPM model, which uses a variety of capacities in its estimate, but preferentially uses summer and winter capacity before nameplate capacity.

Figure 4-1. Wet FGD Systems at Coal-Fired Power Plants (Current and Projected 2020)

4.2 Process Description and Wastewater Generation

4.2.1 Forced Oxidation FGD Systems

The EPA site visit and sampling program focused primarily on forced oxidation systems because these types of FGD systems are the most common systems operating segregated wastewater treatment systems prior to discharging FGD wastewater. In addition, based on discussions with industry representatives, EPA expects that the majority of future wet FGD systems will be forced oxidation.

Most forced oxidation systems use limestone as the sorbent in the process, but lime can also be used in a forced oxidation system. The limestone forced oxidation FGD system works by contacting the flue gas stream with a liquid slurry stream containing a limestone ($CaCO_3$) sorbent, which effects the mass transfer of pollutants from the flue gas to the liquid stream. Equation 4-1 shows the reaction that occurs between limestone and sulfur dioxide, producing hydrated calcium sulfite ($CaSO_3$) [EPRI, 2006a].

$$CaCO_{3\,(s)} + SO_{2\,(g)} + 1/2\ H_2O \rightarrow CaSO_3 \bullet 1/2\ H_2O_{\,(s)} + CO_{2\,(g)} \tag{4-1}$$

The calcium sulfite is then oxidized to calcium sulfate (gypsum) by injecting air into the calcium sulfite slurry. Equation 4-2 shows the reaction producing gypsum ($CaSO_4 \bullet 2H_2O$) from calcium sulfite [EPRI, 2006a].

$$CaSO_3 \bullet 1/2\ H_2O_{\,(s)} + \tfrac{1}{2}\ O_{2\,(g)} + 3/2\ H_2O_{\,(l)} \rightarrow CaSO_4 \bullet 2H_2O_{\,(s)} \tag{4-2}$$

During the site visits to power plants, EPA determined that the operation of these limestone forced oxidation systems varies somewhat by plant; however, most of the systems follow the same general operating procedure. Figure 4-2 presents a typical process flow diagram for a limestone forced oxidation FGD system.

Most of the plants EPA visited operate a spray or tray tower FGD scrubber, in which the flue gas and the limestone slurry are configured with countercurrent flow. The fresh limestone slurry is typically fed to the reaction tank at the bottom of the FGD scrubber to maintain the pH levels in the system. This fresh limestone slurry mixes with the already reacted scrubber slurry and is pumped to the top of the FGD scrubber where it is sprayed downward from several different spray levels. The flue gas enters near the bottom of the FGD scrubber, just above the water level of the reaction tank. As the flue gas rises through the absorber vessel, the spray droplets of the limestone/water slurry contact the flue gas and absorb the sulfur dioxide. The limestone and water react with the sulfur dioxide to produce calcium sulfite (see Equation 4-1). To increase the sulfur dioxide removal efficiency, some plants use additives such as organic acids (e.g., DBA or formic acid) in the FGD system. These additives buffer the scrubber slurry, which controls the sulfur dioxide vapor pressure in the scrubbers, thereby maximizing the sulfur dioxide absorption rate [Babcock & Wilcox, 2005]. The scrubbed flue gas exits the top of the FGD scrubber through a mist eliminator and then is emitted through the stack.

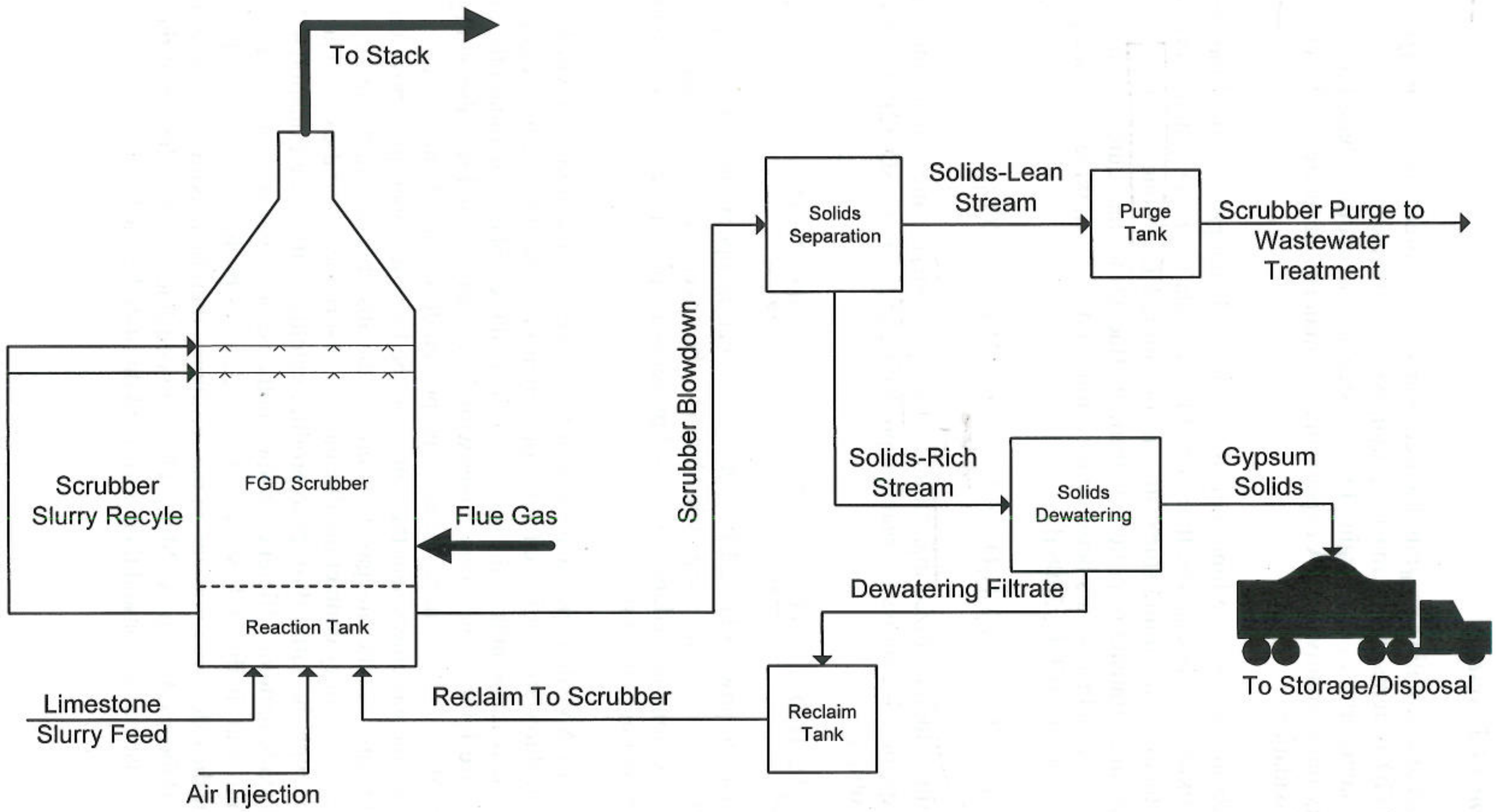


Figure 4-2. Typical Process Flow Diagram for a Limestone Forced Oxidation FGD System

The spray droplets, some containing the calcium sulfite product and others with unreacted limestone, fall to the bottom of the FGD scrubber into a reaction tank. The plant injects air into the reaction tank and vigorously mixes the slurry to oxidize the calcium sulfite to gypsum (see Equation 4-2). The scrubber recycle pumps pump the slurry from the reaction tank to the various spray levels within the FGD scrubber. The plant continuously recirculates the slurry in the FGD scrubber. When the percent solids or the chlorides concentration in the slurry reach a certain high set point in the reaction tank, the plant uses the scrubber blowdown pumps to remove some of the slurry from the FGD scrubber. As the blowdown stream is removed from the scrubber, the levels of solids and chlorides in the scrubber slurry decreases until a low set point is reached within the FGD scrubber. The plant then shuts off the blowdown pumps until the solids and chlorides build up again to the point of triggering a blowdown. Therefore, the scrubber blowdown is typically an intermittent transfer from the scrubber. Some plants, however, operate an FGD scrubber with a continuous blowdown, which can either be a once-through FGD system with no recycle or an FGD system that recycles some of the slurry but is constantly blowing down slurry at a rate that maintains the solids and chlorides levels within a defined operating range.

The parameter used to control the FGD system (e.g., percent solids or chlorides concentration) and the level at which it is controlled varies by plant. Plants maintain a chlorides concentration below the maximum level which the FGD scrubber materials of construction can withstand to prevent corrosion, normally around 12,000 – 20,000 ppm; however, some systems operate with chloride concentrations as low as 2,000 to 3,000 ppm and other plants may operate near 40,000 ppm. Plants also monitor and control the FGD system based on the percent solids because the solids can affect the operation of the FGD system and because the plant must limit the amount of fines (small inert particles) in the gypsum by-product [EPRI, 2006a].

The scrubber blowdown, which for a forced oxidation system is a gypsum slurry, is transferred to a solids separation process. Often, this process uses one or two sets of hydrocyclones, referred to in the industry as hydroclones.[15] The hydroclones separate the gypsum solids from the water using centrifugal force. The gypsum solids are forced outward to the walls of the hydroclones and fall downward, while the water exits the top of the hydroclones. The underflow, or solids-rich stream, from the solids separation process contains the gypsum solids and is transferred to a dewatering process. The overflow, or solids-lean stream (which is mostly water and fines), from the solids separation process is typically transferred to the purge tank.

The solids-rich stream from the solids separation process is transferred to a dewatering process, which is usually a vacuum belt filter or a vacuum drum filter. The dewatering process removes the water from the gypsum, drying the gypsum to its desired moisture content. If the plant intends to market the gypsum for wallboard production, then a vacuum belt filter is typically used because it can dry the gypsum to a lower moisture content than a drum filter. Additionally, the gypsum is usually rinsed with service water at the beginning of the belt filter to reduce the chlorides concentration to meet the wallboard manufacturer's specifications. If the plant does not intend to market the gypsum, then the gypsum does not need to be rinsed and either a vacuum belt or vacuum drum filter can be used for the dewatering because the gypsum

[15] Another approach for solids separation practiced by some plants entails using settling ponds instead of hydroclones or other mechanical devices.

most likely will not need to meet any chloride or moisture content specifications. However, EPA has visited several plants that are currently unable to market the gypsum, but the plant still rinses the gypsum prior to on-site disposal in case a future gypsum market develops for the gypsum. The dried gypsum product is removed from the dewatering process and transferred to a storage area until it is transported off site (for beneficial use or disposal at an off-site landfill) or to a disposal area on site. The filtrate from the dewatering process is recovered in a reclaim tank and either returned to the FGD scrubber or used in the limestone slurry preparation process.

The solids-lean stream from the solids separation process is typically transferred to a purge tank and then sent to a wastewater treatment system and discharged. Alternatively, the solids-lean stream can be transferred to a second solids separation process (e.g., a second set of hydroclones) to remove additional solids prior to wastewater treatment. Many plants that are operating clarifiers in the FGD wastewater treatment system have two stages of solids separation to minimize the size requirements and/or prevent overloading of the clarifier. In this case, the solids-lean stream from the second solids separation process is transferred to the purge tank and the solids-rich stream is typically transferred to the reclaim tank and recycled back to the FGD system or limestone preparation process.

From the purge tank, the scrubber purge[16] is typically transferred to some type of FGD wastewater treatment system, such as a settling pond or a more advanced system (see Section 4.4). It may also be commingled with other wastewater streams (e.g., cooling water or ash pond wastewater) and discharged. Because most FGD treatment systems currently being used do not significantly affect the level of chlorides in the wastewater, the treated FGD wastewater is not recycled back to the FGD scrubber.

Some plants are able to operate their solids removal process in a manner that purges sufficient chlorides along with the solids to allow reuse of the FGD wastewater. For example, plants that dispose of their gypsum solids in a landfill do not typically have to meet specifications for the chlorides or fines content in the gypsum; therefore, these plants can operate the FGD system (including the solids separation and dewatering process) to allow the gypsum to retain more water and, therefore, more chlorides and fines. Operating the system in this manner allows the plant to purge scrubber water (and by extension chlorides and fines) through the solids disposal process. If they are able to purge enough chlorides with the FGD solids, these plants may then be able to recycle the solids-lean stream from the solids separation process. Most of the plants that sell the gypsum for beneficial use have to meet chloride and fines specifications, and therefore, must operate with a scrubber purge stream [Sargent & Lundy, 2007].

4.2.2 Inhibited Oxidation FGD System

Both the forced oxidation and inhibited oxidation FGD systems remove sulfur dioxide from the flue gas; however, in the inhibited oxidation FGD system, a chemical such as emulsified sulfur is added to the system to prevent gypsum from forming during the process.

[16] For the purpose of this document, the scrubber blowdown refers to the slurry stream exiting the FGD scrubber, which is typically transferred to a solids separation process. The scrubber purge refers to the waste stream from the FGD scrubber system (typically from a solids separation process) that is transferred to a wastewater treatment system or discharged. Both the scrubber blowdown and scrubber purge waste streams are depicted in Figure 4-2. In some instances, the scrubber blowdown and scrubber purge may be the same waste stream if the plant does not operate a solids separation process prior to wastewater treatment or discharge.

Many of the plants operating inhibited oxidation systems do not have wastewater treatment systems, other than settling ponds, to treat the scrubber purge. In addition, some plants are able to recycle their FGD wastewater back to the FGD system and, therefore, do not produce a scrubber purge waste stream.

The lime or limestone inhibited oxidation FGD systems work by contacting the flue gas stream with a liquid slurry stream containing a lime ($Ca(OH)_2$) or limestone sorbent, which effects mass transfer. Equation 4-1 shows the reaction between limestone and sulfur dioxide and Equation 4-3 shows the reaction that occurs between lime and sulfur dioxide, producing hydrated calcium sulfite.

$$Ca(OH)_{2\,(s)} + SO_{2\,(g)} \rightarrow CaSO_3 \bullet \tfrac{1}{2} H_2O_{\,(s)} + \tfrac{1}{2} H_2O_{\,(l)} \quad (4\text{-}3)$$

The operation and absorption of the SO_2 in an inhibited oxidation FGD system is similar to the forced oxidation FGD system. A FGD process operation description for a forced oxidation system is presented in Section 4.2.1. The most significant differences between the two systems are that in an inhibited oxidation FGD system, elemental or emulsified sulfur is added to the FGD system, and oxidation air is not introduced to the absorber. The sulfur forms thiosulfate within the FGD system, which is an oxygen scavenger. Because thiosulfate reacts so readily with the dissolved oxygen, it inhibits the calcium sulfite from oxidizing to calcium sulfate, thereby generating a calcium sulfite by-product instead of a gypsum by-product.

Although the operation of the FGD scrubber is similar for the two FGD systems, there are some differences in the solids separation and solids dewatering processes. Figure 4-3 presents a typical process flow diagram for a lime or limestone inhibited oxidation FGD system. One of the major differences between the forced oxidation and inhibited oxidation systems is that inhibited oxidation systems are more likely than forced oxidation systems to be operated in a manner that recycles the solids-lean stream from the solids separation process back to the scrubber, and thus are less likely to discharge a scrubber purge stream.

As is done for the limestone forced oxidation system, the scrubber blowdown is transferred to a solids separation process. The calcium sulfite by-product generated from the inhibited oxidation process is more difficult to dewater than the gypsum by-product generated by the limestone forced oxidation process; therefore, plants operating inhibited oxidation FGD systems typically use a thickener for the solids separation process; however, hydroclones can also be used for inhibited oxidation systems. Thickeners operate with long residence times that allow the solids to settle out of the solution. The underflow, or solids-rich stream, from the solids separation process contains the calcium sulfite and is transferred to a dewatering process which is typically a centrifuge or vacuum drum filter.

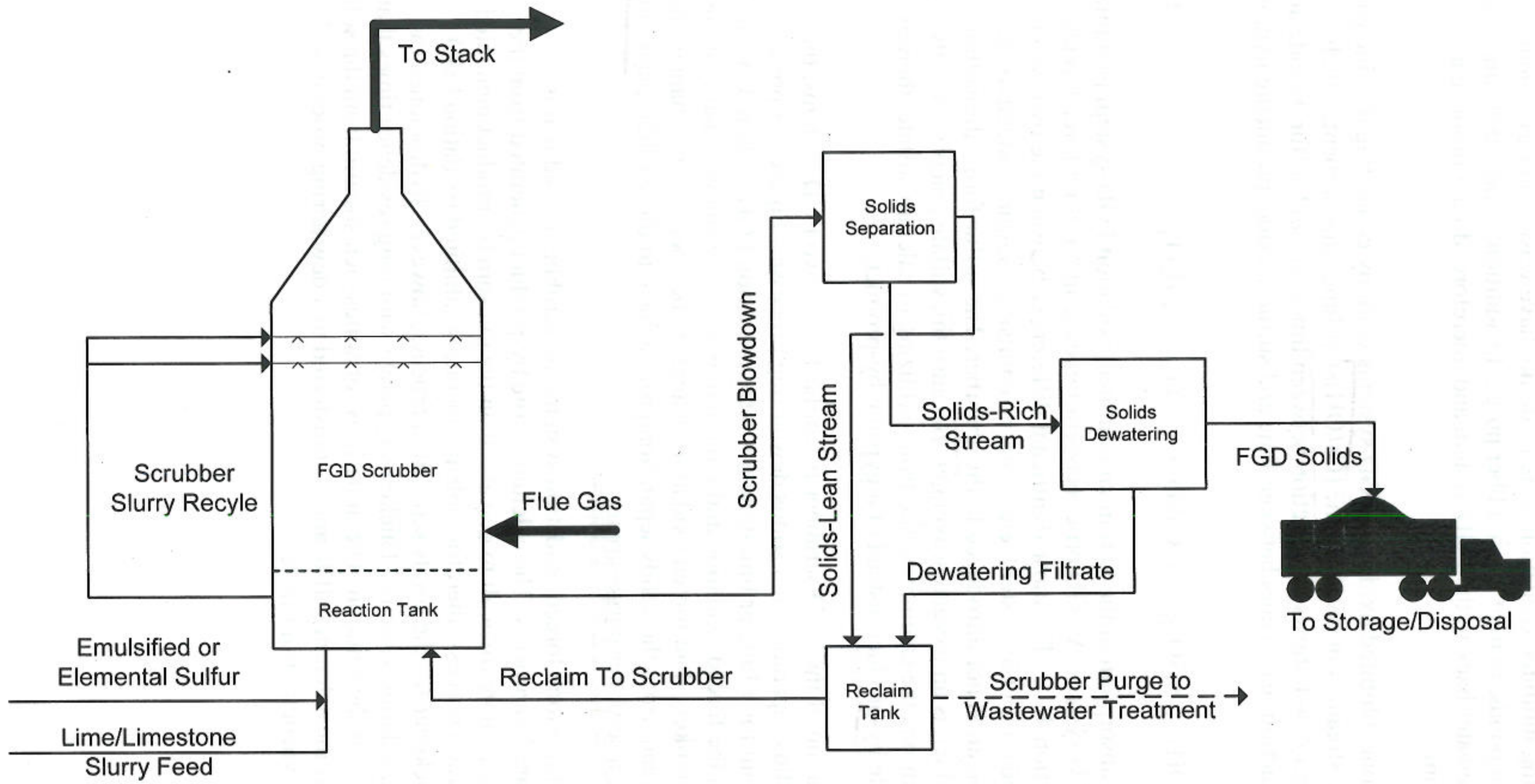


Figure 4-3. Process Flow Diagram for a Lime or Limestone Inhibited Oxidation FGD System

The dewatering process removes water from the calcium sulfite, drying it to its desired moisture content. The filtrate from the dewatering process is transferred to a reclaim tank. The solid cake from the final dewatering process is usually sent to a landfill, either on or off site. Although the calcium sulfite FGD solids can be landfilled after the final dewatering process, some plants operating inhibited oxidation systems further process the calcium sulfite by mixing it with dry fly ash and lime in a pug mill to generate a cementitious material similar to concrete. The resultant cementitious material is transported to a landfill.

The overflow, or solids-lean stream, from the solids separation process and the filtrate from the dewatering process are typically transferred to a reclaim tank. Some of the wastewater collected in the reclaim tank is recycled back to the FGD scrubber process and some may be discharged or transferred to an additional treatment system. Because the inhibited oxidation system typically does not generate a saleable solid product, the solids are typically disposed of in a landfill. Like the limestone forced oxidation systems that are not beneficially using the gypsum, the plant may be able to recycle the FGD wastewater without a purge stream because the chlorides can be removed from the FGD system by retaining the chlorides with the solids that are sent to the landfill [Sargent & Lundy, 2007]. However, not all plants operating inhibited oxidation FGD systems completely recycle the FGD wastewater. For example, Louisville Gas & Electric Company's Cane Run plant stated that they do not achieve complete recycle because of instances where they have accumulated rainfall in their ponds which treat the recycle water. When this happens, they manage the additional water volume by discharging from the FGD ponds.

4.2.3 Other Types of FGD Systems

Natural Oxidation FGD Systems

Sections 4.2.1 and 4.2.2 describe the operation of the forced oxidation and inhibited oxidation systems. A natural oxidation system operates similarly to both the forced oxidation and inhibited oxidation systems, except that air is not fed to the reaction tank to force the oxidation of calcium sulfite to calcium sulfate as in the forced oxidation system; likewise, emulsified sulfur is not added to inhibit the calcium sulfite from oxidizing as in the inhibited oxidation system. In a natural oxidation system, some of the calcium sulfite (typically the majority) is oxidized to calcium sulfate using the dissolved oxygen present in the system; however, because the plant is not forcing the oxidation, some of the calcium sulfite may not oxidize and the FGD process may produce a mixture of calcium sulfite and calcium sulfate. The solids handling associated with the operation of a natural oxidation FGD system is also similar to the solids handling of the forced oxidation and/or the inhibited oxidation systems (see Figure 4-2 and Figure 4-3).

During the detailed study, EPA visited one plant that operates a natural oxidation FGD system. The plant operates a thickener for the solids separation process and a vacuum drum filter for the dewatering process. The FGD solids produced, which consist predominantly of calcium sulfate, are transferred to a third party distributor for sale (primarily to a cement manufacturer). The overflow from the thickeners is transferred to a reclaim tank and is typically reused within the FGD process. The plant occasionally transfers the thickener overflow to a settling pond, which is ultimately discharged [ERG, 2009o].

Dual-Alkali FGD Systems

The dual-alkali FGD process is different from the other FGD processes previously discussed because two alkaline sorbents are used in the process. For this type of FGD system, a soda ash (sodium carbonate, Na_2CO_3) liquor/solution is fed into the FGD scrubber to absorb the sulfur dioxide from the flue gas. The sodium is dissolved in this liquor, and therefore the liquor contains almost no suspended solids. The sodium reacts with the sulfur dioxide and the product is transferred to the reaction tank where the second alkaline sorbent, lime, is added. The lime reacts with this product to generate hydrated calcium sulfite. Additionally, the sodium solution is regenerated in this reaction and can be reused in the scrubbing process. The slurry from the reaction tank is then sent to a solids separation process, such as a thickener. The underflow, or solids-rich stream, from the solids separation process contains mostly calcium sulfite, and is transferred to a dewatering process similar to the description for the lime inhibited oxidation system (see Section 4.2.2). The overflow, or solids-lean stream, that contains the sodium solution is recycled back to the FGD system as the sorbent for the scrubbing process. Because some of the sodium will leave the system with the solids-rich stream from the solids separation process, a make-up soda ash solution is added to the sodium solution that is recycled back to the FGD scrubber.

Dry FGD Systems

A dry FGD system is a spray dryer absorption process in which a lime slurry removes sulfur dioxide from the flue gas. These dry FGD systems are also sometimes referred to as semi-dry FGD systems because a wet slurry is injected into the flue gas; a dry sorbent is not used in the process. In the dry FGD process, the wet lime slurry, which ranges from approximately 18 to 25 percent solids, is atomized and sprayed into the spray dryer. The percent solids in the lime slurry is calculated to control the sulfur dioxide removal from the flue gas but also allows for essentially all the water to evaporate within the spray dryer. The flue gas can enter the spray dryer from one or more different locations and typically enters through a disperser to allow for effective contact with the atomized spray droplets. The sulfur dioxide in the flue gas is absorbed by the spray droplets and reacts with the lime to generate calcium sulfite. These reactions take place in the aqueous phase of the spray droplets at the same time that the heat from the flue gas is evaporating the water from the spray droplets. The evaporation of the water cools the flue gas and produces a calcium sulfite product with low moisture content [Babcock & Wilcox, 2005].

The flue gas exiting the spray dryer is then transferred to a particulate removal system (e.g., electrostatic precipitator (ESP) or baghouse), which collects the solids generated in the spray dryer and some unreacted lime, as well as fly ash if there is no particulate removal system upstream of the spray dryer. A plant may operate a pre-collection particulate removal system if it intends to market the fly ash generated. The particulates removed from the process are usually transferred to a silo for storage until the plant disposes of the material or transfers it off site. Additionally, the solids removed from the particulate removal process can be reused in the process as slurry feed to reduce lime usage. This recycle also has the benefit of using the inherent alkalinity in the fly ash for the sulfur dioxide absorption. In these recycle systems, some of the solids removed from the particulate removal process are mixed with water to approximately 35 to 45 percent solids and returned to the process. Not all of the solids can be recycled for the process; therefore, the remaining solids are stored on site, sold for beneficial use, or disposed of in a landfill [Babcock & Wilcox, 2005].

4.3 FGD Wastewater Characteristics

This section discusses the pollutant characteristics and flow rates for FGD wastewaters based on information EPA collected during the detailed study. Pollutant concentration data are presented for samples collected during the EPA wastewater sampling program and monitoring data provided by the individual plants/companies. These pollutant concentration data represent information from limestone forced oxidation systems. This section also presents flow rate data from EPA's site visit and sampling program and responses to EPA's data request. These flow rate data include information from limestone forced oxidation systems, as well as non-forced oxidation systems. Chapter 2 describes EPA's data collection activities.

The FGD system works by contacting the flue gas stream with a slurry stream containing a sorbent. The contact between the streams allows for a mass transfer of sulfur dioxide as it is absorbed into the slurry stream. Other pollutants in the flue gas (e.g., metals, nitrogen compounds, chloride) are also transferred to the scrubber slurry and leave the FGD system via the scrubber blowdown (i.e., the slurry stream exiting the FGD scrubber that is not immediately recycled back to the spray/tray levels). Depending upon the pollutant, the type of solids separation process and the solids dewatering process used, the pollutants may partition to either the solid phase (i.e., FGD solids) or the aqueous phase (i.e., scrubber purge waste stream).

As described in Section 4.2 and shown in Figure 4-2 and Figure 4-3, the FGD scrubber blowdown is typically intermittently transferred from the FGD scrubber to the solids separation process. As a result, the FGD scrubber purge (i.e., the waste stream from the FGD scrubber system that is transferred to a wastewater treatment system or discharged) is also usually intermittent. Factors that can affect the characteristics and flow rate of the FGD scrubber purge wastewater include the type of coal, scrubber design and operating practices, solids separation process, and solids dewatering process used at the plant.

The type of coal burned at the plant can affect the FGD scrubber purge flow rate associated with the system. Generally, burning a higher sulfur coal will lead to a higher flow rate for the scrubber blowdown and scrubber purge. Higher sulfur coals produce more sulfur dioxide in the combustion process, which in turn increases the amount of sulfur dioxide removed in the FGD scrubber. As a result, more solids are generated in the reaction in the scrubber, which increases blowdown volumes.

Likewise, a high chlorine coal can increase the volume and frequency of the scrubber blowdown and scrubber purge. Many FGD systems are designed with materials resistant to corrosion for specific chloride concentrations. An electric generating unit burning coal with higher chlorine content will more quickly reach the maximum allowable chloride concentration in the scrubber, which may trigger more frequent blowdowns. In addition, the plant will need to purge more FGD wastewater from the system to prevent chlorides from building up to an unacceptable concentration.

Table 4-4 summarizes the FGD scrubber purge flow rates reported in the data request responses and collected during EPA's site visit and sampling program. In Table 4-4, there are 26 plants that operate a total of 57 wet FGD systems, which scrub the flue gas from 65 coal-fired electric generating units. The size of the plants varies from scrubbed capacities of 300 to 2,700 MW. The average scrubbed capacity per plant is 1,310 MW, with a median scrubbed capacity of

1,330 MW/plant. Most of the plants operate limestone forced oxidation systems; however, several plants operate lime inhibited oxidation systems.

Table 4-4. FGD Scrubber Purge Flow Rates

	Number of Plants	Average Flow Rate	Median Flow Rate	Range of Flow Rate
Flow Rate per Plant				
gpm/plant	26	448	340	30.0 – 2,300
gpd/plant	26	598,000	410,000	24,300 – 3,310,000
gpy/plant	26	211,000,000	142,000,000	4,980,000 – 1,210,000,000
Normalized Flow Based on Wet-Scrubbed Capacity				
gpm/scrubbed MW	26	0.423	0.250	0.0365 – 2.04
gpd/scrubbed MW	26	578	301	19.7 – 2,940
gpy/scrubbed MW	26	202,000	106,000	2,500 – 1,070,000

Source: Data request information [U.S. EPA, 2008a] and site visit and sampling information.
a – The flow rates presented have been rounded to three significant figures.
b – The instantaneous (gpm) flow rate represents the rate during the actual purge, unless it is a design scrubber purge flow rate for a planned FGD wastewater treatment system installation.
c – Because some FGD scrubber purge flows are intermittent, instantaneous rates cannot be directly used to calculate daily and annual average flows.

Table 4-4 presents the actual purge flow rates for the 26 plants, as well as calculated normalized purge flow rates that are based on the plants' wet scrubbed capacity. The scrubber purge flow rates reported, including the normalized flow rates, vary significantly from plant to plant. Figure 4-4 and Figure 4-5 present the distribution of the scrubber purge flow rates for the 26 plants included in Table 4-4. The majority of plants report scrubber purge flow rates less than 1.5 mgd. However, one plant operates a once-through FGD system (i.e., no recirculation of the scrubber slurry) and has a scrubber purge flow rate exceeding 3 mgd (see Figure 4-4). There are three plants that have normalized scrubber purge flow rates greater than 2,000 gpd/MW scrubbed. One of the three plants operates a once-through FGD system, as described above. The other two plants operate lime inhibited oxidation systems that transfer the FGD wastewater to a settling pond for treatment. Because these plants are generating a calcium sulfite byproduct, which is not marketable, and the scrubber purge is being transferred to a settling pond for treatment, the plants are transferring the entire scrubber blowdown to the settling pond (i.e., there is no solids separation process). For this reason, the normalized scrubber purge flow rate for these plants is larger than the other plants because the solids, as well as the water retained in the solids, are included in the scrubber purge flow rate.

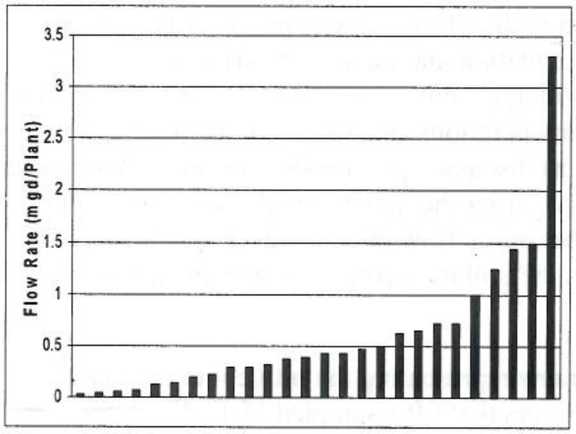


Figure 4-4. Distribution of FGD Scrubber Purge Daily Flow Rates

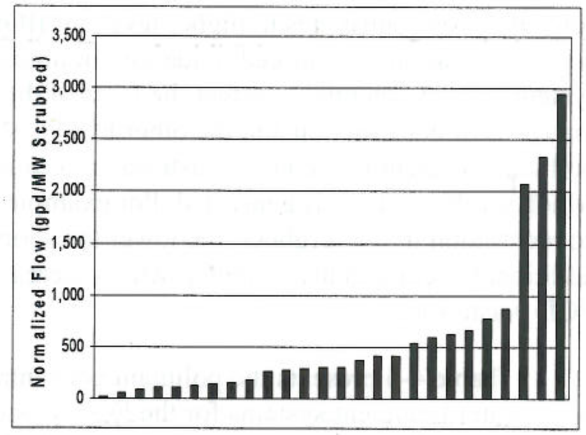


Figure 4-5. Distribution of FGD Scrubber Purge Normalized Daily Flow Rates

Source: Data request information [U.S. EPA, 2008a] and site visit and sampling information.

The average gpd/plant and gpd/scrubbed MW purge flow rates calculated for these 26 plants are similar to the FGD blowdown stream flow rates EPA observed when developing the effluent guidelines promulgated in 1982 (671,000 gpd/plant and 811 gpd/MW) [U.S. EPA, 1982].

The pollutant concentrations in FGD scrubber purge vary from plant to plant depending on the coal type, the sorbent used, the materials of construction in the FGD system, the FGD system operation, and the air pollution control systems operated upstream of the FGD system. The coal is the source of the majority of the pollutants that are present in the FGD wastewater (i.e., the pollutants present in the coal are likely to be present in the FGD wastewater). The sorbent used in the FGD system also introduces pollutants into the FGD wastewater and therefore, the type and source of the sorbent used affects the pollutant concentrations in the FGD wastewater.

The air pollution controls operated upstream of FGD system can also affect the pollutant concentrations in the FGD wastewater. For example, if a plant does not operate a particulate collection system (e.g., ESP) upstream of the FGD system, then the FGD system will act as the particulate control system and the FGD blowdown exiting the scrubber will contain fly ash and other particulates. As a result, the FGD scrubber purge will likely contain increased amounts of pollutants associated with the fly ash.

Research conducted by EPA's ORD has observed that the use of post-combustion NOx controls (e.g., SCR and SNCR) is correlated to an increased fraction of chromium in CCR (including FGD wastes) being oxidized to hexavalent chromium (Cr^{+6}), a more toxic form of chromium than trivalent chromium (Cr^{+3}). Hexavalent chromium is more a soluble form of chromium than the Cr^{+3} usually measured in CCRs, which could explain why ORD has observed increased leachability of chromium when post-combustion NOx controls are operating [U.S. EPA, 2008c].

The materials of construction in the FGD system and the FGD system operation affect the pollutants present in the wastewater, as well as the levels of the pollutants. The use of organic acid additives contributes to higher levels of BOD5 in the FGD scrubber purge. Additionally, the type of oxidation (i.e., forced oxidation, inhibited oxidation, natural oxidation) in the FGD system has the potential to affect the form of the pollutants present in the FGD wastewater. The materials of construction and the other FGD system operations can also affect the levels of pollutants present in the FGD wastewater because as discussed previously, they affect the rate at which scrubber purge is generated. For example, the larger the maximum allowable chlorides concentration in the scrubber, the lower the scrubber purge flow rate; however, this leads to additional cycling in the scrubber, which increases the pollutant concentrations present in the FGD wastewater.

Table 4-5 presents the pollutant concentrations representing the influent to the FGD wastewater treatment systems for the FGD wastewaters that EPA sampled.[17] FGD wastewater contains significant concentrations of chloride, TDS, nutrients, and metals, including bioaccumulative pollutants such as arsenic, mercury, and selenium. Table 4-5 also shows that some of the pollutants are more likely to be present in the particulate phase (e.g., aluminum, chromium, mercury), whereas other pollutants are almost exclusively present in the dissolved phase (e.g., boron, magnesium, manganese).

For the Big Bend sampling episode, EPA collected a grab sample of the influent to the wastewater treatment system downstream of the equalization tank feeding the treatment system. The equalization tank receives FGD scrubber purge from secondary hydroclones, treatment system recirculation flows, and other related treatment process waste streams. During sampling, the plant was recirculating 154 gpm off-specification filter press filtrate to the equalization tank, which caused the plant to divert some of the FGD scrubber purge away from the equalization tank. As a result, the scrubber purge comprised only one-third (96 gpm of 250 gpm) of the total influent-to-treatment flow sampled by EPA. The sampling episode report for Big Bend contains more detailed information regarding the sampling event [ERG, 2008n].

For the Homer City sampling episode, EPA collected a grab sample of the influent to the wastewater treatment system downstream of the equalization tank feeding the treatment system. The equalization tank receives FGD scrubber purge from the secondary hydroclones and backwash from sand filters. During sampling, the flow rate from the equalization tank to the wastewater treatment system was 109 gpm. The sampling episode report for Homer City contains more detailed information regarding the sampling event [ERG, 2008l].

[17] Note that the influent-to-treatment sample obtained for a given plant does not necessarily represent the unaltered scrubber purge, since the sample collected may include both scrubber purge and treatment system recirculation flow streams.

Table 4-5. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Routine Total Metals – 200.7							
Aluminum	200.7	µg/L	31,200	289,000	234,000	17,900	33,100 R
Antimony	200.7	µg/L	62.5	86.4	ND (86.9)	28.7	18.1 R
Arsenic	200.7	µg/L	75.5	1,590	523	72.5	236
Barium	200.7	µg/L	1,590	11,900 R	7,200	588	651
Beryllium	200.7	µg/L	12.9	28.8	44.3	8.04	3.60 R
Boron	200.7	µg/L	626,000	224,000	28,900	229,000	307,000 R
Cadmium	200.7	µg/L	224	150	89.2	19.7	ND (0.250)
Calcium	200.7	µg/L	6,690,000	3,220,000	5,990,000	3,030,000	6,070,000
Chromium	200.7	µg/L	757	1,400	1,360	70.7	84.8 R
Cobalt	200.7	µg/L	172	369	ND (217)	68.0	14.7 R
Copper	200.7	µg/L	120	811	653	164	37.6
Iron	200.7	µg/L	23,500	824,000	299,000	60,600	59,100 R
Lead	200.7	µg/L	69.1	340	436	103	31.2 R
Magnesium	200.7	µg/L	4,830,000	2,760,000	321,000	1,470,000	990,000
Manganese	200.7	µg/L	21,900	225,000	2,780	28,800	9,020 R
Mercury	245.1	µg/L	ND (10.0)	243	26.5	67.5	NA
Molybdenum	200.7	µg/L	618	375	1,340	65.0	NA
Nickel	200.7	µg/L	2,090	2,560 R	489	554	1.59 R
Selenium	200.7	µg/L	4,150	4,000 R	652	2,130	2,930 R
Silver	200.7	µg/L	ND (20.0)	ND (40.0)	ND (86.9)	ND (20.0)	10.0
Sodium	200.7	µg/L	2,530,000	1,430,000	104,000	314,000	61,000
Thallium	200.7	µg/L	ND (10.0)	Exclude	ND (43.4)	ND (10.0)	41.2 R
Titanium	200.7	µg/L	420	1,300 R	8,180	377	NA
Vanadium	200.7	µg/L	724	766	1,580	203	77.6
Yttrium	200.7	µg/L	245	586	217	64.9	NA

Table 4-5. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Zinc	200.7	µg/L	1,540	1,900	3,140	885	ND (25.0)
Routine Dissolved Metals – 200.7							
Aluminum	200.7	µg/L	ND (50.0)	ND (50.0)	86.6	ND (50.0)	ND (50.0)
Antimony	200.7	µg/L	33.9	ND (20.0)	ND (20.0)	ND (20.0)	ND (4.00)
Arsenic	200.7	µg/L	18.6	ND (10.0)	13.9	ND (10.0)	24.7 R
Barium	200.7	µg/L	1,820	149 R	257	488	489 R
Beryllium	200.7	µg/L	ND (5.00)	10.5	ND (5.00)	6.02	ND (1.00)
Boron	200.7	µg/L	618,000	254,000	24,100	232,000	301,000 R
Cadmium	200.7	µg/L	179	26.2	ND (5.00)	ND (5.00)	ND (0.250)
Calcium	200.7	µg/L	4,470,000	1,990,000	849,000	2,350,000	5,370,000
Chromium	200.7	µg/L	ND (10.0)	ND (10.0)	18.7	ND (10.0)	19.2 R
Hexavalent Chromium	D1687-92	µg/L	24.0	ND (2.00)	ND (2.00)	5.00	4.20
Cobalt	200.7	µg/L	ND (50.0)	201	ND (50.0)	ND (50.0)	8.40 L,R
Copper	200.7	µg/L	27.2	14.5	ND (10.0)	ND (10.0)	ND (2.50)
Iron	200.7	µg/L	ND (100)	ND (100)	ND (100)	ND (100)	ND (25.0)
Lead	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (1.50)
Magnesium	200.7	µg/L	4,110,000	3,100,000	176,000	1,370,000	955,000 R
Manganese	200.7	µg/L	9,610	173,000	583	27,900	8,540
Mercury	245.1	µg/L	ND (10.0)	ND (10.0)	ND (2.00)	ND (10.0)	NA
Molybdenum	200.7	µg/L	581	30.6	876	22.2	NA
Nickel	200.7	µg/L	851	1,350	ND (50.0)	355	105 R
Selenium	200.7	µg/L	3,610	656 R	366	46.9	105 R
Silver	200.7	µg/L	ND (20.0)	ND (20.0)	ND (20.0)	ND (20.0)	7.80
Sodium	200.7	µg/L	1,970,000	1,440,000	76,700	324,000	58,700
Thallium	200.7	µg/L	14.3	61.2	14.3	ND (10.0)	106 R
Titanium	200.7	µg/L	12.5	ND (10.0)	ND (10.0)	ND (10.0)	NA

Table 4-5. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Vanadium	200.7	µg/L	108	ND (20.0)	ND (20.0)	ND (20.0)	2.00 R
Yttrium	200.7	µg/L	ND (5.00)	6.28	ND (5.00)	ND (5.00)	NA
Zinc	200.7	µg/L	16.8	ND (10.0)	ND (10.0)	87.8	ND (25.0)
Low-Level Total Metals – 1631E, 1638, HG-AFS							
Antimony	1638	µg/L	24.9	31.1	51.8	9.23	17.6 R
Arsenic	1638	µg/L	165	1,220	617	59.9	1,270
Arsenic	1638 – DRC	µg/L	NA	NA	NA	NA	1,010 R
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	929
Cadmium	1638	µg/L	238	52.8 R	86.0	5.28	4.84 R
Chromium	1638	µg/L	651 L	1,270	1,380	176 L	256
Chromium	1638 – DRC	µg/L	NA	NA	NA	NA	262 R
Copper	1638	µg/L	103	747	826	139	188 R
Lead	1638	µg/L	69.9	351	545	68.1	193 R
Mercury	1631E	µg/L	16.4	533	24.7	138	85.6
Nickel	1638	µg/L	2,570	2,840	634	650	1,240
Nickel	1638 – DRC	µg/L	NA	NA	NA	NA	396 R
Selenium	1638	µg/L	3,470	3,530	651	1,990	8,660
Selenium	1638 – DRC	µg/L	NA	NA	NA	NA	8,250 R
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	9,100
Thallium	1638	µg/L	39.8	37.3	93.8	6.33	9.51 R
Zinc	1638	µg/L	1,870	2,130	2,720	730	438
Zinc	1638 – DRC	µg/L	NA	NA	NA	NA	526 R
Low-Level Dissolved Metals - 1631E, 1636, 1638, HG-AFS							
Antimony	1638	µg/L	21.9	ND (0.400)	8.90	1.97	3.83
Arsenic	1638	µg/L	137	24.2 R	18.0	20.2	133
Arsenic	1638-DRC	µg/L	NA	NA	NA	NA	17.4 R

Table 4-5. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]	
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	11.4	
Cadmium	1638	µg/L	190	24.5	3.16	ND (1.00)	4.47	
Chromium	1638	µg/L	ND (160)	ND (16.0)	ND (16.0)	ND (80.0)	19.1	
Chromium	1638-DRC	µg/L	NA	NA	NA	NA	ND (5.00)	
Copper	1638	µg/L	ND (40.0)	11.3	ND (4.00)	ND (20.0)	ND (5.00)	
Lead	1638	µg/L	ND (10.0)	ND (1.00)	ND (1.00)	ND (0.500)	ND (2.00)	
Mercury	1631E	µg/L	0.206	0.0809	0.0761	0.0111	0.0844	
Nickel	1638	µg/L	1,030	1,450	29.6	433	382	
Nickel	1638-DRC	µg/L	NA	NA	NA	NA	316	R
Selenium	1638	µg/L	3,280	584	325	443	468	
Selenium	1638-DRC	µg/L	NA	NA	NA	NA	412	R
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	206	
Thallium	1638	µg/L	39.4	23.2	22.5	4.47	11.1	R
Zinc	1638	µg/L	ND (100)	34.7	ND (10.0)	160	78.6	
Zinc	1638-DRC	µg/L	NA	NA	NA	NA	69.7	R
Classicals								
Ammonia As Nitrogen (NH_3-N)	4500-NH_3F[b]	mg/L	31.5	4.12	2.26	1.89	1.50	
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	mg/L	NA	54.5	1.00	20.6	14.7	
Total Kjeldahl Nitrogen (TKN)	4500-N,C[b]	mg/L	51.6	14.2	22.3	13.3	6.20	
Biochemical Oxygen Demand (BOD)	5210B	mg/L	1,370	ND (120)	172	21.0	ND (4.00)	
Chemical Oxygen Demand (COD)	5220 C	mg/L	NA	NA	NA	NA	304	
Chloride	4500-CL-C[b]	mg/L	24,200	11,800	832	7,200	9,680	
Hexane Extractable Material (HEM)	1664A	mg/L	ND (6.00)	ND (5.00)	22.0	11.0	ND (5.00)	

Table 4-5. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]	Belews Creek – FGD Scrubber Purge [a]
Silica Gel Treated HEM (SGT-HEM)	1664A	mg/L	NA	NA	6.00 E	ND (5.00)	ND (5.00)
Sulfate	D516-90[b]	mg/L	3,590	6,920	11,900	1,640	1,290
Total Dissolved Solids (TDS)	2540 C	mg/L	44,600	23,200	4,740	18,100	34,600
Total Phosphorus	365.3[b]	mg/L	0.990	2.64	10.5	3.57	9.90
Total Suspended Solids (TSS)	2540 D	mg/L	4,970	13,300	25,300 E	7,320	5,200

Source: [ERG, 2008l; ERG, 2008m; ERG, 2008n; ERG, 2008o; ERG, 2009q].

Note: EPA used several analytical methods to analyze for metals during the sampling program. For the purposes of sampling program, EPA designated some of the analytical methods as "routine" and some of them as "low-level." EPA designated all of the methods that require the use of clean hands/dirty hands sample collection techniques (i.e., EPA Method 1669 sample collection techniques) as "low-level" methods. Note that although not required by the analytical method, EPA used clean hands/dirty hands collection techniques for all low-level and routine metals samples.

a – The concentrations presented have been rounded to three significant figures.

b – The method used for the Belews Creek sampling analysis is different than the method presented in the table. See Table 2-3 for details.

DRC – Dynamic reaction cell. For the Belews Creek analysis, a DRC was used in combination with EPA Method 1638 for certain analytes.

E – Sample analyzed outside holding time.

HG-AFS – Hydride generation and atomic fluorescence spectrometry.

L – Sample result between 5x and 10x the blank result.

R – MS/MSD % recovery outside method acceptance criteria.

Exclude – Results were excluded because the MS/MSD samples had a zero percent recovery.

NA – Not analyzed.

ND – Not detected (number in parentheses is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

Widows Creek operates once-though FGD scrubbers (i.e., no recirculation of slurry within the absorber), with the scrubber blowdown continuously sent to settling ponds. For the Widows Creek sampling episode, EPA collected a four-hour composite sample of the influent to the FGD settling pond from a diked channel containing FGD scrubber blowdown from the two FGD scrubbers. EPA collected the samples from the diked channel at a point downstream of the influent to the channel to allow for some initial solids settling, but upstream of the inlet to the FGD settling pond. At the time of the sampling, although one of the electric generating units operating a FGD system was shut down and therefore not sending flue gases through the scrubber, the plant continued to transfer water from the scrubber to the FGD settling pond. The flow rate entering the open water area of the FGD settling pond at the time of sampling was approximately 1,170 gpm, and plant personnel estimated that approximately 390 gpm of the flow rate (one-third of the entire flow) was from the FGD system of the electric generating unit that was shut down. The sampling episode report for Widows Creek contains more detailed information regarding the sample collection procedures [ERG, 2008o].

For the Mitchell sampling episode, EPA collected a grab sample of the FGD scrubber purge transfer to the FGD wastewater treatment system. The sample collected contained only FGD scrubber purge, which was transferred to the system at a flow rate of approximately 500 gpm. The sampling episode report for Mitchell contains more detailed information regarding the sampling event [ERG, 2008m].

For the Belews Creek sampling episode, EPA collected a grab sample of the FGD scrubber purge transfer to the FGD wastewater treatment system. The sample collected contained only FGD scrubber purge, which was transferred from the purge tank to the system at a flow rate of 489 gpm during the sample collection. The sampling episode report for Belews Creek contains more detailed information regarding the sampling event [ERG, 2009q].

EPA also collected self-monitoring data for the FGD scrubber purge from four plants. Table 4-6 presents the number of facilities that reported concentration data for specific analytes, the total number of samples from all the plants for each analyte, and the average, minimum, and maximum concentrations for all the monitoring data. These monitoring data were used along with EPA's sampling data to calculate the pollutant mass loads in scrubber purge, as discussed in Section 4.6.

The monitoring data collected from industry confirm EPA's sampling data and demonstrate that FGD scrubber purge wastewater contains significant concentrations of chloride, TSS, TDS, and metals. The type of treatment system operated at an individual plant is typically dependent on the permit limits that the plant must meet. Section 4.4 describes the wastewater treatment systems planned or currently operated by coal-fired power plants to treat FGD wastewaters.

Table 4-6. FGD Scrubber Purge Self-Monitoring Data

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Total Metals					
Aluminum	1	38	8,200	333,000	µg/L
Antimony	1	38	4.1	23	µg/L
Arsenic	4	99	58	5,070	µg/L
Barium	1	38	110	2,050	µg/L
Beryllium	1	38	ND (0.7)	113	µg/L
Boron	3	95	7,410	250,000	µg/L
Cadmium	2	51	ND (0.5)	302	µg/L
Chromium	2	51	1.7	350	µg/L
Cobalt	1	38	6.4	148	µg/L
Copper	2	43	12.8	456	µg/L
Iron	3	79	1,100	300,000	µg/L
Lead	1	38	14.7	252	µg/L
Magnesium	1	13	1,200,000	1,800,000	µg/L
Manganese	1	38	339	5,460	µg/L
Mercury	4	132	ND (0.1)	872	µg/L
Molybdenum	1	38	ND (2)	250	µg/L
Nickel	3	67	23.4	710	µg/L
Selenium	4	158	400	21,700	µg/L
Silver	3	44	ND (0.2)	65	µg/L
Thallium	2	46	ND (4)	746	µg/L
Vanadium	1	38	14.2	14,800	µg/L
Zinc	4	72	33.1	1,060	µg/L
Dissolved Metals					
Mercury	1	17	60	440	µg/L
Selenium	2	33	130	3,000	µg/L
Classicals					
BOD_5	1	8	3.40	21.0	mg/L
COD	2	49	140	1,100	mg/L
Total suspended solids	2	111	24.0	14,000	mg/L
Total dissolved solids	3	106	6,500	26,000	mg/L
Sulfate	4	85	780	4,100	mg/L
Chloride	4	104	1,100	13,000	mg/L
Bromide	1	28	43.0	96.0	mg/L
Fluoride	1	37	6.80	57.0	mg/L
Nitrate/nitrite	2	76	ND (10.0)	270	mg/L
Total Kjeldahl nitrogen	2	37	2.80	24.0	mg/L
Total phosphorus	1	1	4.00	4.00	mg/L

Source: [ERG, 2009x].

a – The maximum concentration presented is the maximum detected value in the data set, unless all the results in the data set were not detected for the analyte.

4.4 FGD Wastewater Treatment Technologies

During this detailed study, EPA identified and investigated wastewater treatment systems operated by steam electric plants for the treatment of FGD scrubber purge, as well as operating/management practices that were used to reduce the discharge of FGD wastewater. This section describes the following technologies:

- Settling ponds;
- Chemical precipitation (using hydroxide and/or sulfide precipitation);
- Biological treatment;
- Constructed wetlands;
- Vapor-compression evaporation system;
- Design/operating practices achieving zero discharge; and
- Other technologies under investigation.

Most plants currently discharging FGD wastewater use settling ponds; however, the use of more advanced wastewater treatment systems is increasing to a limited extent due to more stringent requirements imposed by some states on a site-specific basis. Section 4.4.8 presents information EPA has compiled on the types of FGD wastewater treatment systems currently operating or expected to be installed.

4.4.1 Settling Ponds

Settling ponds are designed to remove particulates from wastewater by means of gravity. For this to occur, the wastewater must stay in the pond long enough to allow sufficient time for particles to fall out of suspension before being discharged from the pond. The size and configuration of settling ponds varies by plant; some settling ponds operate as a system of several ponds, while others consist of one large pond. The ponds are initially sized to provide a certain residence time to reduce the TSS levels in the wastewater and to allow for a certain life-span of the pond based on the expected rate of solids buildup within the pond. Coal-fired power plants do not typically add treatment chemicals to settling ponds, other than to adjust the pH of the wastewater before it exits the pond to bring it into compliance with NPDES permit limits.

Settling ponds can reduce the amount of TSS in wastewater, as well as specific pollutants that are in particulate form, provided that the settling pond has a sufficiently long residence time; however, settling ponds are not designed to reduce the amount of dissolved metals in the wastewater. The FGD wastewater entering a treatment system contains significant concentrations of several pollutants in the dissolved phase, including boron, manganese, and selenium. These dissolved metals are likely discharged largely unremoved from FGD wastewater settling ponds. Additionally, EPRI has reported that adding FGD wastewater to ash ponds may reduce the settling efficiency in the ash ponds, due to gypsum particle dissolution, thus increasing the effluent TSS concentration [EPRI, 2006b]. EPRI has also reported that the FGD wastewater includes high loadings of volatile metals which can impact the solubility of metals in the ash pond, thereby potentially leading to increases in the effluent metal concentrations [EPRI, 2006b]. Section 5.4.1 contains a more detailed discussion of this topic.

EPA compiled data for plants operating wet FGD systems and wastewater treatment systems used to treat the FGD wastewaters generated. Based on these data, settling ponds are the most commonly used systems for managing FGD wastewater. Most plants using ponds transfer

doesn't mean its "cutting edge"

FGD scrubber purge directly to a settling pond that also treats other waste streams, specifically fly ash transport water and/or bottom ash transport water. Approximately one-third of the plants using FGD ponds transfer the FGD scrubber purge to a settling pond specifically designated to treat FGD wastewater. In these cases, the FGD wastewater pond effluent is either discharged directly to surface waters (with or without first mixing with cooling water or other large volume wastes streams) or transferred to an ash pond for further settling and dilution.

EPA has also identified two plants (one currently operating an FGD system and one planned) that transfer the FGD scrubber purge to a settling pond for initial solids removal and then transfer the wastewater to a biological treatment system for further treatment.

EPA reviewed information to determine whether the use of settling ponds to treat FGD wastewater was limited to relatively older scrubbers. Approximately 20 percent of the plants using settling ponds began operating an additional wet FGD system after 2000. Each of these plants was already operating another FGD system prior to 2000. This suggests plants do not replace the settling pond treatment system with a more advanced system when a new FGD system is installed; instead, the plants begin transferring the additional FGD wastewater to the existing treatment system. In addition, some plants currently without scrubbers have announced that they intend to rely on settling ponds to treat their FGD wastewater. The information compiled by EPA for this study indicates that the use of pond systems will continue to be significant in the future, with about half of plants discharging FGD wastewater in 2020 using settling ponds.

4.4.2 Chemical Precipitation

In a chemical precipitation wastewater treatment system, chemicals are added to the wastewater to alter the physical state of dissolved and suspended solids to facilitate settling and removal of the solids. The specific chemical(s) used depends upon the type of pollutant requiring removal. Steam electric plants commonly use the following three types of precipitation systems to precipitate metals out of FGD wastewater:

- Hydroxide precipitation;
- Iron coprecipitation; and
- Sulfide precipitation.

chemicals used in treatment

In a hydroxide precipitation system, lime (calcium hydroxide) is often added to elevate the pH of the wastewater and help precipitate metals into insoluble metal hydroxides that can be removed by settling or filtration. Sodium hydroxide can also be used in a hydroxide chemical precipitation system, but it is more expensive than lime and therefore, not used as commonly.

Many plants use iron coprecipitation as a way to increase the removal of metals in a hydroxide precipitation system. Ferric or ferrous chloride can also be added to the precipitation system to coprecipitate additional metals and organic matter. The ferric chloride also acts as a coagulant, forming a dense floc that enhances settling of the metals precipitate in downstream clarification stages.

In a sulfide precipitation system, sulfide chemicals (e.g., trimercapto-s-triazine (TMT), Nalmet®, sodium sulfide) are used to precipitate and remove heavy metals, such as mercury. While hydroxide precipitation can remove some heavy metals, sulfide precipitation can be more effective because metal sulfides have lower solubilities than metal hydroxides. FGD wastewater chemical precipitation systems may include various configurations of lime, ferric chloride, and sulfide addition stages, as well as clarification stages.

A process flow diagram for a typical chemical precipitation system using both hydroxide and sulfide addition to treat FGD wastewater is illustrated by Figure 4-6. A chemical precipitation system that omits the sulfide precipitation stage would be similar, but would exclude the reaction tank where sulfide is added.

For the system illustrated by Figure 4-6, the FGD scrubber purge from the plant's solid separation/dewatering process is transferred to an equalization tank, where the intermittent flows are equalized, allowing the plant to pump a constant flow of wastewater through the treatment system. The equalization tank also receives wastewater from a filtrate sump, which includes water from the gravity filter backwash and filter press filtrate.

The FGD scrubber purge is transferred at a continuous flow from the equalization tank to reaction tank 1, where the plant adds hydrated lime to raise the pH of the wastewater from between 5.5 – 6.0 to between 8.0 – 10.5 to precipitate the soluble metals as insoluble hydroxides and oxyhydroxides. The reaction tank also desaturates the remaining gypsum in the wastewater, which prevents gypsum scale formation in the downstream wastewater treatment equipment.

From reaction tank 1, the wastewater flows to reaction tank 2, where organosulfide (most commonly TMT) or inorganic sulfide is added. The treatment system can also be configured so that the organosulfide addition occurs before the hydroxide precipitation step, or with a clarification step between the two chemical addition steps.

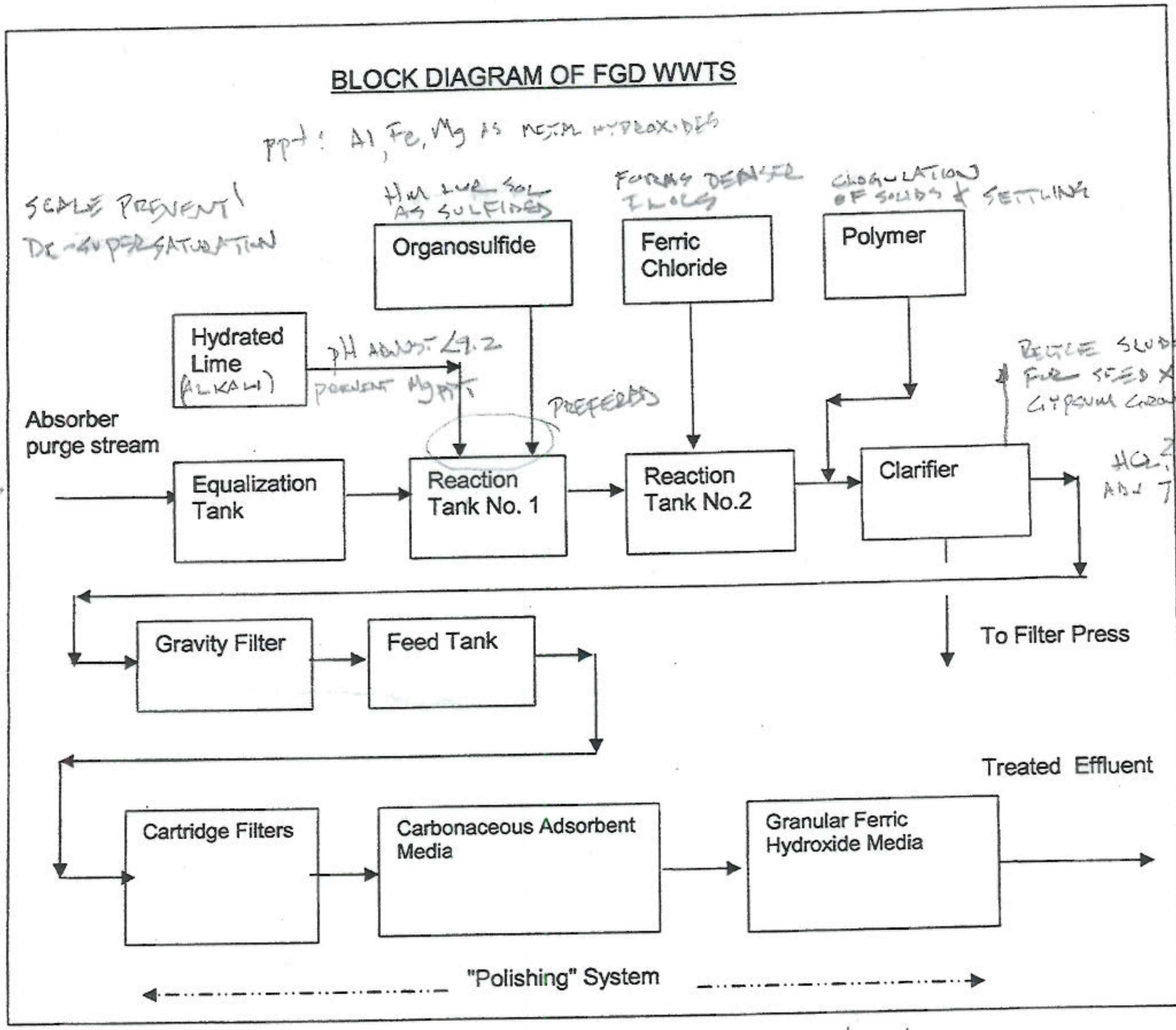
From reaction tank 2, the wastewater flows to reaction tank 3, where ferric chloride is added to the wastewater for coagulation and coprecipitation. The effluent from reaction tank 3 flows to the flash mix tank, where polymer is added to the wastewater, prior to be being transferred to the clarifier. Alternatively, the polymer can be added directly to the waste stream as it enters the clarifier or added to reaction tank 3. The polymer is used to flocculate fine suspended particles in the wastewater.

The clarifier settles the solids that were initially present in the FGD scrubber purge as well as the additional solids (precipitate) that were formed during the chemical precipitation steps. A sand filter may also be included in the process to further reduce solids, as well as metals attached to the particulates. The backwash from the sand filters is transferred to a filtrate sump and recycled back to the equalization tank at the beginning of the treatment system.

The treated FGD wastewater is collected in a wastewater holding tank and either discharged directly to surface waters or, in most cases, commingled with other waste streams prior to discharge to dilute the concentration of pollutants in the wastewater. As described in Section 4.2, plants do not typically reuse this treated FGD wastewater because the chlorides are at levels that have the potential to corrode downstream equipment.

HEAVY METAL (HM)

Exhibit A



Si: 0.5-2%
gypsum & fines
high chlorides
fm FGD

PHYSICAL/CHEMICAL

- DE-SUPERSATURATION
- pH
- HEAVY METAL REDUCTION

Ni, NH3 slip fm SCR

Se FIX FILM BIO

350
2460
2100 GPM

4800
5040 GPD

BIOLOGICAL

SELENIUM

Linda
(617-549-2517

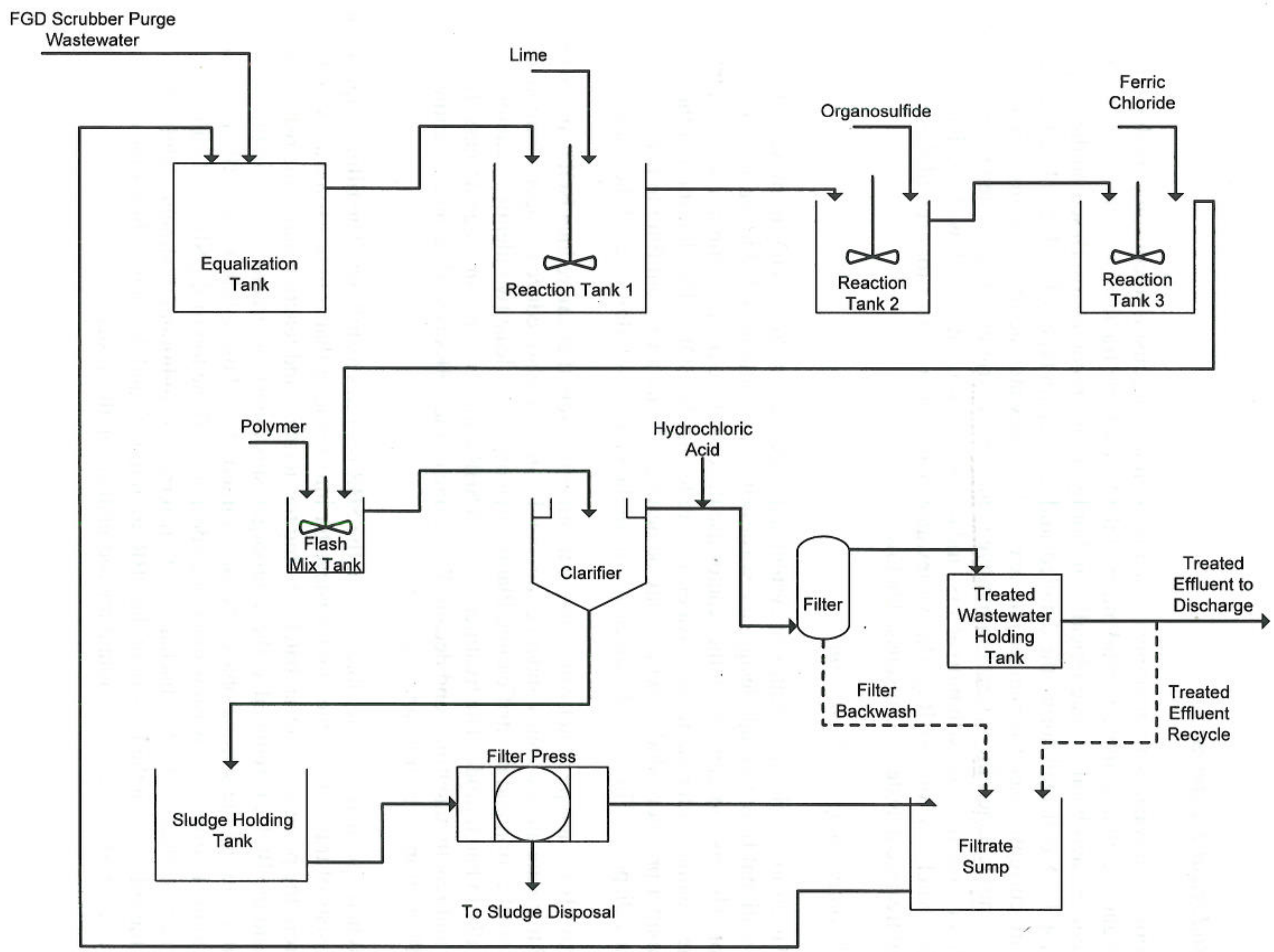


Figure 4-6. Process Flow Diagram for a Hydroxide and Sulfide Chemical Precipitation System

The solids settling in the clarifier (clarifier sludge) are transferred by pumps to the sludge holding tanks, after which the sludge is dewatered using a filter press. The dewatered sludge, or filter cake, is typically sent to an on-site landfill for disposal. The filtrate from the filter press is transferred to a sump and recycled back to the equalization tank at the beginning of the treatment system.

4.4.3 Biological Treatment

Biological wastewater treatment systems use microorganisms to consume biodegradable soluble organic contaminants and bind much of the less soluble fractions into floc. Pollutants may be reduced aerobically, anaerobically, and/or by using anoxic zones. Based on the information EPA collected during the detailed study, two main types of biological treatment systems are currently used (or planned) to treat FGD wastewater: aerobic systems to remove BOD_5 and anoxic/anaerobic systems to remove metals and nutrients. These systems can use fixed film or suspended growth bioreactors, and operate as conventional flow-through or as sequencing batch reactors (SBRs). The wastewater treatment processes for each of these biological treatment systems is discussed below.

Aerobic Biological Treatment

An aerobic biological treatment system can effectively reduce BOD_5 from wastewaters. In a conventional flow-through design, the wastewater is continuously fed to the aerated bioreactor. The microorganisms in the reactor use the dissolved oxygen from the aeration to digest the organic matter in the wastewater, thus reducing the BOD_5. The digestion of the organic matter produces sludge, which may be dewatered with a vacuum filter to better manage its ultimate disposal. The treated wastewater from the system overflows out of the reactor.

An SBR is a type of activated sludge treatment system that can reduce BOD_5 and, when operated to create anoxic zones under certain conditions, can also reduce nitrogen compounds through nitrification and denitrification. Plants often operate at least two identical reactors sequentially in batch mode. The treatment in each SBR consists of a four-stage process: fill, aeration and reaction, settling, and decant. While one of the SBRs is settling and decanting, the other SBR is filling, aerating, and reacting.

When operated as an aerobic system, the SBR operates as follows. The filling stage of the SBR consists of transferring the FGD wastewater into a reactor that contains some activated sludge from the previous reaction batch. During the aeration and reaction stage, the reactor is aerated and the BOD_5 is reduced as the microorganisms digest the organic matter in the wastewater. During the settling phase, the air is turned off and the solids in the SBR are allowed to settle to the bottom. The wastewater is then decanted off the top of the SBR and either transferred to surface water for discharge or transferred for additional treatment. Additionally, some of the solids from the bottom of the SBR are removed and dewatered, but some of the solids are retained in the SBR to retain microorganisms in the system.

Anoxic/Anaerobic Biological Treatment

Some coal-fired power plants are moving towards using anoxic/anaerobic biological systems to achieve better reductions of certain pollutants (e.g., selenium, mercury, nitrates) than has been possible with other treatment processes used at power plants. Figure 4-7 presents a process flow diagram for an anoxic/anaerobic biological treatment system. These biological systems include either a settling pond or chemical precipitation system as a pretreatment step to reduce TSS entering the bioreactors. Additionally, the microorganisms are susceptible to high temperatures, which may require the FGD wastewater to be cooled prior to entering the biological system.

The fixed-film bioreactor consists of an activated carbon bed that is inoculated with microorganisms which reduce selenium and other metals. Growth of the microorganisms within the activated carbon bed creates a fixed-film that retains the microorganisms and precipitated solids within the bioreactor. A molasses-based feed source for the microorganisms is added to the wastewater before it enters the bioreactor [Pickett, 2006].

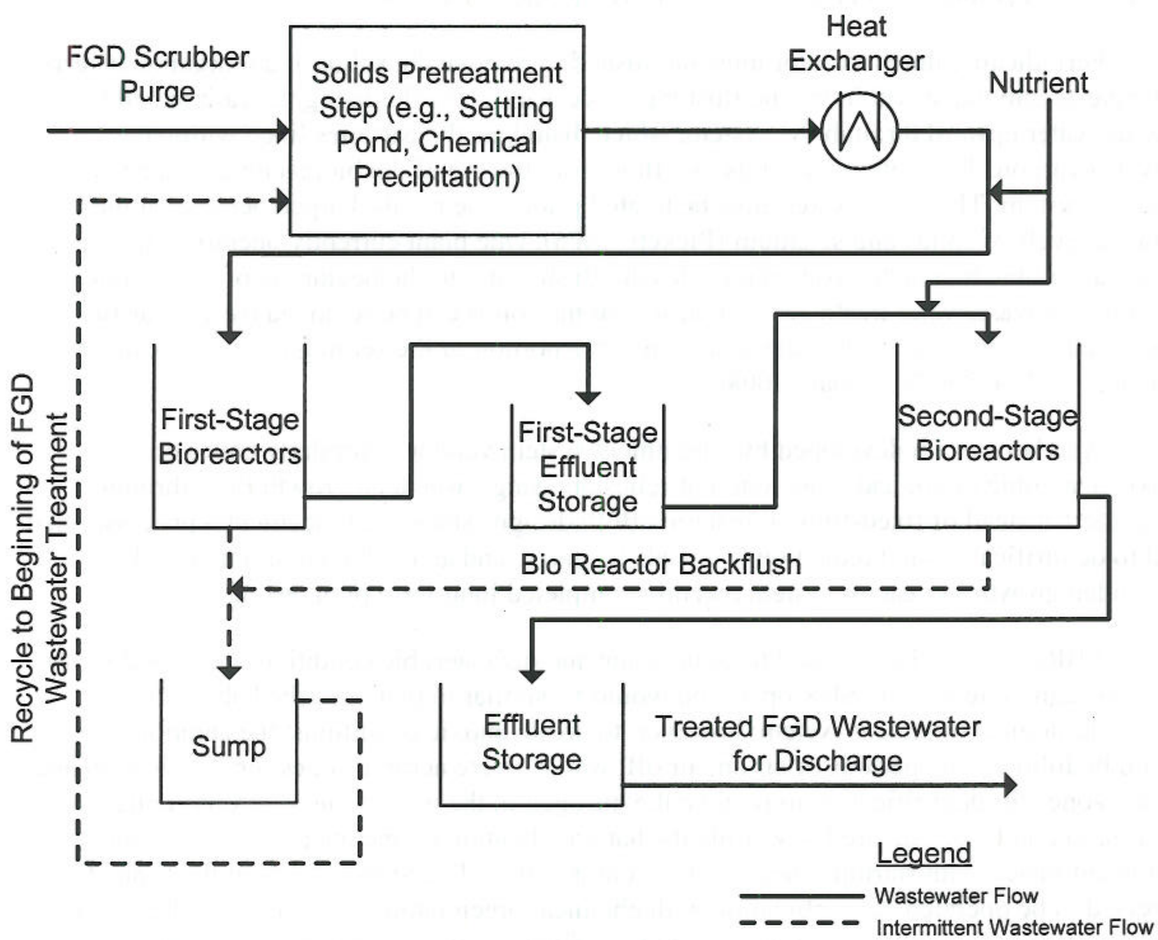


Figure 4-7. Process Flow Diagram for an Anoxic/Anaerobic Biological Treatment System

The bioreactor is designed for plug flow, containing different zones within the reactor that have differing oxidation potential. The top part of the bioreactor is aerobic and allows for nitrification and organic carbon oxidation. As the wastewater moves down through the bioreactor, it enters an anoxic zone where denitrification occurs as well as chemical reduction of both selenate and selenite, which are forms of selenium [Pickett, 2006].

As selenate and selenite are reduced within the bioreactor, elemental selenium forms nanospheres that adhere to the cell walls of the microorganisms. Because the microorganisms are retained within the bioreactor by the activated carbon bed, the elemental selenium is essentially fixed to the activated carbon until it is removed from the system. The bioreactor can also reduce other metals, including arsenic, cadmium, and mercury, by forming metal sulfides within the system [Pickett, 2006].

The bioreactor system typically contains multiple bioreactors; however, they can either be set up in series, as shown in Figure 4-7, or they can be set up in parallel, where the FGD wastewater is split and treated in separate bioreactors. Multiple bioreactors are typically required to allow for additional residence time to achieve the specified removals.

Periodically, the bioreactor must be flushed to remove the solids and inorganic materials that have accumulated within it. The flushing process involves fluidizing the carbon bed by flowing water upward through the system, which dislodges the particles fixed within the activated carbon. The water and solids overflow from the top of the bioreactor and are removed from the system. This flush water must be treated prior to being discharged because of the elevated levels of solids and selenium [Pickett, 2006]. One plant currently operating an anoxic/anaerobic bioreactor system recycles the flush water to the beginning of the chemical precipitation wastewater treatment system so that the solids can be removed by the clarifier. The other plant transfers the flush water to a segregated portion of the settling pond upstream of the bioreactor [ERG, 2008h; Jordan, 2008a].

Another system developed by a treatment system vendor is similarly based on anoxic/anaerobic biological treatment, but relies on using suspended growth flow-through bioreactors instead of fixed-film bioreactors. Both designs share the fundamental processes that lead to denitrification and reduction of metals in anoxic and anaerobic environments. This suspended growth bioreactor system recently completed long-term pilot testing.

SBRs can also be operated to achieve the anoxic/anaerobic conditions described for the flow-through systems. The SBR operation would be similar to that described above for the aerobic biological treatment system; however, to create anoxic conditions, the aeration stage would be followed by periods of air on, air off, which create aerobic zones for nitrification and anoxic zones for denitrification to remove the nitrogen in the wastewater. EPA has collected information on four coal-fired power plants that are planning to operate anoxic/anaerobic biological SBRs, with startup scheduled to occur by 2010. The SBR systems at these plants are expected to be operated in combination with chemical precipitation systems, with the overall systems designed to optimize removal of metals and nitrogen compounds. According to the treatment system vendor, these SBR systems will denitrify the wastewaters, but the oxidation reduction potential in the system will not be conducive for reducing metals.

4.4.4 Constructed Wetlands

A constructed wetland treatment system is an engineered system that uses natural biological processes involving wetland vegetation, soils, and microbial activity to reduce the concentrations of metals, nutrients, and TSS in wastewater. A constructed wetland typically consists of several cells that contain bacteria and vegetation (e.g., bulrush, cattails), which are selected based on the specific pollutants targeted for removal. The vegetation completely fills each cell and produces organic matter (i.e., carbon) used by the bacteria. The bacteria reduce metals that are present in the aqueous phase of the wastewater, such as mercury and selenium, to their elemental state. The targeted metals partition into the sediment where they either accumulate or are taken up by the vegetation in the wetland cells [EPRI, 2006b; Rodgers, 2005].

High temperature, COD, nitrates, sulfates, boron, and chlorides in wastewater can adversely affect constructed wetlands performance. To overcome this FGD wastewater is typically diluted with service water before it enters a constructed wetland to reduce the temperature and concentration of chlorides and other pollutants, which can harm the vegetation in the treatment cells. Chlorides in a constructed wetlands treatment system typically must be maintained below 4,000 mg/L. Most plants operate their FGD scrubber system to maintain chloride levels within a range of 12,000-20,000 ppm, so plants must dilute the FGD wastewater prior to transferring it to the wetlands. EPA has observed that power plants operating a constructed wetland tend to operate the FGD scrubber at the lower end of the chloride range. To do this, the plants purge FGD wastewater from the system at a higher flow rate than they otherwise would do if operating the FGD scrubber at a higher chloride level.

4.4.5 Vapor-Compression Evaporation System

Evaporators in combination with a final drying process can significantly reduce the quantity of wastewater discharged from certain process operations at various types of industrial plants, including power plants, oil refineries, and chemical plants. One type of evaporation system uses a falling-film evaporator (also referred to as a brine concentrator) to produce a concentrated wastewater stream and a reusable distillate stream. The concentrated wastewater stream may be further processed in a crystallizer or spray dryer, in which the remaining water is evaporated, eliminating the wastewater stream. When used in conjunction with a crystallizer or spray dryer, this process reportedly generates a clean distillate and a solid by-product that can then be disposed of in a landfill. Figure 4-8 presents a process flow diagram for a vapor-compression evaporation system.

Power plants most often use vapor-compression evaporator systems to treat waste streams such as cooling tower blowdown and demineralizer waste, but they have recently begun to operate vapor-compression evaporator systems to treat FGD wastewater as well. One U.S. coal-fired plant and six coal-fired power plants in Italy are treating FGD wastewater with vapor-compression evaporator systems [Rao, 2008; Veolia, 2007; ERG, 2009a].

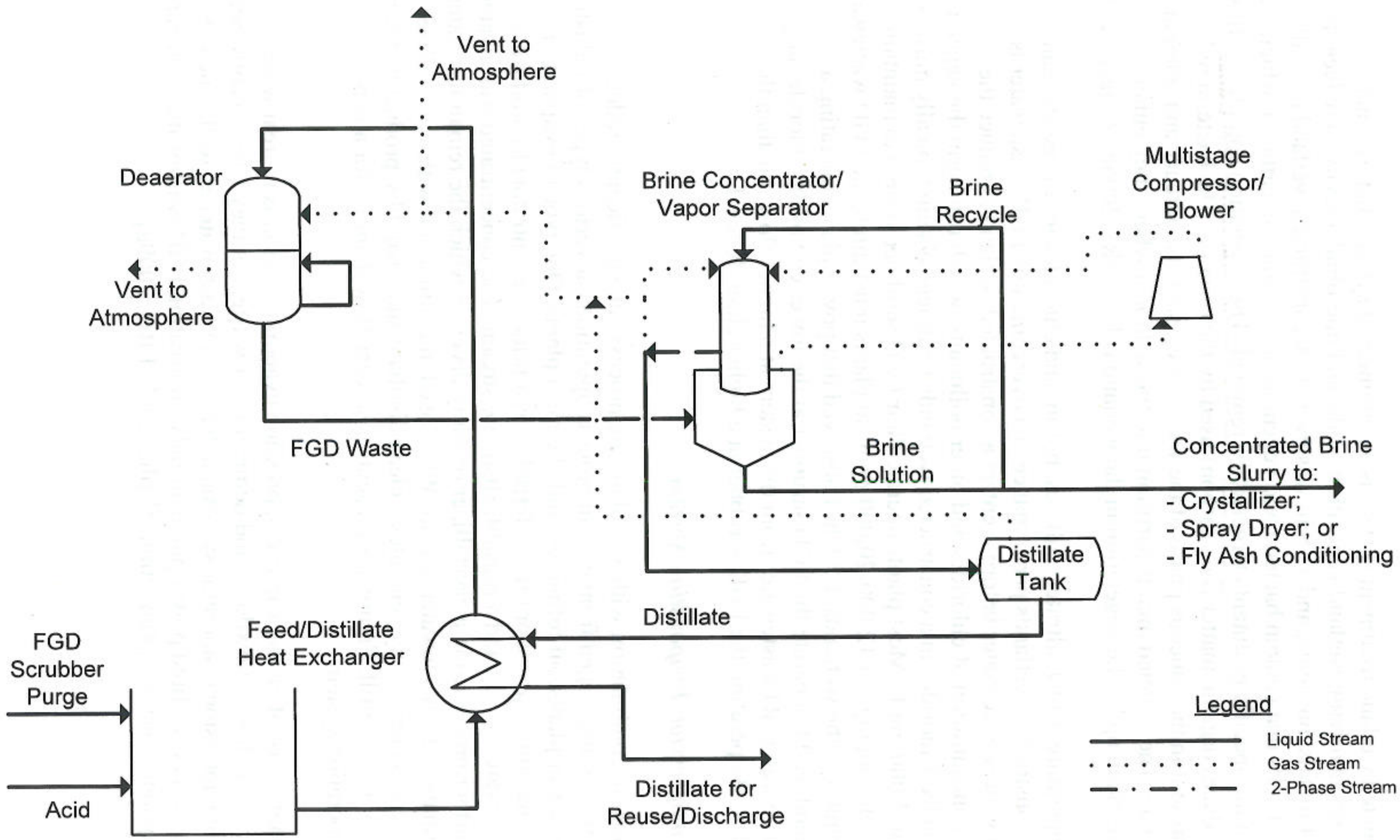


Figure 4-8. Process Flow Diagram for a Vapor-Compression Evaporation System

When a vapor-compression evaporator system is used to treat FGD wastewater, the first step is to adjust the pH of the FGD scrubber purge to approximately 6.5. Following pH adjustment, the scrubber purge is sent through a heat exchanger to bring the waste stream to its boiling point. The waste stream continues to a deaerator where the noncondensable materials such as carbon dioxide and oxygen are vented to the atmosphere [Aquatech, 2006].

From the deaerator, the waste stream enters the sump of the brine concentrator. Brine from the sump is pumped to the top of the brine concentrator and enters the heat transfer tubes. While falling down the heat transfer tubes, part of the solution is vaporized and then compressed and introduced to the shell side of the brine concentrator (i.e., the outside of the tubes). The temperature difference between the compressed vapor and the brine solution causes the compressed vapor to transfer heat to the brine solution, which flashes to a vapor. As heat is transferred to the brine, the compressed vapor cools and condenses as distilled water [Aquatech, 2006].

The condensed vapor (distillate water) can be recycled back to the FGD process, used in other plant operations (e.g., boiler make-up water), or discharged. If the distillate is used for other plant operations that generate a discharge stream (e.g., used as boiler make-up and ultimately discharged as boiler blowdown), then the FGD process/wastewater treatment system is not achieving true zero liquid discharge. Therefore, the operation of the vapor-compression evaporation system itself does not guarantee that the FGD process/wastewater treatment system achieves zero discharge.

To prevent scaling within the brine concentrator as a result of the gypsum present in the FGD scrubber purge, the brine concentrator is seeded with calcium sulfate. The calcium salts preferentially precipitate onto the seed crystals instead of the tube surfaces of the brine concentrator [Shaw, 2008].

The concentrated brine slurry from the brine concentrator tubes falls into the sump and is recycled with the feed (FGD scrubber purge) back to the top of the brine concentrator, while a small amount is continuously withdrawn from the sump and typically transferred to a final drying process. The brine concentrator can typically concentrate the FGD scrubber purge five to ten times, which reduces the inlet FGD scrubber purge water volume by 80 to 90 percent [Shaw, 2008].

Three options are typically considered to be available for eliminating the brine concentrate: (1) final evaporation in a brine crystallizer; (2) evaporation in a spray dryer; or (3) using the brine to condition (add moisture to) dry fly ash or other solids, and disposal of the mixture in a landfill.

Power plants may use brine concentrators to treat a waste stream other than FGD scrubber purge (e.g., cooling tower blowdown). For these non-FGD systems, the concentrated brine withdrawn from the sump is typically sent to a forced-circulation crystallizer to evaporate the remaining water from the concentrate and generate a solid product for disposal. However, the calcium and magnesium salts present in the scrubber purge can pose difficulties for the forced-circulation crystallizer. To prevent this, the FGD scrubber purge can be pretreated using a lime-softening process (i.e., chemical precipitation) upstream of the brine concentrator. With water softening, the magnesium and calcium ions precipitate out of the purge water and are replaced with sodium ions, producing an aqueous solution of sodium chloride that can be more effectively treated with a forced-circulation crystallizer [Shaw, 2008].

Coal-fired power plants can avoid having to operate the chemical precipitation pretreatment process by using a spray dryer to evaporate the residual waste stream from the brine concentrator. Because the material is hygroscopic (i.e., readily taking up and retaining moisture), the solid residual from the brine concentrator is typically bagged immediately and disposed of in a landfill. Alternatively, the concentrated brine waste stream can be combined with dry fly ash or other solids and disposed of in a landfill.

4.4.6 Design/Operating Practices Achieving Zero Discharge

During its site visit program, EPA observed that many of the plants operating wet FGD systems were able to design and/or manage the FGD system in a manner that prevented the need for a discharge of FGD wastewater. Based on information EPA collected during the detailed study, EPA identified four design/operating practices available to prevent the discharge of FGD wastewater: evaporation ponds, conditioning dry fly ash, underground injection, and several variations of complete recycle. The wastewater treatment processes for each of these practices are discussed below.

Complete Recycle

As discussed in Section 4.2, most plants do not recycle the treated FGD wastewater within the FGD system because of the elevated chloride levels in the treated effluent. Some plants, however, can completely recycle the FGD wastewater within the system without using a wastewater purge stream to remove chlorides. Such plants generally do not produce a saleable solid product from the FGD system (e.g., wallboard-grade gypsum). Because the FGD solid by-product is not being sold and is most likely disposed of in a landfill, there are no specific chloride specifications for the material. Therefore, the plant can operate the FGD system and solids separation/dewatering process such that the moisture retained with the landfilled solids entrains sufficient chlorides that a separate wastewater purge stream is not needed. By operating in this manner, the transfer of the FGD solids to the landfill essentially serves as the chloride purge from the system.

EPA visited four plants that operate limestone forced oxidation FGD systems that do not discharge any FGD wastewaters directly to surface waters. Case Study I describes how one of these plants, Dominion Resources' Mount Storm Plant, is able to completely reuse the FGD wastewaters within the system.

EPA also visited three plants that operate lime or limestone inhibited oxidation FGD systems and do not discharge any FGD wastewaters directly to surface waters. Case Study II describes how one of these plants was able to completely reuse the FGD wastewaters within the system.

Case Study I: Coal-Fired Power Plant Water Reuse
Limestone Forced Oxidation FGD System
Dominion Resources' Mount Storm Plant

The Facility

FGD type:	Limestone forced oxidation spray tower
Scrubber chlorides conc.:	40,000 ppm
Materials of construction chlorides limit:	120,000 ppm
FGD WWT system:	None: complete recycle
Gypsum destination:	Landfill, concrete manufacturing, land application

The FGD Wastewater Handling System

The gypsum slurry blowdown from the FGD system is transferred to hydroclones for initial dewatering. The underflow from the hydroclones contains the gypsum solids and is transferred to vacuum rotary drum filters. The hydroclone overflow, which is mostly water and fines, is recycled back to the FGD scrubber.

The hydroclone underflow sent to the vacuum rotary drum filters is not rinsed with service water, as some plants do. The underflow is fed to a tray that holds the underflow as the vacuum drum filter rotates and the bottom of the drum filter is dipped in the underflow water. The vacuum on the rotary drum filter pulls the solids and water to the drum and then pulls the water out of the solids to dry the gypsum. The dry gypsum (20-25% moisture content) is then scraped off the drum as it rotates. The gypsum collected from the vacuum rotary drum filters is conveyed to the storage area until it is either sent to the on-site landfill, transferred off site to a concrete manufacturer, or transferred off site for land application. The filtrate from the vacuum rotary drum filters is either recycled back to the FGD scrubber or to the limestone preparation process.

Why the Plant is Able to Completely Reuse FGD Wastewater

Gypsum is not sold to a wallboard manufacturer; therefore, the gypsum dried on the vacuum rotary drum filters does not need to meet any particular specifications. Since higher levels of chlorides are acceptable, the gypsum does not require washing. Chlorides are purged from the system entrained in the gypsum (20-25% moisture), and the mass removal rate is sufficient to maintain the chlorides in the FGD system at a constant level.

Source: [ERG, 2008p].

Case Study II: Coal-Fired Power Plant Water Reuse
Lime or Limestone Inhibited Oxidation FGD System
Ohio Power Company's General James M Gavin Plant

The Facility

FGD type:	Magnesium-enhanced lime inhibited oxidation spray/tray towers
Scrubber chlorides conc.:	2,500 to 3,000 ppm
FGD WWT system:	None: complete recycle
Calcium sulfite destination:	Landfilled as cementitious material

The FGD Wastewater Handling System

The calcium sulfite slurry from the FGD system is transferred to a pair of thickeners to separate the solids from the water. The underflow from the thickener contains the calcium sulfite solids and is transferred to centrifuges for final dewatering. The thickener overflow is sent to a reclaim tank and recycled back to the FGD scrubber.

The thickener underflow sent to the centrifuges is not rinsed with service water. The underflow is fed to a centrifuge to dewater the solids. The water leaving the centrifuge, referred to as centrate, is recycled back to the FGD scrubber. The solids stream from the centrifuge contains 40-50 percent moisture. This stream is combined with dry fly ash and lime in a pug mill to generate a cementitious material that can be landfilled.

How FGD Wastewater is Completely Reused

The calcium sulfite does not need to meet any particular specifications; therefore, it is not washed to remove chlorides prior to dewatering. The dewatered calcium sulfite has a moisture content of 40 to 50 percent water (before mixing with fly ash and lime) and chlorides are retained in the cementitious material sent to the landfill. The FGD system has reached a steady state operation in which the chlorides entering the system from the coal are equal to the chlorides that are leaving the system in the cementitious material.

Source: [ERG, 2009b].

Evaporation Ponds

EPA identified three coal-fired power plants located in the southwestern United States using evaporation ponds to avoid discharging FGD wastewater. Because of the warm, dry climate in this region, the plants can send the FGD wastewater to one or more ponds where the water is allowed to evaporate. At these plants, the evaporation rate from the pond is greater than or equal to the flow rate of the FGD wastewater to the pond and no water is discharged from the evaporation pond.

Conditioning Dry Fly Ash

Many plants that operate dry fly ash handling systems need to add water to the fly ash for dust suppression or to improve handling and/or compaction characteristics. EPA has identified one plant that uses FGD wastewater to condition its dry fly ash. In addition, another plant is using a vapor-compression evaporation system in combination with conditioning dry fly ash to prevent the discharge of FGD wastewater [ERG, 2009a]. The plant uses the vapor-compression evaporation system to reduce the volume of the FGD scrubber purge and then mixes the effluent from the brine concentrator with dry fly ash and disposes of it in a landfill.

Underground Injection

Underground injection is a technique used to dispose of wastes by injecting them into an underground well. This technique is an alternative to discharging wastewater to surface waters. One plant began using underground injection to dispose of the FGD wastewater in 2007, but due to unexpected pressure issues and problems with building the wells due to geological formations encountered, which may not be related to the characteristics of the FGD wastewater, the plant has not been able to continuously inject the wastewater. The plant operates a chemical precipitation system as pretreatment for the injection system. When the plant is not injecting the FGD wastewater, the effluent from the chemical precipitation system is transferred to the plant's pond system. Since the pond water is used as make-up for the plant's service water, the chlorides from the FGD wastewater are not purged from the system. The plant needs to sustain continuous injection of the wastewater to avoid chlorides increasing to a level that would promote corrosion of equipment [ERG, 2009e]. Another plant is also scheduled to begin injecting the FGD wastewater underground later this year [Gulf Power, 2009]. Underground injection has its own permitting and regulations, which are not covered under the NPDES program.

Combination of Wet and Dry FGD Systems

The combination of a wet and a dry FGD system operated on the same unit or at the same plant can result in elimination of the scrubber purge associated with the wet FGD process. As described in Section 4.2.3, the dry FGD process involves atomizing and injecting wet lime slurry, which ranges from approximately 18 to 25 percent solids, into a spray dryer. The water contained in the slurry is evaporated from the heat of the flue gas within the system, leaving behind a dry residue which is removed from the flue gas by a fabric filter (i.e., baghouse). By operating a combination of a wet and dry FGD system, the scrubber purge associated with the wet FGD system can be used as make-up water for the lime slurry feed to the dry FGD process, thereby eliminating the FGD wastewater.

From its data collection activities, EPA has identified one plant that is expected to operate a dry FGD system in combination with a wet FGD system to eliminate the need to discharge the FGD wastewater associated with the wet FGD system. Case Study III describes how this plant is expected to operate when the new electric generating unit begins operation in 2012.

4.4.7 Other Technologies under Investigation

Industry-funded studies are being conducted by EPRI to evaluate and demonstrate technologies that have the potential to remove trace metals from FGD wastewater. EPRI is conducting pilot- and full-scale optimization field studies on some technologies already in use by coal-fired power plants to treat FGD wastewater, such as chemical precipitation (organosulfide and iron coprecipitation), constructed wetlands, and an anoxic/anaerobic biological treatment system. EPRI is also conducting lab- and pilot-scale studies for other technologies that may be capable of removing metals from FGD wastewaters. EPA obtained limited information regarding these other technologies, which include iron cementation, reverse osmosis, absorption media, ion exchange, and electro-coagulation. Each of these technologies are discussed below.

Iron Cementation

EPRI conducted laboratory feasibility studies of the metallic iron cementation treatment technology as a method for removing all species of selenium from FGD wastewater. EPRI believes this process may also be effective at removing mercury. The iron cementation process consists of contacting the FGD wastewater with an iron powder, which reduces the metal to its elemental form (cementation). The pH of the wastewater is raised to form metal hydroxides, and the wastewater is filtered to remove the precipitated solids. The iron powder used in the process is separated from the wastewater and recycled back to the cementation step. From the initial studies, EPRI concluded that the metallic iron cementation approach is promising for treating FGD wastewater for multiple species of selenium, including selenite, selenate, and other unknown selenium compounds. EPRI is planning to continue conducting laboratory- and pilot-scale feasibility studies of the technology to evaluate selenium and mercury removal performance [EPRI, 2008b].

Case Study III: Coal-Fired Power Plant Water Reuse
Integrated Dry and Wet FGD Systems
Duke Energy Carolinas' Cliffside Steam Station

The Facility

FGD type:	Unit 6: Lime spray dryer and wet limestone forced oxidation spray tower; Unit 5: wet limestone forced oxidation spray tower
FGD WWT system:	Unit 6: None; Unit 5: chemical precipitation system
FGD solids destination:	Sold for wallboard production or landfilled

The FGD Operation and Wastewater Handling System

When Unit 6 begins operation (expected in 2012), its flue gas will first be treated with a dry lime FGD system (spray dryer). The flue gas exiting the spray dryer will pass through a fabric filter baghouse to remove the FGD solids, fly ash, and other particulates from the flue gas. The flue gas will then be directed to the wet limestone forced oxidation system. The wet FGD system will operate similarly to Figure 4-2; however, instead of the scrubber purge being transferred to wastewater treatment and discharged, the scrubber purge will be reused in the lime slurry feed to the dry FGD system.

Unit 5 is currently operating at the plant, but its wet FGD system is not yet operating. Once the FGD system is operating, the Unit 5 flue gas will be treated by a cold-side ESP followed by a wet limestone forced oxidation system. When Unit 6 is not operating, the scrubber purge from Unit 5 will be transferred to a chemical precipitation wastewater treatment system. When Unit 6 is operating, most, if not all, of the scrubber purge from Unit 5 can be used in the lime slurry feed for the Unit 6 dry FGD system; the remainder will be transferred to the wastewater treatment system. Units 5 and 6 operate independently from each other and, therefore, the wastewater treatment system will allow the plant to operate Unit 5 and discharge its scrubber purge stream when Unit 6 is not operating.

How the FGD Wastewater Discharge will be Eliminated

The scrubber purge streams from Units 5 & 6 will be reused in the feed stream to Unit 6's dry FGD system, which will evaporate the water during the process and generate only solid residues that are removed in the fabric filter baghouse.

Source: [McGinnis, 2009].

Reverse Osmosis

Reverse osmosis systems are currently in use at power plants, usually to treat boiler make-up water or cooling tower blowdown wastewaters. EPRI has identified a high-efficiency reverse osmosis (HERO™) process which operates at a high pH, allowing the system to treat high silica wastewaters without scaling or membrane fouling because silica is more soluble at higher pHs. The wastewater undergoes a water-softening process to raise the pH of the wastewater prior to entering the HERO™ system.

Although the HERO™ system has been demonstrated for use with power plant cooling tower blowdown wastewater, its use for FGD wastewater is potentially limited due to the osmotic pressure of the FGD wastewater resulting from the high concentrations of chloride and TDS [EPRI, 2007a].

Although many power plants may not be able to use the HERO™ system to treat FGD wastewater, some plants with lower TDS and chloride concentrations may be able to do so. The HERO™ system is of particular interest for treating boron from FGD wastewaters because boron becomes ionized at an elevated pH and, therefore, could be removed using a reverse osmosis system [EPRI, 2007a].

Sorption Media

Sorption media has been used by the drinking water industry to remove arsenic from the drinking water. These sorption processes are designed to adsorb pollutants onto the media's surface area using physical and chemical reactions. The designs most commonly used in the drinking water industry use metal-based adsorbents, typically granular ferric oxide, granular ferric hydroxide, or titanium-based oxides. The sorption media is usually a single use application that can typically be disposed of in a nonhazardous landfill after its use. In addition, the single-use design prevents the plant from needing to further treat the residuals. According to EPRI, these sorption media have been shown to remove the common forms of arsenic and selenium from drinking water [EPRI, 2007a].

Ion Exchange

Ion exchange systems are currently in use at power plants to pretreat boiler make-up water. Ion exchange systems are designed to remove specific constituents from wastewater; therefore, specific metals can be targeted by the system. The typical metals targeted by ion exchange systems include boron, cadmium, cobalt, copper, lead, mercury, nickel, uranium, vanadium, and zinc. Although the ion exchange process does not generate any residual sludge, it does generate a regenerant stream that contains the metals stripped from the wastewater. EPA has compiled information on a plant that is pilot testing two ion exchange resins for treatment of FGD wastewater. The plant and the ion exchange resins tested in the pilot study are focused specifically on the removal of mercury. [EPRI, 2007a].

Electro-Coagulation

Electro-coagulation uses an electrode to introduce an electric charge to the wastewater, which neutralizes the electrically charged colloidal particles. These systems typically use aluminum or iron electrodes, which are dissolved into the waste stream during the process. The dissolved metallic ions precipitate with the other pollutants present in the wastewater and form insoluble metal hydroxides. According to EPRI, additional polymer or supplemental coagulants may need to be added to the wastewater depending on the specific characteristics. These systems are typically used to treat small waste streams, ranging from 10 to 25 gpm, but may also be able to treat waste streams of up to 50 or 100 gpm [EPRI, 2007a].

Other Technologies

Other technologies under laboratory-scale study include polymeric chelates, taconite tailings, and nano-scale iron reagents. In addition, EPRI is investigating various physical treatment technologies, primarily for mercury removal, including filtration [EPRI, 2008a].

4.4.8 Wastewater Treatment System Use in the Coal-Fired Steam Electric Industry

Table 4-7, presents information on the FGD wastewater treatment systems currently operating (as of June 2008) at plants included in EPA's combined data set. Table 4-7 also includes information on FGD wastewater treatment systems projected to be operating in 2020. EPA's combined data set includes wastewater treatment system information for 84 of the 108 plants (78 percent) operating wet FGD scrubber systems as of June 2008, representing 175 of the 223 wet-scrubbed coal-fired electric generating units (78 percent). Of these 84 plants, 32 plants (38 percent) do not discharge FGD wastewater.[18] These plants are able to achieve "zero discharge" by either recycling all FGD wastewater back to the scrubber (28 plants), using evaporation ponds (3 plants), mixing the FGD wastewater with dry fly ash (1 plant), or deep well injecting the FGD wastewater (1 plant[19]). Figure 4-9 shows the distribution of FGD wastewater management/treatment within the group of 84 plants.

[18] There is a plant that operates several wet FGD systems and for some of the wet FGD systems there is a wastewater discharge; however, the other wet FGD systems operate without discharging. In Table 4-7, this plant is included in the count of plants for both the "zero discharge" wastewater treatment systems and the other type of wastewater treatment system operated by the plant.

[19] As discussed in Section 4.4.6, the plant began using underground injection to dispose of the FGD wastewater in 2007, but due to issues encountered with the system, has not been able to continuously inject the wastewater.

Table 4-7. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Operating as of June 2008 [a]			Wet FGD Systems in the Combined Data Set Projected to be Operating in 2020 [b]		
	Number of Plants with FGD Wastewater Treatment Systems	Number of Electric Generating Units Serviced by FGD Wastewater Treatment Systems	Wet Scrubbed Capacity [c] (MW)	Number of Plants With or Expected to Operate FGD Wastewater Treatment Systems	Projected Number of Electric Generating Units Serviced by the Treatment Systems	Projected Wet Scrubbed Capacity [c] (MW)
Settling Ponds	**29**	**63**	**27,700**	**35**	**95**	**44,000**
Combined FGD and Ash Ponds (FGD solids removal prior) [d, e]	17	41	14,400	18	48	16,600
Combined FGD and Ash Ponds (No FGD solids removal prior) [d, f]	2	4	1,440	2	4	1,440
FGD Ponds (FGD solids removal prior) [e, g]	4	8	4,450	7	18	12,500
FGD Ponds (No FGD solids removal prior) [f, g]	6	10	7,350	8	25	13,400
Chemical Precipitation ("Chem Precip")	**15**	**27**	**14,200**	**24**	**52**	**28,300**
Chem Precip (type unknown)	—	—	—	5	11	5,800
Hydroxide Chem Precip	10	18	10,500	11	25	14,800
Hydroxide and Sulfide Chem Precip	2	4	2,350	5	11	6,460
Combination Settling Pond and Chem Precip	2	3	896	2	3	896
Chem Precip and Constructed Wetland	1	2	414	1	2	414
Tank-Based Biological	**1**	**3**	**2,150**	**2**	**6**	**3,294**
Combination Settling Pond and Anoxic/Anaerobic Biological (designed for metals & nitrogen removal)	1	3	2,150	2	6	3,294

Table 4-7. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Operating as of June 2008 [a]			Wet FGD Systems in the Combined Data Set Projected to be Operating in 2020 [b]		
	Number of Plants with FGD Wastewater Treatment Systems	Number of Electric Generating Units Serviced by FGD Wastewater Treatment Systems	Wet Scrubbed Capacity [c] (MW)	Number of Plants With or Expected to Operate FGD Wastewater Treatment Systems	Projected Number of Electric Generating Units Serviced by the Treatment Systems	Projected Wet Scrubbed Capacity [c] (MW)
Combination Chem Precip and Tank-Based Biological	**3**	**5**	**4,720**	**8**	**23**	**12,500**
Chem Precip and Aerobic Biological (designed for metals and BOD_5 removal)	2	3	2,560	1	2	1,870
Chem Precip and Aerobic/Anaerobic Biological (designed for removing nitrogen and selected metals)	—	—	—	4	11	5,260
Chem Precip and Anoxic/Anaerobic Biological (designed for metals & nitrogen removal)	—	—	—	3	10	5,330
Chem Precip, Anoxic/Anaerobic Biological (designed for metals & nitrogen removal), and CWTS	1	2	2,160	—	—	—
Zero Discharge	**33**	**65**	**38,700**	**35**	**75**	**43,000**
Zero Discharge: Recycle All FGD Water	28	56	33,800	27	58	34,700
Zero Discharge: Evaporation Pond	3	4	1,800	3	4	1,800
Zero Discharge: Conditioning Dry Fly Ash	1	2	1,140	1	2	1,140
Zero Discharge: Deep Well Injection	1	3	2,000	2	7	3,140
Zero Discharge: Evaporator & Conditioning Dry Fly Ash	—	—	—	1	2	1,580
Zero Discharge: Recycled to Dry FGD	—	—	—	1	2	571

Table 4-7. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Operating as of June 2008 [a]			Wet FGD Systems in the Combined Data Set Projected to be Operating in 2020 [b]		
	Number of Plants with FGD Wastewater Treatment Systems	Number of Electric Generating Units Serviced by FGD Wastewater Treatment Systems	Wet Scrubbed Capacity [c] (MW)	Number of Plants With or Expected to Operate FGD Wastewater Treatment Systems	Projected Number of Electric Generating Units Serviced by the Treatment Systems	Projected Wet Scrubbed Capacity [c] (MW)
Other Handling	**5**	**12**	**5,010**	**5**	**12**	**5,010**
Clarifier	1	3	521	1	3	521
Clarifier and Constructed Wetland	1	4	2,000	1	4	2,000
Commingled with other Wastewater	3	5	2,490	3	5	2,490
No Information	**24**	**48**	**15,600**	**85**	**164**	**65,900**
Subtotal: Wastewater treatment systems for which EPA has information available [h]	**84**	**175**	**92,500**	**107**	**237**	**123,000**
Subtotal: Systems treating FGD wastewater discharged to surface waters [h]	**53**	**110**	**53,800**	**74**	**162**	**79,900**
Total [h]	**108**	**223**	**108,000**	**192**	**401**	**189,000**

a – Source: Combined data set (UWAG-provided data [ERG, 2008g], data request information [U.S. EPA, 2008a], and site visit and sampling information). Includes treatment systems servicing electric generating units identified in the "combined data set" with wet FGD systems operating as of June 2008. Excludes OSWER data for surface impoundments containing CCRs.
b – Source: Combined data set (UWAG-provided data [ERG, 2008g], data request information [U.S. EPA, 2008a], and site visit and sampling information). Includes treatment systems servicing electric generating units identified in the "combined data set" with wet FGD systems operating by 2020.
c – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities presented represent the reported nameplate capacity for the unit.
d – The combined FGD and ash pond system refers to a settling pond that handles untreated FGD scrubber purge and ash wastewaters (either bottom ash or fly ash transport water). Some plants transfer treated FGD wastewaters to an ash pond for dilution prior to discharge, but these systems are not reflected in this table.
e – "FGD Solids removal prior" means that gypsum or calcium sulfite sludge was removed prior to treatment.
f – "No FGD Solids removal prior" means that gypsum or calcium sulfite sludge was sent to the settling pond.
g – The FGD pond system refers to settling ponds that handle untreated FGD scrubber purge, but do not handle ash wastewaters. The FGD pond may handle other wastewaters along with the FGD scrubber purge, such as low-volume wastes, but the pond cannot receive ash wastewaters to be considered an FGD pond.
h – There are two plants with multiple types of wastewater treatment systems; therefore, there is overlap in these totals.

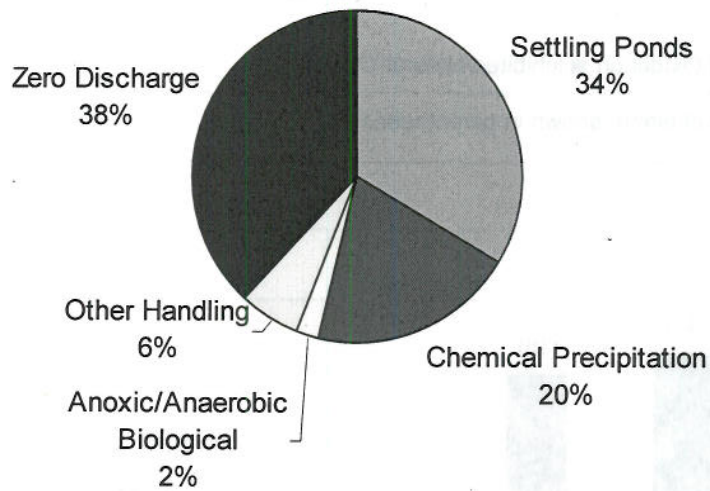


Figure 4-9. Distribution of FGD Wastewater Treatment Systems Among Plants Operating Wet FGD Systems

Figure 4-10 compares the distribution of FGD wastewater treatment systems within the group of plants that operate limestone forced oxidation FGD systems, to the group of plants operating inhibited/natural oxidation FGD systems. EPA has information about FGD wastewater management/treatment for 50 plants operating forced oxidation FGD systems servicing 111 electric generating units, and 36 plants operating inhibited or natural oxidation FGD systems servicing 65 electric generating units[20]. A larger percentage of the plants operating forced oxidation FGD systems discharge the FGD wastewater, relative to plants that operate inhibited and natural oxidation FGD systems. This is largely due to the fact that inhibited oxidation FGD systems produce calcium sulfite by-product which, since it has little or no value in the marketplace, typically is disposed of in a landfill. This provides plants the opportunity to operate the FGD system in a manner that purges chlorides from the FGD system along with the landfilled solids and eliminates the need for the FGD wastewater discharge. See section 4.2 for additional discussion of this operational practice.

[20] EPA has information regarding FGD wastewater treatment systems for 84 plants; however, two of these plants operated both forced oxidation and natural/inhibited oxidation FGD systems.

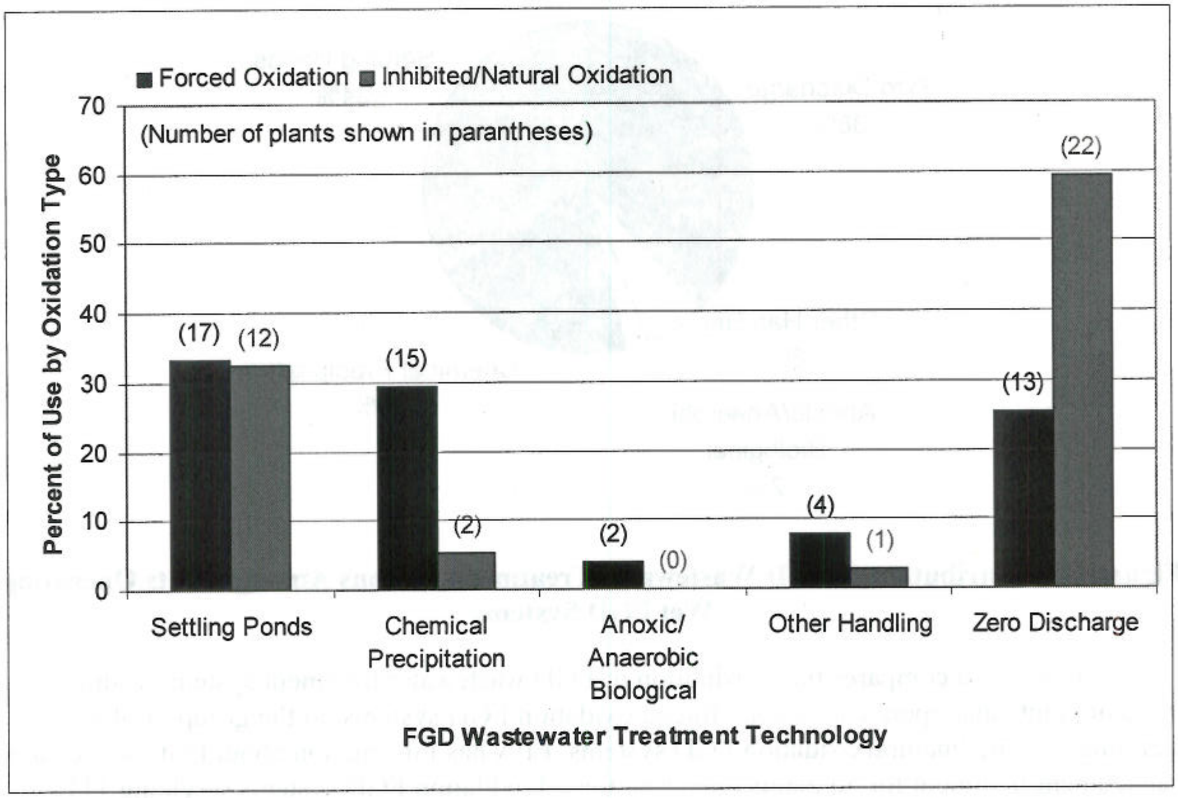


Figure 4-10. Comparison of Distribution of FGD Wastewater Treatment Systems by Type of Oxidation System

Of the 84 plants for which EPA has information about FGD wastewater, 53 discharge the FGD wastewater. The technologies used by these 53 plants to treat FGD wastewater is summarized below, and illustrated by Figure 4-11. It should be noted that most of these plants subsequently commingle the treated FGD wastewater with other waste streams (e.g., ash wastewater or cooling water) to enable dilution to reduce the pollutant concentrations in the discharged wastewater.

- Twenty-nine plants treat the wastewater using a settling pond.[21]
- Eighteen plants operate chemical precipitation systems. Fifteen of these 18 plants operate a hydroxide chemical precipitation system, and three use both hydroxide and sulfide precipitation in the treatment system. Additionally, two of the 15 hydroxide plants currently have equipment installed to also perform a sulfide precipitation step, but are no longer adding sulfide to the system.
- Two of the 18 plants with chemical precipitation systems also operate aerobic biological reactors following the precipitation system. Both of these plants use

[21] For comparison, note that the OSWER data on surface impoundments identifies 78 plants operating a total of 170 ponds that contain FGD wastes. There is insufficient data to determine whether the FGD wastestream undergoes solids separation to remove gypsum or calcium sulfite prior to the ponds, nor is there information to determine which of these ponds may discharge to surface water. Some of the ponds also contain ash wastes and may be more accurately described as ash ponds that also receive FGD wastes (with or without first removing FGD solids) [Schroeder, 2009].

organic acid additives in their FGD scrubbers to improve the SO2 removal efficiency, increasing the BOD5 concentration in the scrubber purge.

- Two plants operate fixed-film anoxic/anaerobic bioreactors. One of these plants also operates a chemical precipitation system (one of the 18 plants described previously) and the other operates a settling pond as pretreatment to the bioreactor. Two additional plants are in the process of installing similar fixed-film bioreactors. One will operate the biological system in conjunction with chemical precipitation; the other will use a settling pond for pretreatment.
- One plant uses a clarifier and one plant uses a constructed wetlands treatment system as the primary treatment mechanism. Two other plants also operate constructed wetland systems; however, the constructed wetland acts as a polishing step following chemical precipitation and/or biological treatment.
- Three plants commingle the FGD wastewater with other waste streams (other than ash transport water).

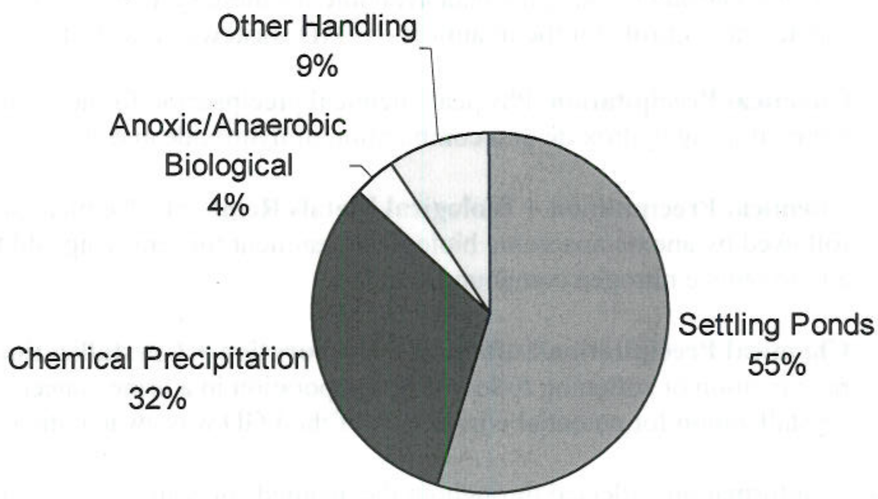


Figure 4-11. Distribution of FGD Wastewater Treatment Systems Among Plants that Discharge FGD Wastewater

Table 4-7 also presents information for the type of treatment systems that, based on the combined data set, EPA anticipates will be used to treat wastewater from the FGD scrubbers that will be operating in 2020. Despite recent interest in the use of more advanced wastewater treatment systems, the data compiled by EPA indicate that widespread use of settling ponds to treat FGD wastewater will continue.

EPA expects that more than 192 plants will be operating wet FGD scrubbers by 2020 and that 158 of these plants will discharge FGD wastewater[22]. Of these 158 plants, there are 74 for which EPA has information on their expected system use. Below is a description of the type of

[22] As discussed in section 4.1.2, EPA's projections for new FGD systems do not include the systems that will be installed at new generating units or new plants. Thus, the projections for 2020 are considered to under-estimate the actual number of FGD systems that will be installed.

wastewater treatment systems either currently operating or expected to be operating at these 74 plants:

- Thirty-five plants are expected to treat the wastewater using a settling pond;
- Thirty-four plants are expected to rely on more advanced treatment such as chemical precipitation or biological treatment;
- One plant is expected to use a clarifier and one plant is expected to use a constructed wetlands treatment system as the primary treatment mechanism; and
- Three plants are expected to commingle the FGD wastewater with other waste streams (other than ash transport water).

4.5 Comparison of FGD Wastewater Control Technologies

As part of the detailed study, EPA evaluated several treatment technologies or combinations of treatment technologies that plants are using to remove heavy metals and other pollutants from FGD wastewater. Using the data available for these systems, EPA evaluated these systems as potential controls for the treatment of FGD wastewater, as follows:

- **Chemical Precipitation.** Physical/chemical precipitation for heavy metals removal using hydroxide or a combination of hydroxide and sulfide precipitation;

- **Chemical Precipitation + Biological Metals Removal.** Chemical precipitation followed by anoxic/anaerobic biological treatment for removing additional metals and to reduce nitrogen compounds; and

- **Chemical Precipitation/Softening + Evaporation + Crystallization.** Chemical precipitation or softening followed by evaporation in a brine concentrator and crystallization for potential elimination of the FGD wastewater stream.

EPA used information collected throughout the detailed study in evaluating these technologies, including operational and performance information from plants, vendors, and EPA's site visit and sampling programs. Data collected during EPA's sampling program and self-monitoring data obtained from individual plants were used to evaluate the performance of the chemical precipitation and biological treatment technologies. These data show that chemical precipitation is an effective means for removing many metals from the FGD wastewater. Biological treatment, specifically fixed-film anoxic/anaerobic bioreactors when paired with a chemical precipitation pretreatment stage, is very effective at removing additional pollutants such as selenium and nitrogen compounds (e.g., nitrates, nitrites). If operated with a nitrification step, the technology would also be expected to remove ammonia that may be present in the waste stream. Coal-fired power plants have only recently begun to use evaporation/crystallization systems to treat FGD scrubber purge, so EPA was able to collect only limited data for these systems.

Figure 4-12 (A-G) and Figure 4-13 (A-G) present a series of graphs of monitoring data collected in 2008 from the FGD wastewater treatment systems at Duke Energy Carolinas' Belews Creek Steam Station and Progress Energy Carolinas' Roxboro Power Plant, respectively. For each plant, the graphs present the concentrations of arsenic, mercury, selenium, and TDS at the following points in the FGD wastewater treatment systems:

- FGD scrubber purge;
- Intermediate point preceding the biological treatment stage (i.e., settling pond effluent for Roxboro and chemical precipitation effluent for Belews Creek); and
- Effluent from the anoxic/anaerobic biological treatment system.

The Belews Creek FGD wastewater treatment system consists of an equalization tank followed by a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation, ferric chloride for iron co-precipitation, and a clarifier and sand filter for solids removal. After the sand filter, the wastewater is transferred to a fixed-film, anoxic/anaerobic biological treatment system designed to remove metals and nitrogen compounds. Belews Creek operates two stages of the biological reactors in series. After the biological system, the wastewater is transferred to a constructed wetland and then to the ash pond and discharged.

The Roxboro FGD wastewater treatment system consists of a settling pond followed by a fixed-film, anoxic/anaerobic biological treatment system designed to remove metals and nitrogen compounds. The settling pond was designed specifically for FGD wastewater, to reduce the wastewater temperature and TSS prior to the bioreactor. The bioreactor operates with four parallel trains that each has two biological cells in series. Wastewater flows from the bioreactor to the ash pond discharge canal and is discharged.

The Belews Creek and Roxboro graphs show that the chemical precipitation system, the settling pond, and the biological treatment systems are all able to remove arsenic, mercury, and selenium to some extent from the FGD scrubber purge. Figure 4-12 and Figure 4-13 show that the chemical precipitation system at Belews Creek is achieving lower pollutant concentrations of metals than the settling pond at Roxboro. Despite the two plants having relatively comparable levels of mercury, selenium, and arsenic in their scrubber purge stream, the chemical precipitation stage at Belews Creek achieved pollutant concentrations approximately an order of magnitude lower than was observed for the settling pond at Roxboro. In addition, the anoxic/anaerobic biological treatment stage at both plants further reduced the metals in the FGD wastewater. The effectiveness of the biological treatment stage is particularly notable for selenium which, depending on the form of selenium present in the wastewater, usually is not effectively nor consistently removed by settling ponds or chemical precipitation. The bioreactor effluent selenium concentrations at Belews Creek are substantially lower than those observed for Roxboro's bioreactor effluent, presumably due to the chemical precipitation stage providing more effective pretreatment than achieved by the settling pond. Finally, the figures show that TDS is not significantly removed by the settling pond, the chemical precipitation system, or the biological treatment system.

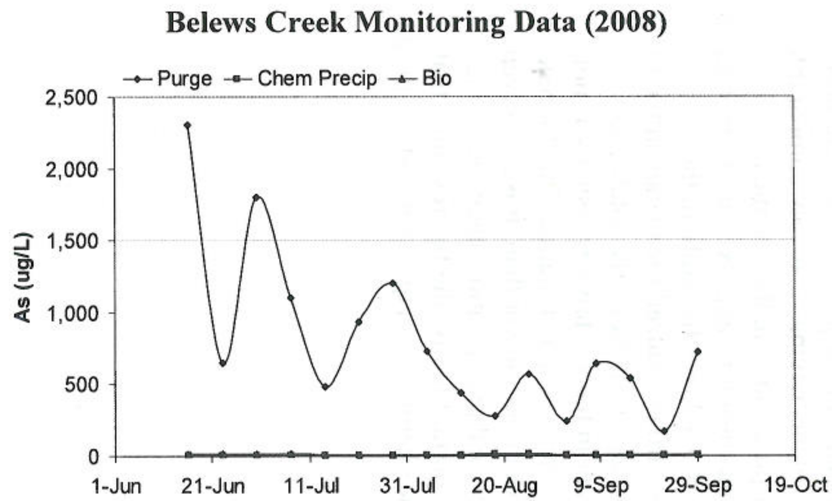


Figure 4-12A. Concentration of Arsenic in FGD Scrubber Purge and Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

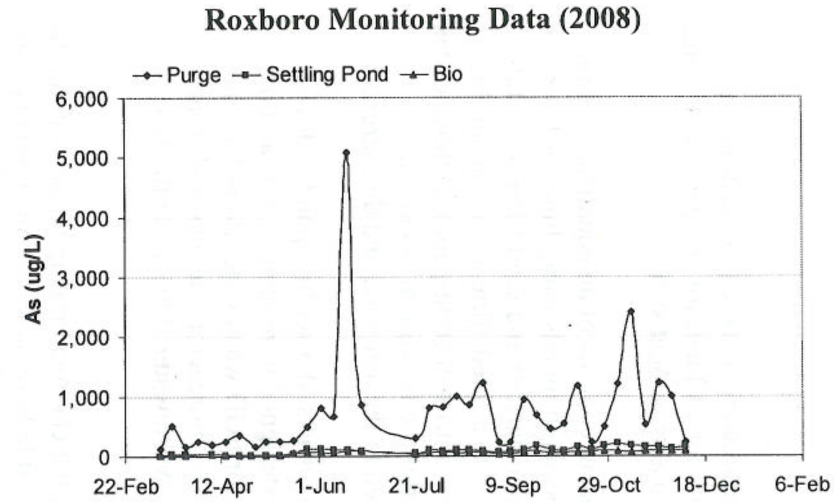


Figure 4-13A. Concentration of Arsenic in FGD Scrubber Purge and Effluent from Settling Pond and Biological Treatment Systems at Roxboro

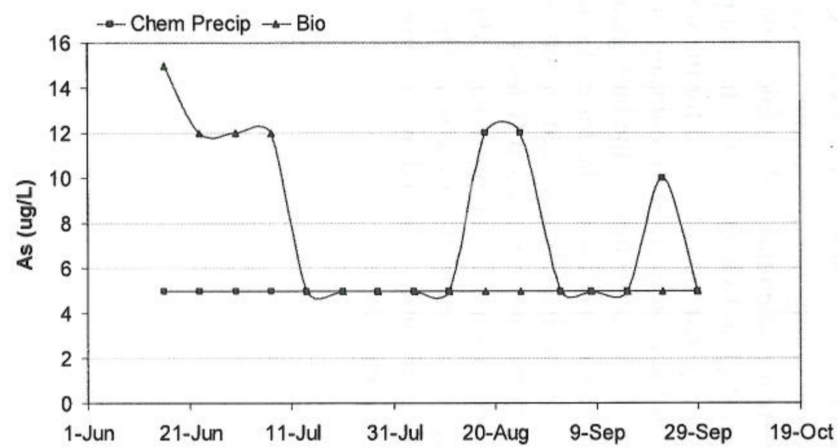


Figure 4-12B. Concentration of Arsenic in Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

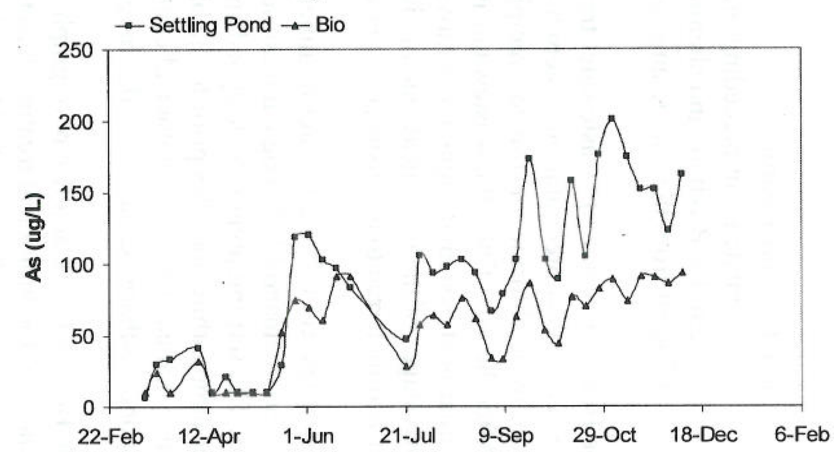


Figure 4-13B. Concentration of Arsenic in Effluent from Settling Pond and Biological Treatment Systems at Roxboro

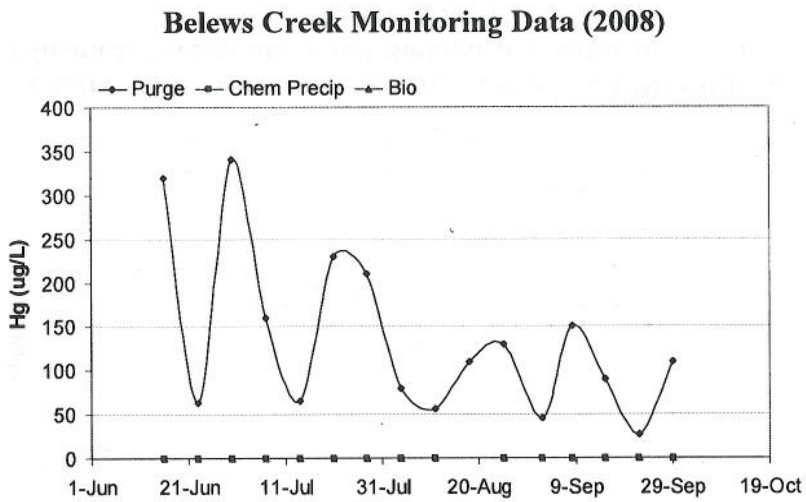


Figure 4-12C. Concentration of Mercury in FGD Scrubber Purge and Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

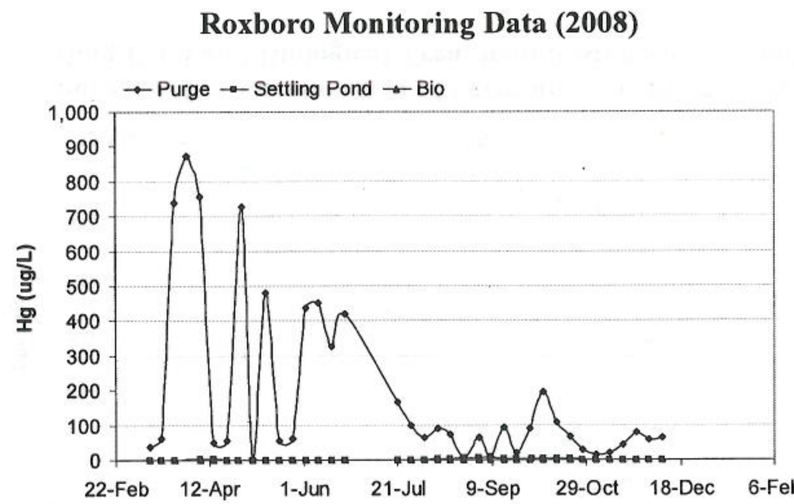


Figure 4-13C. Concentration of Mercury in FGD Scrubber Purge and Effluent from Settling Pond and Biological Treatment Systems at Roxboro

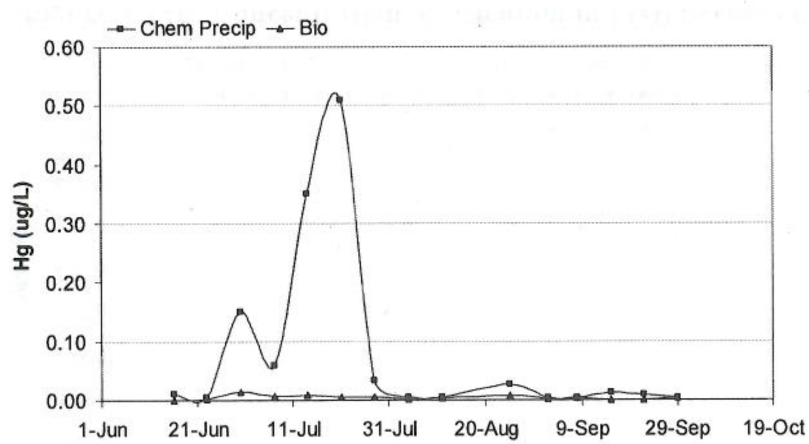


Figure 4-12D. Concentration of Mercury in Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

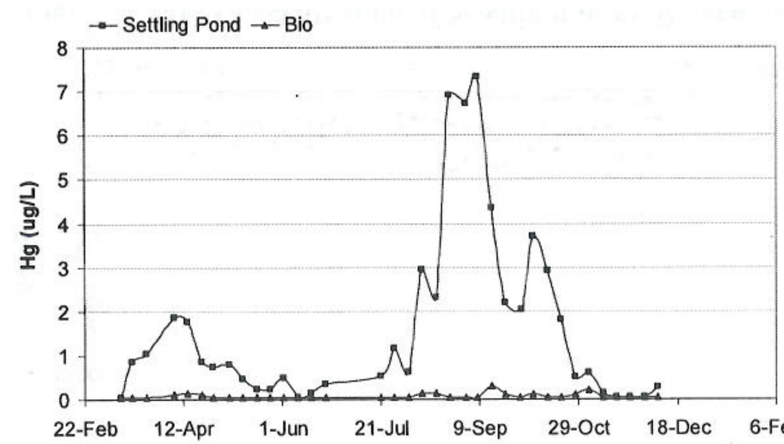


Figure 4-13D. Concentration of Mercury in Effluent from Settling Pond and Biological Treatment Systems at Roxboro

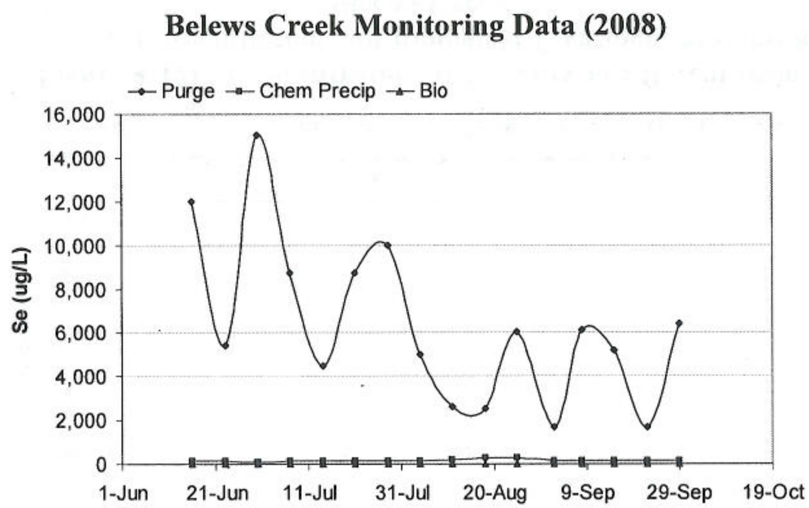


Figure 4-12E. Concentration of Selenium in FGD Scrubber Purge and Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

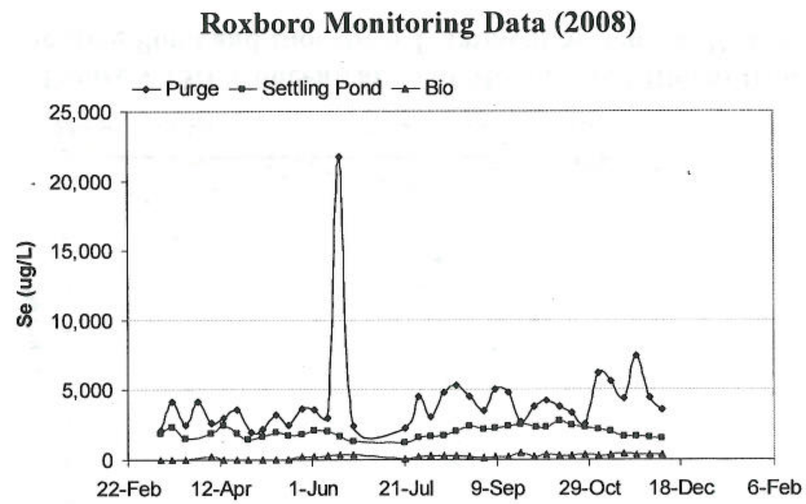


Figure 4-13E. Concentration of Selenium in FGD Scrubber Purge and Effluent from Settling Pond and Biological Treatment Systems at Roxboro

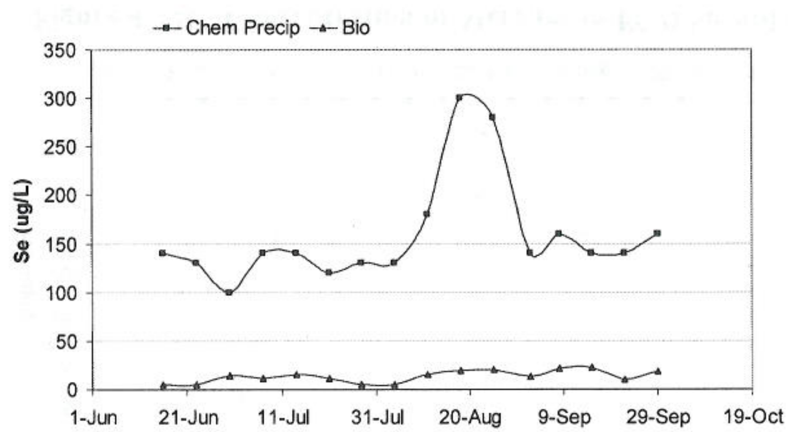


Figure 4-12F. Concentration of Selenium in Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

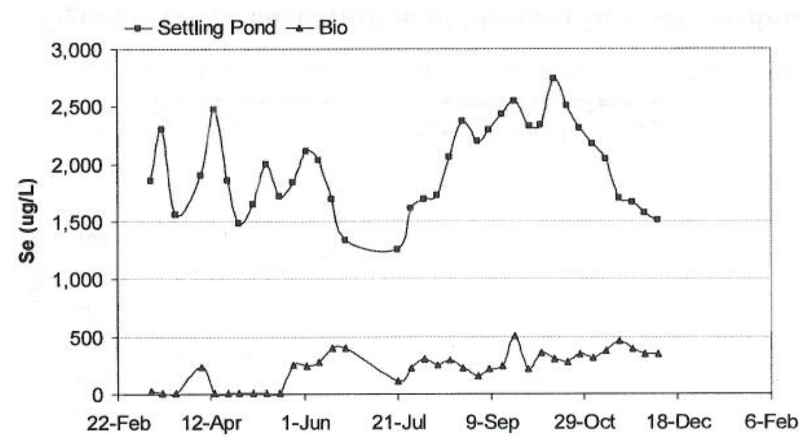


Figure 4-13F. Concentration of Selenium in Effluent from Settling Pond and Biological Treatment Systems at Roxboro

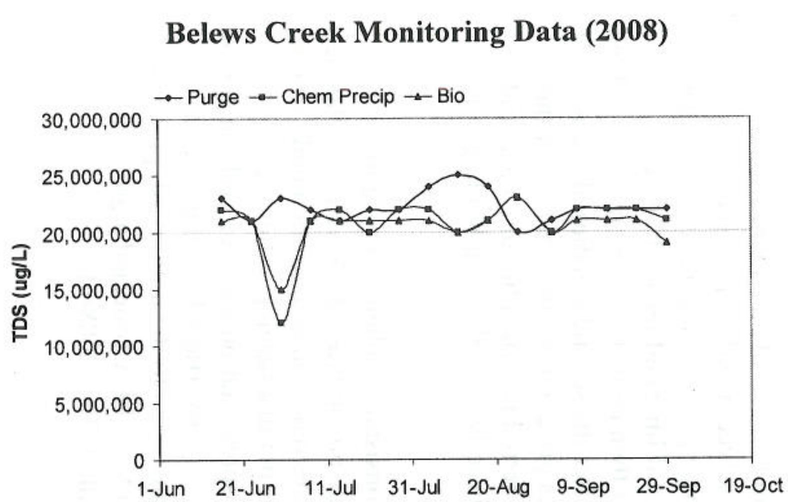


Figure 4-12G. Concentration of TDS in FGD Scrubber Purge and Effluent from Chemical Precipitation and Biological Treatment Systems at Belews Creek

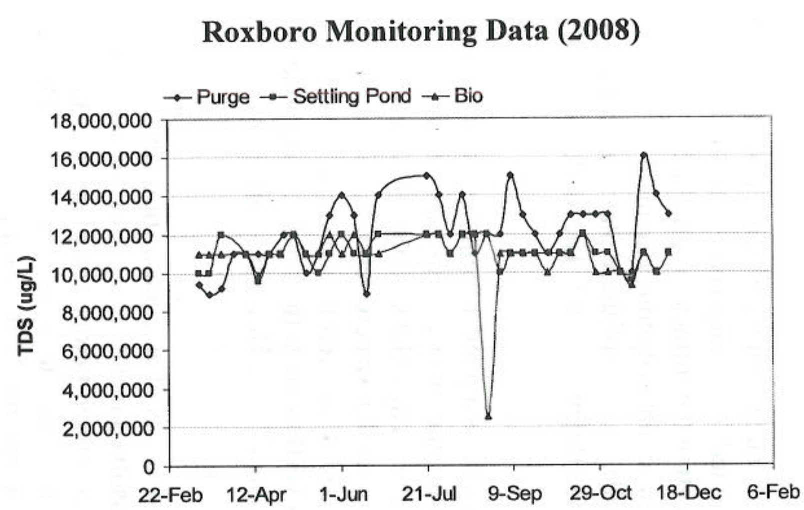


Figure 4-13G. Concentration of TDS in FGD Scrubber Purge and Effluent from Settling Pond and Biological Treatment Systems at Roxboro

Table 4-8 presents the pollutant concentrations associated with the effluent from the FGD wastewater treatment systems for the plants that EPA sampled. For comparison, refer to Table 4-5 in Section 4.3 for the pollutant concentrations representing the influent to the FGD wastewater treatment systems for these plants. Three of these plants operate chemical precipitation systems (Big Bend, Homer City, and Mitchell), and one of these plants operates both chemical precipitation and biological treatment stages (Belews Creek). The Widows Creek plant operates only a settling pond system.

The Widows Creek FGD wastewater treatment system is a pond system that consisted of three settling ponds at the time of sampling; however, during the two site visits prior to the sampling episode, the plant was operating four settling ponds. The FGD scrubber blowdown is pumped to the inlet channels of the pond system, which direct the wastewater to the first FGD settling pond. The overflow from the first FGD settling pond is transferred to a second FGD settling pond and then to a final FGD settling pond. The overflow from the final settling pond is then discharged from the plant. EPA collected a grab sample of the effluent from the third settling pond. [ERG, 2008o].

The Big Bend FGD wastewater treatment system consists of an equalization tank followed by a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation and ferric chloride for coagulation and iron co-precipitation. The plant then adds a flocculating polymer to the wastewater and transfers it to a clarifier to remove the solids. The overflow from the clarifiers is filtered using sand gravity filters, transferred to a final holding tank, and then discharged. EPA collected a grab sample of the effluent downstream of the final holding tank. [ERG, 2008n].

The Homer City FGD wastewater treatment system consists of an equalization tank followed by a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation, ferric chloride for coagulation and iron co-precipitation, and a clarifier for solids removal. The FGD wastewater is sent through a first stage of lime and ferric chloride precipitation followed by a clarifier, and the wastewater is then treated in a second stage of lime and ferric chloride precipitation followed by a clarifier. After the second clarifier, the wastewater is transferred to an aerobic biological treatment system designed to remove BOD. After the aerobic biological system, the wastewater is filtered, transferred to a final holding tank, and discharged. EPA collected a grab sample of the effluent directly from the final holding tank. [ERG, 2008l].

The Mitchell FGD wastewater treatment system consists of a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation followed by a clarifier for solids removal. The overflow from the clarifier is transferred to an equalization tank, where treated effluent is recycled by the plant when the system is not discharging. After the equalization tank, the plant uses ferric chloride for iron co-precipitation and then adds an anionic polymer and transfers the wastewater to a second clarifier. The overflow from the second clarifier is transferred to a final holding tank and either transferred to the bottom ash pond and eventually discharged or recycled back to the equalization tank. EPA collected a grab sample of the effluent from the discharge line of the final holding tank. [ERG, 2008m].

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

Analyte	Method	Unit	Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
			Widows Creek – Effluent from FGD Pond System [a, b]	Big Bend [a, b]	Homer [a, b]	Mitchell [a, b]	Belews Creek [b, c]	Belews Creek [b, d]
Routine Total Metals – 200.7								
Aluminum	200.7	µg/L	111	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Antimony	200.7	µg/L	ND (20.0)	22.1 R	<20.8	ND (20.0)	ND (4.00)	ND (4.00)
Arsenic	200.7	µg/L	49.5	ND (10.0)	ND (10.0)	<10.3	ND (2.00)	ND (2.00)
Barium	200.7	µg/L	179	1,490	71.3 R	433	326	296 R
Beryllium	200.7	µg/L	ND (5.00)	ND (5.00)	7.68	ND (5.00)	ND (1.00)	ND (1.00)
Boron	200.7	µg/L	31,500	369,000	191,000	208,000	291,000	283,000 R
Cadmium	200.7	µg/L	ND (5.00)	24.9	ND (5.00)	ND (5.00)	ND (0.250)	ND (0.250)
Calcium	200.7	µg/L	987,000	4,420,000	2,000,000	2,380,000	5,670,000	5,570,000
Chromium	200.7	µg/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	25.3	24.2 R
Cobalt	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (2.50)	ND (2.50)
Copper	200.7	µg/L	ND (10.0)	<10.3	12.5	16.2	ND (2.50)	ND (2.50)
Iron	200.7	µg/L	ND (100)	ND (100)	<117	318	ND (25.0)	ND (25.0)
Lead	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (1.50)	ND (1.50)
Magnesium	200.7	µg/L	189,000	2,510,000	2,610,000	1,280,000	983,000	950,000
Manganese	200.7	µg/L	623	60.1	30,100	4,440	3,280	2,340 R
Mercury	245.1	µg/L	ND (2.00)	ND (10.0)	ND (10.0)	ND (10.0)	NA	NA
Molybdenum	200.7	µg/L	1,500	450 R	37.6	22.9	NA	NA
Nickel	200.7	µg/L	ND (50.0)	221	ND (50.0)	ND (50.0)	21.1	ND (1.00)
Selenium	200.7	µg/L	236	2,910 R	771	83.6 R	82.5	ND (5.00)
Silver	200.7	µg/L	ND (20.0)	ND (20.0)	ND (20.0)	ND (20.0)	7.90	7.75
Sodium	200.7	µg/L	69,500	1,590,000	1,280,000	305,000	60,300	58,900
Thallium	200.7	µg/L	ND (10.0)	16.8	ND (10.0)	ND (10.0)	62.5	52.7 R
Titanium	200.7	µg/L	ND (10.0)	13.5	ND (10.0)	<10.1	NA	NA
Vanadium	200.7	µg/L	42.1	ND (20.0)	ND (20.0)	ND (20.0)	2.10	ND (0.500)
Yttrium	200.7	µg/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)	NA	NA
Zinc	200.7	µg/L	ND (10.0)	ND (10.0)	ND (10.0)	25.4	ND (25.0)	ND (25.0)

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

			Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
Analyte	Method	Unit	Widows Creek – Effluent from FGD Pond System [a,b]	Big Bend [a,b]	Homer [a,b]	Mitchell [a,b]	Belews Creek [b,c]	Belews Creek [b,d]
Routine Dissolved Metals – 200.7								
Aluminum	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	97.0 L	<78.5 L
Antimony	200.7	µg/L	ND (20.0)	20.8 T	ND (20.0)	ND (20.0)	4.50	ND (4.00)
Arsenic	200.7	µg/L	46.7	10.8 R,T	ND (10.0)	ND (10.0)	6.40 L	8.70 L,R
Barium	200.7	µg/L	191	1,410	70.6 R,T	389	270	271 R
Beryllium	200.7	µg/L	ND (5.00)	ND (5.00)	7.71	ND (5.00)	ND (1.00)	ND (1.00)
Boron	200.7	µg/L	29,200	397,000	184,000	199,000	306,000	284,000 R
Cadmium	200.7	µg/L	ND (5.00)	19.3	ND (5.00)	ND (5.00)	2.30	<0.875
Calcium	200.7	µg/L	932,000	5,210,000	1,930,000	2,270,000	5,790,000	5,760,000
Chromium	200.7	µg/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	ND (0.500)	<10.7 R
Hexavalent Chromium	D1687-92	µg/L	ND (2.00)	ND (2.00)	ND (2.00)	11.0	1.57	ND (0.500)
Cobalt	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (2.50)	ND (2.50)
Copper	200.7	µg/L	ND (10.0)	ND (10.0)	11.8	14.1	ND (2.50)	ND (2.50)
Iron	200.7	µg/L	ND (100)	ND (100)	166 R	ND (100)	ND (25.0)	<27.9
Lead	200.7	µg/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)	ND (1.50)	ND (1.50)
Magnesium	200.7	µg/L	184,000	2,930,000	2,510,000	1,220,000	970,000	938,000
Manganese	200.7	µg/L	543 R	55.6	29,100	4,120	3,240	2,310
Mercury	245.1	µg/L	ND (2.00)	ND (10.0)	ND (10.0)	ND (10.0)	NA	NA
Molybdenum	200.7	µg/L	1,470	430 T	35.8	21.4	NA	NA
Nickel	200.7	µg/L	ND (50.0)	210	ND (50.0)	ND (50.0)	28.2	<2.15
Selenium	200.7	µg/L	226	2,860 R	741 R	71.7	58.7	ND (5.00)
Silver	200.7	µg/L	ND (20.0)	ND (20.0)	ND (20.0)	ND (20.0)	7.70	8.10
Sodium	200.7	µg/L	66,200	1,880,000	1,230,000	300,000	59,300	58,500
Thallium	200.7	µg/L	ND (10.0)	12.5	ND (10.0)	ND (10.0)	105	120 R
Titanium	200.7	µg/L	ND (10.0)	13.7	ND (10.0)	ND (10.0)	NA	NA
Vanadium	200.7	µg/L	40.0	ND (20.0)	ND (20.0)	ND (20.0)	2.50	0.665 R
Yttrium	200.7	µg/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)	NA	NA
Zinc	200.7	µg/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	ND (25.0)	ND (25.0)

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

Analyte	Method	Unit	Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
			Widows Creek – Effluent from FGD Pond System [a, b]	Big Bend [a, b]	Homer [a, b]	Mitchell [a, b]	Belews Creek [b, c]	Belews Creek [b, d]
Routine Total Metals – 200.8								
Aluminum	200.8	µg/L	NA	NA	NA	NA	61.6	67.2 R
Antimony	200.8	µg/L	NA	NA	NA	NA	3.60	0.465
Arsenic	200.8	µg/L	NA	NA	NA	NA	200	194
Arsenic	200.8 – DRC	µg/L	NA	NA	NA	NA	6.94	5.47
Barium	200.8	µg/L	NA	NA	NA	NA	465	466 R
Beryllium	200.8	µg/L	NA	NA	NA	NA	ND (0.300)	ND (0.300)
Boron	200.8	µg/L	NA	NA	NA	NA	260,000	250,000 R
Cadmium	200.8	µg/L	NA	NA	NA	NA	1.77	0.360 R
Calcium	200.8	µg/L	NA	NA	NA	NA	4,920,000	5,030,000
Chromium	200.8	µg/L	NA	NA	NA	NA	13.7	9.25
Chromium	200.8 – DRC	µg/L	NA	NA	NA	NA	0.855	ND (0.500)
Cobalt	200.8	µg/L	NA	NA	NA	NA	17.4	12.1
Copper	200.8	µg/L	NA	NA	NA	NA	2.13	1.08
Iron	200.8	µg/L	NA	NA	NA	NA	173	165
Iron	200.8 – DRC	µg/L	NA	NA	NA	NA	ND (50.0)	66.9
Lead	200.8	µg/L	NA	NA	NA	NA	ND (0.200)	ND (0.200)
Magnesium	200.8	µg/L	NA	NA	NA	NA	973,000	998,000
Manganese	200.8	µg/L	NA	NA	NA	NA	3,110	2,240
Manganese	200.8 – DRC	µg/L	NA	NA	NA	NA	3,330	2,350 R
Nickel	200.8	µg/L	NA	NA	NA	NA	159	102
Nickel	200.8 – DRC	µg/L	NA	NA	NA	NA	72.9	11.5 R
Selenium	200.8	µg/L	NA	NA	NA	NA	1,120	803
Selenium	200.8 – DRC	µg/L	NA	NA	NA	NA	313	159 R
Sodium	200.8	µg/L	NA	NA	NA	NA	48,200	50,000 R
Thallium	200.8	µg/L	NA	NA	NA	NA	7.03	ND (0.0250)
Vanadium	200.8	µg/L	NA	NA	NA	NA	113	154
Vanadium	200.8 – DRC	µg/L	NA	NA	NA	NA	3.67	<1.93

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

Analyte	Method	Unit	Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
			Widows Creek – Effluent from FGD Pond System [a,b]	Big Bend [a,b]	Homer [a,b]	Mitchell [a,b]	Belews Creek [b,c]	Belews Creek [b,d]
Zinc	200.8	µg/L	NA	NA	NA	NA	5.87	5.89
Zinc	200.8 – DRC	µg/L	NA	NA	NA	NA	ND (2.00)	ND (2.00)
Routine Dissolved Metals – 200.8								
Aluminum	200.8	µg/L	NA	NA	NA	NA	51.8	58.7
Antimony	200.8	µg/L	NA	NA	NA	NA	3.69	0.430
Arsenic	200.8	µg/L	NA	NA	NA	NA	194	205
Arsenic	200.8 – DRC	µg/L	NA	NA	NA	NA	8.15	4.15
Barium	200.8	µg/L	NA	NA	NA	NA	457	459
Beryllium	200.8	µg/L	NA	NA	NA	NA	ND (0.300)	ND (0.300)
Boron	200.8	µg/L	NA	NA	NA	NA	261,000	238,000 R
Cadmium	200.8	µg/L	NA	NA	NA	NA	1.66	0.250 R
Calcium	200.8	µg/L	NA	NA	NA	NA	5,050,000	4,730,000
Chromium	200.8	µg/L	NA	NA	NA	NA	13.4	6.93
Chromium	200.8 – DRC	µg/L	NA	NA	NA	NA	0.775	ND (0.500)
Cobalt	200.8	µg/L	NA	NA	NA	NA	17.9	12.2
Copper	200.8	µg/L	NA	NA	NA	NA	2.20	ND (1.00)
Iron	200.8	µg/L	NA	NA	NA	NA	151	138
Iron	200.8 – DRC	µg/L	NA	NA	NA	NA	ND (50.0)	59.7
Lead	200.8	µg/L	NA	NA	NA	NA	ND (0.200)	ND (0.200)
Magnesium	200.8	µg/L	NA	NA	NA	NA	1,010,000	960,000
Manganese	200.8	µg/L	NA	NA	NA	NA	3,080	2,250
Manganese	200.8 – DRC	µg/L	NA	NA	NA	NA	3,140	2,300 R
Nickel	200.8	µg/L	NA	NA	NA	NA	158	104
Nickel	200.8 – DRC	µg/L	NA	NA	NA	NA	74.2	10.9
Selenium	200.8	µg/L	NA	NA	NA	NA	1,110	711
Selenium	200.8 – DRC	µg/L	NA	NA	NA	NA	281	151
Sodium	200.8	µg/L	NA	NA	NA	NA	48,700	47,100 R
Thallium	200.8	µg/L	NA	NA	NA	NA	7.04	ND (0.0250)

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

			Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
Analyte	Method	Unit	Widows Creek – Effluent from FGD Pond System [a, b]	Big Bend [a, b]	Homer [a, b]	Mitchell [a, b]	Belews Creek [b, c]	Belews Creek [b, d]
Vanadium	200.8	µg/L	NA	NA	NA	NA	131	148
Vanadium	200.8 – DRC	µg/L	NA	NA	NA	NA	4.66	ND (1.00)
Zinc	200.8	µg/L	NA	NA	NA	NA	6.23	5.81
Zinc	200.8 – DRC	µg/L	NA	NA	NA	NA	ND (2.00)	ND (2.00)
Low-Level Total Metals - 1631E, 1638, HG-AFS								
Antimony	1638	µg/L	11.8	14.2	ND (0.400)	<1.37	3.75	0.545
Arsenic	1638	µg/L	47.6	68.0	23.0	<25.2	197	202
Arsenic	1638 – DRC	µg/L	NA	NA	NA	NA	4.86	2.51
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	2.27	0.247
Cadmium	1638	µg/L	3.73	25.8	ND (2.00)	ND (3.00)	1.51	0.230
Chromium	1638	µg/L	ND (16.0)	ND (80.0)	ND (16.0)	ND (120)	6.06	5.37
Chromium	1638 – DRC	µg/L	NA	NA	NA	NA	0.610	ND (0.500)
Copper	1638	µg/L	ND (4.00)	ND (20.0)	9.67	ND (30.0)	2.13	ND (1.00)
Lead	1638	µg/L	ND (1.00)	ND (5.00)	ND (1.00)	ND (1.50)	ND (0.200)	ND (0.200)
Mercury	1631E	µg/L	0.0438	0.156	0.117	0.788	0.0765	0.0133
Nickel	1638	µg/L	36.2	381	92.1	<155	113	97.1
Nickel	1638 – DRC	µg/L	NA	NA	NA	NA	54.3	9.00
Selenium	1638	µg/L	208	2,500	613	431 T	616	581
Selenium	1638 – DRC	µg/L	NA	NA	NA	NA	300	191
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	139	4.93
Thallium	1638	µg/L	11.1	31.1	16.0	3.96	8.43	ND (0.0250)
Zinc	1638	µg/L	ND (10.0)	ND (50.0)	15.2	<83.5	6.24	4.87
Zinc	1638 – DRC	µg/L	NA	NA	NA	NA	ND (2.00)	ND (2.00)
Low-Level Dissolved Metals - 1631E, 1636, 1638, HG-AFS								
Antimony	1638	µg/L	11.9	13.7	ND (0.400)	1.64	3.73	0.545
Arsenic	1638	µg/L	46.5	72.4	22.5	20.9 T	196	199
Arsenic	1638 – DRC	µg/L	NA	NA	NA	NA	5.79	2.63
Arsenic	HG-AFS	µg/L	NA	NA	NA	NA	2.12	0.227

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

Analyte	Method	Unit	Settling Pond	Chemical Precipitation				Anoxic/Anaerobic Biological
			Widows Creek – Effluent from FGD Pond System [a, b]	Big Bend [a, b]	Homer [a, b]	Mitchell [a, b]	Belews Creek [b, c]	Belews Creek [b, d]
Cadmium	1638	µg/L	3.74	22.2	ND (2.00)	ND (1.00)	1.53	0.210
Chromium	1638	µg/L	ND (16.0)	ND (80.0)	ND (16.0)	ND (80.0)	6.23	5.16
Chromium	1638 – DRC	µg/L	NA	NA	NA	NA	0.700	ND (0.500)
Hexavalent Chromium	1636	µg/L	3.20	ND (5.00)	ND (2.50)	ND (2.50)	ND (0.500)	ND (0.500)
Copper	1638	µg/L	ND (4.00)	ND (20.0)	9.39	ND (20.0)	1.57	ND (1.00)
Lead	1638	µg/L	ND (1.00)	ND (5.00)	ND (1.00)	ND (0.500)	ND (0.200)	ND (0.200)
Mercury	1631E	µg/L	0.0107	0.0688	0.0542	0.159	0.00804	<0.00168
Nickel	1638	µg/L	33.3 L	396	93.5	102	84.4	96.2
Nickel	1638 – DRC	µg/L	NA	NA	NA	NA	43.8	10.1
Selenium	1638	µg/L	293	2,560	620	407	651	564
Selenium	1638 – DRC	µg/L	NA	NA	NA	NA	305	194
Selenium	HG-AFS	µg/L	NA	NA	NA	NA	137	2.67
Thallium	1638	µg/L	11.0	31.5	15.8	3.99	8.55	ND (0.0250)
Zinc	1638	µg/L	ND (10.0)	ND (50.0)	15.7	ND (50.0)	4.40	4.93
Zinc	1638 – DRC	µg/L	NA	NA	NA	NA	ND (2.00)	ND (2.00)
Classicals								
Ammonia As Nitrogen (NH_3-N)	4500-NH3F	mg/L	0.220	24.1	0.295	3.49	1.80	2.73
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	mg/L	0.0945	NA	36.5 R	25.4	14.0	ND (0.100)
Total Kjeldahl Nitrogen (TKN)	4500-N,C	mg/L	2.51	98.7	3.04	9.74	4.05	5.77
Biochemical Oxygen Demand (BOD)	5210B	mg/L	<10.0	>1,720	ND (120)	<7.50	ND (4.00)	9
Chemical Oxygen Demand (COD)		mg/L	NA	NA	NA	NA	501	451
Chloride	4500-CL-C	mg/L	1,120	22,500	11,800	6,700	9,720	9,960
Hexane Extractable Material (HEM)	1664A	mg/L	ND (5.00)	6.00	ND (5.00)	5.00	ND (5.00)	ND (5.00)
Silica Gel Treated HEM (SGT-HEM)	1664A	mg/L	NA	ND (6.00)	NA	ND (4.00)	ND (5.00)	ND (5.00)
Sulfate	D516-90	mg/L	2,060	1,920	2,790	1,770	1,210	1,240

Table 4-8. Pollutant Concentrations in Sampled Effluent from FGD Wastewater Treatment Systems

			Settling Pond		Chemical Precipitation				Anoxic/Anaerobic Biological
Analyte	Method	Unit	Widows Creek – Effluent from FGD Pond System [a, b]		Big Bend [a, b]	Homer [a, b]	Mitchell [a, b]	Belews Creek [b, c]	Belews Creek [b, d]
Total Dissolved Solids (TDS)	2540 C	mg/L	5,830		40,600	22,600	17,700	34,000	33,800
Total Phosphorus	365.3	mg/L	0.0115	E	0.355	0.520	0.0745	ND (0.100)	ND (0.100)
Total Suspended Solids (TSS)	2540 D	mg/L	8.00	E	31.5	<5.50	17.5	30.0	21.3

Source: [ERG, 2008l; ERG, 2008m; ERG, 2008n; ERG, 2008o; ERG, 2009q].

Note: EPA used several analytical methods to analyze for metals during the sampling program. For the purposes of sampling program, EPA designated some of the analytical methods as "routine" and some of them as "low-level." EPA designated all of the methods that require the use of clean hands/dirty hands sample collection techniques (i.e., EPA Method 1669 sample collection techniques) as "low-level" methods. Note that although not required by the analytical method, EPA used clean hands/dirty hands collection techniques for all low-level and routine metals samples.

a – The FGD effluent results represent the average of the FGD effluent and the duplicate of the FGD effluent analytical measurements.

b – The concentrations presented have been rounded to three significant figures.

c – The FGD chemical precipitation effluent results represent the average of the FGD chemical precipitation effluent day 1 and FGD chemical precipitation effluent day 2 measurements, if the analyte was collected on both days of sample collection.

d – The FGD effluent results represent the average of the FGD effluent day 1, the FGD effluent day 2, and the duplicate of the FGD effluent analytical measurements, if all three measurements were collected for the analyte. Otherwise, it represents the average of the FGD effluent day 1 and the duplicate of the FGD effluent analytical measurements.

< – Average result includes at least one nondetect value (calculation uses the report limit for nondetected results).

> – Result above measurement range.

E – Sample analyzed outside holding time.

L – Sample result between 5x and 10x blank result.

R – MS/MSD % Recovery outside method acceptance criteria.

T – MS/MSD RPD outside method acceptance criteria.

NA – Not analyzed.

ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

The Belews Creek FGD wastewater treatment system consists of an equalization tank, chemical precipitation system, clarifier, anoxic/anaerobic biological treatment system, and constructed wetland[23]. EPA collected grab samples of the effluents from the chemical precipitation and biological treatment stages. [ERG, 2009q].

Table 4-9 through Table 4-11 summarize the monitoring data EPA collected from individual plants/companies representing the effluent from settling ponds, effluent from chemical precipitation systems, and the effluent from anoxic/anaerobic biological treatment systems, respectively. The tables present the number of plants that reported concentration data for the analyte at the given effluent point, the total number of samples at the point for all the plants, and the minimum and maximum concentrations. Because the data included in these tables were provided by individual plants and the plants may monitor different analytes, the data presented in each table do not necessarily contain the same list of analytes [ERG, 2009x].

Table 4-9. Monitoring Data: Pollutant Concentrations in Effluent from Settling Ponds

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Total Metals					
Aluminum	1	37	ND (50)	632	µg/L
Antimony	1	37	ND (2)	36	µg/L
Arsenic	1	37	6.4	201	µg/L
Barium	1	37	37.5	528	µg/L
Beryllium	1	37	ND (0.7)	1.02	µg/L
Boron	1	37	7,950	108,000	µg/L
Cadmium	1	37	ND (0.5)	6.11	µg/L
Chromium	1	37	ND (0.61)	2,110	µg/L
Cobalt	1	37	ND (1.1)	36	µg/L
Copper	1	37	ND (1.6)	44.4	µg/L
Iron	1	37	ND (20)	13,000	µg/L
Lead	1	37	ND (1.9)	ND (220)	µg/L
Manganese	1	37	ND (11)	3,210	µg/L
Mercury	1	36	ND (0.11)	7.32	µg/L
Molybdenum	1	37	ND (0.11)	47	µg/L
Nickel	1	37	11.5	2,190	µg/L
Selenium	1	37	1,180	2,740	µg/L
Silver	1	37	ND (0.2)	30	µg/L
Thallium	1	37	ND (0.2)	102	µg/L
Vanadium	1	37	ND (0.36)	285	µg/L
Zinc	1	37	ND (3.8)	136	µg/L

[23] At the time sampling was conducted, Belews Creek was transferring the effluent from the biological treatment system to the constructed wetland treatment system (CWTS); however, Belews Creek plans to reroute the biological treatment effluent to bypass the CWTS and be transferred directly to the ash pond.

Table 4-9. Monitoring Data: Pollutant Concentrations in Effluent from Settling Ponds

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Classicals					
COD	1	33	120	370	mg/L
TSS	1	36	2.60	53.0	mg/L
TDS	1	36	9,600	12,000	mg/L
Sulfate	1	34	1,100	1,300	mg/L
Chloride	1	36	3,600	5,300	mg/L
Fluoride	1	36	6.30	10.0	mg/L
Nitrate/nitrite	1	1	12.0	12.0	mg/L
Total Kjeldahl nitrogen	1	1	1.20	1.20	mg/L
Total Phosphorus	1	1	ND (0.050)	ND (0.050)	mg/L

Source: [ERG, 2009x].

a – The maximum concentration presented is the maximum detected value in the data set, unless all the results in the data set were not detected for the analyte.

Table 4-10. Monitoring Data: Pollutant Concentrations in Effluent from Chemical Precipitation Systems

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Total Metals					
Aluminum	1	1	183	183	µg/L
Antimony	2	8	3.7	28	µg/L
Arsenic	5	101	1.6	310	µg/L
Barium	1	1	1,520	1,520	µg/L
Beryllium	3	52	ND (0.03)	0.94	µg/L
Boron	2	7	17,000	474,000	µg/L
Cadmium	3	18	0.07	21.9	µg/L
Calcium	1	7	670,000	790,000	µg/L
Chromium	4	48	0.12	69	µg/L
Cobalt	1	1	ND (10)	ND (10)	µg/L
Copper	4	50	1.3	71	µg/L
Iron	3	16	19	6,000	µg/L
Lead	4	47	ND (0.07)	11	µg/L
Magnesium	2	8	ND (3,000)	9,200,000	µg/L
Manganese	2	7	ND (10)	63,000	µg/L
Mercury	5	275	0.0019	61	µg/L
Molybdenum	1	1	63	63	µg/L
Nickel	5	66	4.7	810	µg/L
Selenium	6	398	16	18,000	µg/L
Silver	3	17	0.02	1.64	µg/L
Sodium	2	7	1,000,000	1,700,000	µg/L

Table 4-10. Monitoring Data: Pollutant Concentrations in Effluent from Chemical Precipitation Systems

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Thallium	1	1	ND (10)	ND (10)	µg/L
Tin	1	1	ND (50)	ND (50)	µg/L
Titanium	1	1	ND (50)	ND (50)	µg/L
Vanadium	1	1	ND (10)	ND (10)	µg/L
Zinc	4	35	1.7	15	µg/L
Dissolved Metals					
Antimony	1	6	4	6	µg/L
Arsenic	1	23	ND (2.4)	240	µg/L
Beryllium	1	19	ND (0.19)	0.94	µg/L
Boron	1	4	17,000	22,000	µg/L
Cadmium	1	3	0.74	0.74	µg/L
Calcium	1	5	660,000	710,000	µg/L
Chromium	1	6	12	27	µg/L
Copper	1	6	11	36	µg/L
Iron	1	5	ND (32)	ND (8,800)	µg/L
Lead	1	4	ND (0.6)	5.2	µg/L
Magnesium	1	6	6,200,000	7,400,000	µg/L
Manganese	1	6	42,000	62,000	µg/L
Mercury	1	195	0.032	54	µg/L
Nickel	1	6	170	810	µg/L
Selenium	1	25	62	4,300	µg/L
Silver	1	4	0.61	1.9	µg/L
Sodium	1	5	1,100,000	1,300,000	µg/L
Zinc	1	5	7.7	17	µg/L
Classicals					
TSS	1	10	3.93	33	mg/L
TDS	1	16	12,000	23,000	mg/L
Sulfate	2	9	930	24,000	mg/L
Chloride	2	21	4,700	20,500	mg/L
Bromide	1	4	180	260	mg/L
Fluoride	1	8	0.91	8.60	mg/L
NH_3-N	2	27	2.30	65.6	mg/L
Total Nitrogen, as N	1	30	2.05	165	mg/L
HEM	1	6	ND (5.00)	ND (5.00)	mg/L
n-Hexane	1	29	ND (1.40)	2.70	mg/L

Source: [ERG, 2009x].

a – The maximum concentration presented is the maximum detected value in the data set, unless all the results in the data set were not detected for the analyte.

Table 4-11. Monitoring Data: Pollutant Concentrations in Effluent from Biological Treatment Systems

Analyte	Number of Plants	Number of Samples	Minimum Concentration	Maximum Concentration [a]	Units
Total Metals					
Aluminum	1	37	ND (32)	602	µg/L
Antimony	1	37	ND (2)	92	µg/L
Arsenic	2	53	ND (10)	93	µg/L
Barium	1	37	26.2	2,440	µg/L
Beryllium	1	37	ND (0.7)	1.89	µg/L
Boron	2	38	7,820	666,000	µg/L
Cadmium	1	37	ND (0.5)	3.57	µg/L
Chromium	1	37	ND (1)	4,020	µg/L
Cobalt	1	37	ND (1.1)	241	µg/L
Copper	1	37	ND (1.6)	628	µg/L
Iron	1	37	ND (22)	23,000	µg/L
Lead	1	37	ND (1.9)	291	µg/L
Manganese	1	37	52	3,170	µg/L
Mercury	2	51	ND (0.001)	0.3	µg/L
Molybdenum	1	37	ND (2)	192	µg/L
Nickel	2	53	ND (1.8)	3,770	µg/L
Selenium	2	53	ND (10)	510	µg/L
Silver	1	37	ND (0.2)	36	µg/L
Thallium	1	37	ND (0.36)	97	µg/L
Vanadium	1	37	ND (1)	293	µg/L
Zinc	2	53	ND (1)	432	µg/L
Dissolved Metals					
Selenium	1	16	ND (10)	18	µg/L
Classicals					
COD	1	33	120	380	mg/L
TSS	1	36	1.10	12.0	mg/L
TDS	2	52	2,500	23,000	mg/L
Sulfate	2	39	970	1,300	mg/L
Chloride	1	36	3,800	5,100	mg/L
Fluoride	1	36	5.30	11.0	mg/L
NO_3-N + NO_2-N	1	1	0.056	0.056	mg/L
TKN	1	1	2.70	2.70	mg/L
Total Phosphorus	1	1	0.160	0.160	mg/L

Source: [ERG, 2009x].

a – The maximum concentration presented is the maximum detected value in the data set, unless all the results in the data set were not detected for the analyte.

4.6 FGD Pollutant Loads Estimates

As discussed in Section 4.2, wet FGD systems need to prevent the buildup of certain constituents (e.g., chlorides), which is often accomplished by purging a wastewater stream. Because of the corrosivity of chlorides, plants do not typically reuse the FGD wastewater for other process operations and will typically discharge the FGD purge stream.

EPA used data collected during EPA's sampling program, as well as self-monitoring data obtained from individual plants, to estimate the mass of pollutants (pollutant loads) associated with the FGD scrubber purge (prior to treatment) and the effluent associated with four treatment alternatives: settling ponds; chemical precipitation; biological treatment; and evaporation/crystallization. EPA estimated these loads for two model plant sizes, which are discussed further below. EPA then used these model plant loads to estimate industry-wide total pollutant loads for FGD wastewaters being discharged from the coal-fired steam electric industry. EPA also estimated the pollutant removals that would be achieved by the industry through installing or upgrading existing FGD wastewater controls.

4.6.1 FGD Wastewater Treatment Industry Profile

To estimate FGD wastewater loads for the entire steam electric industry, EPA developed an industry profile and determined the number of coal-fired power plants that currently operate wet or dry scrubbers (as of June 2008), and the number of plants that are planning or projected to install wet or dry scrubbers by 2020.

To generate this industry profile, EPA used EIA data to identify power plants that operate at least one coal-fired electric generating unit. From the available information, EPA identified 488 coal-fired power plants that are currently operating a coal-fired generating unit as well as three additional plants that are either planning or constructing a coal-fired generating unit. For each of these 491 plants, EPA then determined whether the plant currently operates a wet or dry scrubber (as of June 2008) and whether the plant has announced plans or is projected to install a scrubber by 2020. EPA additionally used information from the site visit and sampling program, the data request, and other publicly available information to identify the wastewater treatment systems that the plants operate to treat the FGD wastewater stream. If EPA did not have information to identify the type of FGD wastewater treatment system for the plant, EPA assumed that the plant operates a settling pond, which is the most commonly used FGD wastewater treatment system.

As part of this industry profile and for estimating the pollutant loads, EPA also classified the plants into one of two model plant sizes, "small" or "large," based on the FGD purge flow rate and the necessary treatment system capacity. For those plants for which purge flow rate is unknown, EPA classified the plants based on the total wet scrubbed capacity of the plant (i.e., the total capacity of the electric generating units that are wet scrubbed).

EPA used these model plants to better estimate the loads associated with the industry, by grouping the plants into two different sizes instead of assuming that all plants in the industry are the same size. The data and methodologies used to generate the FGD wastewater treatment industry profile are discussed in detail in the memorandum entitled "Development of the Current and Future Industry Profile for the Steam Electric Detailed Study," dated October 9, 2009 [ERG, 2009s].

For each model plant size, EPA calculated a flow rate to use in the loads calculation for each of the model plants. The memorandum entitled "Technology Option Loads Calculation Analysis for Steam Electric Detailed Study," dated October 9, 2009 [ERG, 2009t], describes in detail the calculation of the model plant flow rates.

4.6.2 Calculation of Loads

EPA used data collected during EPA's sampling program and monitoring data obtained from individual plants to calculate loads associated with the FGD wastewater discharges from coal-fired power plants. EPA calculated these loads to evaluate the effectiveness of the FGD wastewater treatment systems

To calculate pollutant loads associated with the FGD scrubber purge, EPA calculated plant-specific loads to account for differences in the FGD system configurations and operating characteristics at the plants. EPA first calculated the scrubber purge loads on a plant basis using data from the four plants for which EPA had both scrubber purge concentrations and scrubber purge flow rate data available. After calculating the plant-specific loads for each of these plants, EPA calculated an average load for each pollutant and an average flow rate associated with the load for each pollutant. EPA then divided the average pollutant load by the average flow rate to calculate a weighted-average concentration for each pollutant.

To calculate pollutant loads associated with FGD settling pond effluent, EPA used data representing the effluent from a settling pond treating FGD scrubber purge from all the plants for which EPA had available data. For some plants, EPA estimated the settling pond effluent concentrations based on scrubber purge concentrations obtained during EPA's sampling program. The assumptions used to estimate the settling pond effluent concentrations are described in the memorandum entitled "Technology Option Loads Calculation Analysis for Steam Electric Detailed Study," dated October 9, 2009 [ERG, 2009t]. EPA used the settling pond effluent concentration data from all the plants for which data were available to determine an average concentration for each pollutant.

To calculate the effluent pollutant loads for the chemical precipitation and biological treatment technologies, EPA used effluent concentration data from plants that represent these treatment technologies. The effluent data from these plants were used to determine an average concentration for each pollutant. For the evaporation/crystallization treatment technology, EPA assumed the effluent pollutant loads were equal to zero.

After calculating these average pollutant concentrations, EPA multiplied the concentrations by the "small" and "large" model plant flow rates to determine the individual pollutant loads for the FGD scrubber purge, settling pond effluent, and effluent from each of the treatment technologies for both a "small" and a "large" model plant. EPA then multiplied the loads by each pollutant's individual toxic weighting factor (TWF) to calculate the toxic-weighted pound equivalent (TWPE) for each pollutant. Because the TWPE accounts for each pollutant's toxicity, it allows for a relative comparison of the pollutant discharges. Finally, EPA summed the individual pollutant TWPE to calculate the total TWPE for the FGD scrubber purge, settling pond effluent, and effluent from each of the treatment technologies for each model plant size.

Table 4-12 presents EPA's model plant loads, in TWPE per year, for the FGD scrubber purge, settling pond effluent, and effluent from each of the treatment technologies. The memorandum entitled "Technology Option Loads Calculation Analysis for Steam Electric Detailed Study," dated October 9, 2009 [ERG, 2009t], describes the data and methodology used to calculate pollutant loads.

Table 4-12. Treatment Technology Loads by Model Plant Size

Waste Stream/Treatment System	Small Model Plant Loads (TWPE/Year)	Large Model Plant Loads (TWPE/Year)
FGD Scrubber Purge (prior to treatment)	28,400	97,300
Settling Pond	10,900	37,300
Chemical Precipitation	6,410	22,000
Chemical Precipitation + Biological Treatment	2,650	9,080
Chemical Precipitation + Evaporation	0	0

Source: [ERG, 2009t].

4.6.3 Industry Baseline and Treatment Technology Loads

EPA used the FGD wastewater treatment industry profile information (see Section 4.6.1) and the model plant treatment technology loads (see Section 4.6.2) to estimate the FGD discharge loads associated with the steam electric industry. EPA calculated the loads for the "current" industry, based on the status of FGD operations as of June 2008, and the "future" industry, based on projections of FGD operations in 2020. EPA estimated the baseline loads for the industry by multiplying the model plant loads for each treatment scenario by the number of small and large plants operating that treatment system. If EPA lacked treatment information for a plant, EPA assumed the plant currently operates or will operate a settling pond treatment system.

Based on information in EPA's combined data set, 108 plants are currently operating wet FGD systems and EPA estimates that 77 of these plants discharge FGD wastewater. EPA also estimates that more than 192 plants will be operating wet FGD scrubbers by 2020 and that 158 of these plants will discharge FGD wastewater.[24]

EPA estimated the industry loads for the FGD scrubber purge, settling pond effluent, and the three control technologies by multiplying the model plant loads by the number of plants operating that treatment system. EPA then summed the resulting "small" and "large" model plant TWPE to determine the total TWPE for each scenario. EPA calculated the baseline loads by summing the total TWPE for the settling pond and three treatment technologies.

EPA also calculated industry-level loads that would result from plants installing or upgrading to a particular level of treatment technology (i.e., the industry-level chemical precipitation loads assume that all plants operating a settling pond will install a chemical precipitation system and all other plants will continue operating with their current system). Figure 4-14 presents a comparison of the total baseline industry effluent loads to the effluent loads estimated for each of the different scenarios.

[24] As discussed in section 4.1.2, EPA's projections for new FGD systems do not include the systems that will be installed at new generating units or new plants. Thus, the projections for 2020 are considered to under-estimate the actual number of FGD systems that will be installed.

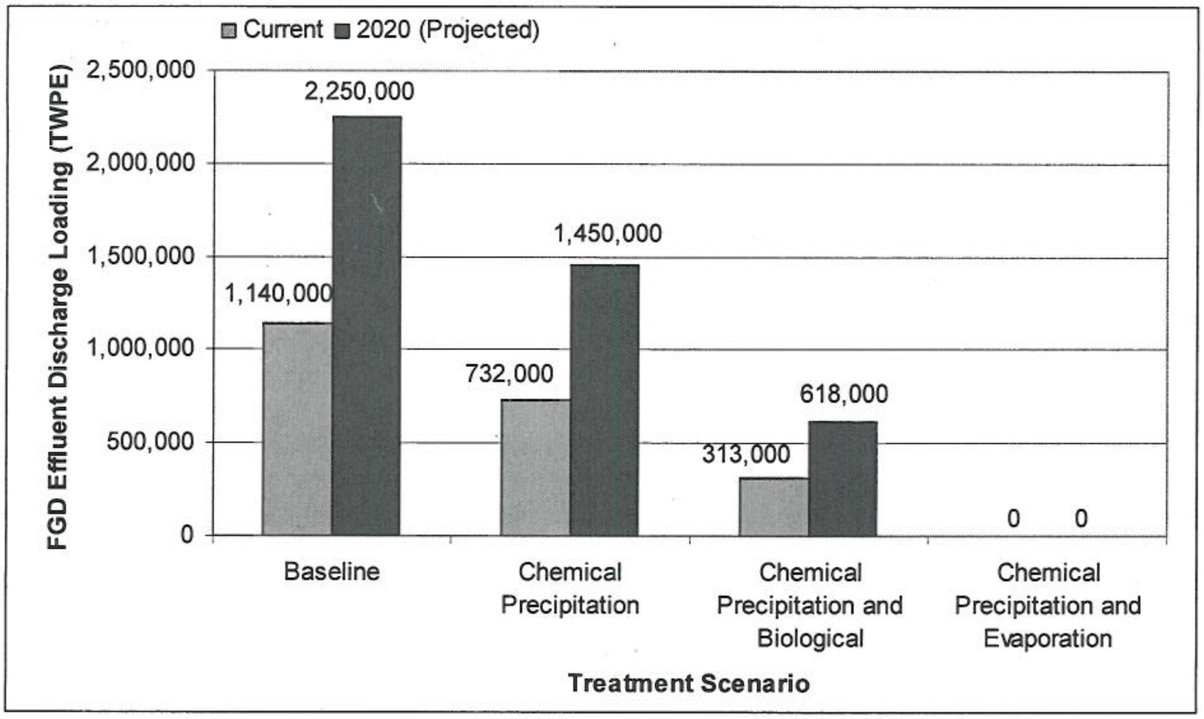


Figure 4-14. Estimated Industry-Level FGD Effluent Discharge Loadings By Treatment Scenario