

# **Preliminary Results from a WFGD Effluent Characterization Study and their Impact on Scrubber Operations and Waste Water Treatment**

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## **ABSTRACT**

The USEPA, along with industry groups, Utility Water Act Group (UWAG) and the Electric Power Research Institute (EPRI) are currently conducting waste water studies at designated coal-fired power plants to determine if effluent guidelines should be revised.<sup>1</sup> Much of their interest is focused on the impact from air pollution control (APC) equipment on water quality and specifically from wet flue gas desulphurization (WFGD) systems or wet scrubbers. In parallel to these studies, Siemens Environmental Systems & Services (SESS) launched a similar program to study effluent water quality from SESS wet scrubbers. The following proceedings paper will present preliminary results from the study. Characterization of these waters will be discussed, including elements that are of regulatory interest, such as mercury, selenium, arsenic, and boron, as well as other water quality parameters, such as organics, chlorides, and suspended solids. The data will serve as a basis to direct future SESS studies and help to develop balanced solutions for scrubber operators to maintain optimum air pollutant removal performance while minimizing the impact to waste water treatment (WWT) and overall plant water quality.

## **INTRODUCTION**

The USEPA is studying effluent waters from coal-fired power plants to determine if overall plant effluent guidelines should be revised. To support their objective, the EPA is sampling and analyzing process water streams from APC equipment and ash handling systems. Their goal is to quantify the individual contribution on plant discharge water quality. Their program includes quantifying quality parameters in the water that are inherent to the operation of various APC equipment, such as ammonia from selective catalytic reduction (SCR) systems and TSS from wet scrubbers. Most of their focus is on studying the elements of regulatory significance such as mercury, selenium, boron, and arsenic, which are released from the coal during combustion and subsequently captured and entrained in the plant effluent water.

EPRI is also studying issues related to the impact that wet scrubbers and SCR systems have on plant water quality. EPRI's program<sup>2</sup> involves a number of different studies, ranging from the fate of specific elements (e.g., mercury, selenium, arsenic, and boron) in WFGD wastewater and solids, the speciation of these elements, their impact on health, to

plant WWT strategies, and improved sampling and analytical techniques for future effluent studies.

In response to this changing regulatory climate, SESS launched its own study in the spring of 2008. The SESS study is designed to characterize WFGD effluent from a number of current SESS wet scrubbers. The study's initial goal is to simply serve as a detailed and current survey of effluent discharged from wet scrubbers under normal operating conditions. The data generated will be analyzed to identify data trends based on coal quality, APC equipment, plant operations, and scrubber chemistry, which will help guide and shape future work. These initial findings will begin to construct a base of information which will allow Siemens to develop total plant solutions for its customers. Solutions comprised of integrated and cost-effective, scrubber and WWT strategies which combine the water expertise of Siemens Water Technologies (SWT) with the scrubber expertise of SESS. As the study evolves, it is anticipated that other benefits will be realized as well, including expertise to work with EPC firms in developing sound and attainable commercial scrubber discharge ranges and generation of a steady stream of current effluent data to help solve challenging WFGD operational issues such as foaming.

## **Methodology**

By design, many WFGD systems require periodic discharge of the scrubber liquor to maintain proper operating conditions. The discharge (or effluent) is typically a dilute slurry with less than 5% TSS. It is a cocktail comprised of varying levels of gypsum, solids, metals, chlorides, and some organics. The effluent is generally bled from the scrubber when solids and/or chlorides reach a specified target level. The effluent is eventually processed through a secondary hydroclone, where gypsum and fine solids are separated. The underflow of the secondary hydroclone is re-circulated back to the scrubber whereas the overflow is sent to a purge or equalization tank, where it is mixed continuously, waiting to be eventually sent to a waste water treatment system.

The sampling location selected for this initial phase of the study is either the secondary hydroclone overflow or purge/equalization tank. Since the objective of the SESS study is to develop a base of information, this first round of sampling examines only feed to the WWT. It is specific to the effluent from the scrubber only. Other points in the process stream (e.g. effluent from WWT) will be included in the future as the scope of study expands.

Approximately 8 to 10 SESS wet scrubbers are identified for participation in the study. The scrubbers selected are based on differences in plant and scrubber operations, coals, and associated air pollution control equipment which will provide a range of wet scrubber effluent profiles.

The SESS study is outlined in detail in a comprehensive sampling and analytical plan which was drafted at beginning of the project. It serves as the guidance document, establishing consistency in the methodology across different plants and over time. It serves as a basis for ensuring that clean and representative samples are collected for analysis. The plan includes the following sections; detailed instructions for on-site

sampling, steps for safe sample handling, filtration of effluent for the dissolved elements analysis, preservation of samples, analytical methods, shipping instructions, and copies of working documents (e.g. chain of custody forms, plant questionnaires). The plan is distributed to the host plant prior to a sampling program. Plant personnel review and are encouraged to make any necessary site specific modifications.

Although it is anticipated that some of the analyte concentrations will be in the thousands of ppm, a “clean hands-dirty hands” based sampling approach<sup>3</sup> is being followed. The approach is more common to sampling “clean” water bodies such as lakes and streams in which analytes are typically present in low ppb and ppt concentrations. And although the “clean hands-dirty hands” sampling methodology is more rigorous procedurally than simple grab sampling, it provides an additional layer of insurance to minimize contamination during sample collection, filtration, sample handling, and shipment to the laboratory.

The sampling and analytical details are listed in Table 1. These are chosen with respect to a number of factors, including the current understanding of WFGD effluent, elements of regulatory interest, parameters important to WWT, and anticipated contribution from process streams such as coal, limestone, feed water and plant chemicals.

**Table 1.** Sampling and Analytical – WFGD Effluent

<b>Parameter</b>	<b>Bottle Type</b>	<b>Preservation</b>	<b>Holding Time</b>	<b>Analytical Method</b>
pH, Temperature	Plastic	No	On site.	Meter
BOD <sub>5</sub>	Plastic	No	48 hours	SM 5210B
TSS, TDS,	Plastic	No	14 days	EPA 160.2, EPA 160.1,  EPA 300.0
Alkalinity, Carbonate, Bicarbonate	Plastic	No	14 days	EPA 310.1
COD	Plastic	H <sub>2</sub> SO <sub>4</sub> to a pH of < 2.	28 days	EPA 410.4
TOC	Plastic	H <sub>2</sub> SO <sub>4</sub> to a pH of < 2.	28 days	EPA 415.1
NH <sub>3</sub> (N), TKN	Plastic	H <sub>2</sub> SO <sub>4</sub> to a pH of < 2.	28 days	EPA 350.1, EPA 351.2
Cl <sup>-</sup> , F <sup>-</sup> , Br <sup>-</sup> , NO <sub>3</sub> <sup>-</sup> , NO <sub>2</sub> , SO <sub>4</sub> <sup>2-</sup>	Plastic	No	48 hours	EPA 300.0A

Dissolved Elements  (Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, P, Ni, Se, Ag, Sr, Na, Tl, Sn, Ti, V, Zn)	Plastic	Filter in the field through 0.45µm filter.  HNO <sub>3</sub> to a pH of < 2.	6 months	EPA 200.7 and EPA 200.8
Dissolved Hg	Glass	Filter in field through 0.45µm filter.  HCl to a pH of < 2.	28 days	EPA 7470 and EPA 1631E

As detailed in Table 1, the analyte list includes classicals, nutrients, ions, and dissolved elements. Note that total elements are not included as part of the suite of analyses since only scrubber effluent (feed to WWT) is sampled. It is assumed that much of the elements associated with the solids are removed in the initial steps of WWT. Therefore it was decided not to include total elements analysis because this sample stream would provide little useful information. Operationally defined, dissolved elements represent what remains in the liquor phase after solids removal. Dissolved elements require field filtration through a 0.45µm filter.

In the SESS study, a safe and clean, field-ready approach is used for filtering the effluent for dissolved elements. The scrubber effluent is initially collected in 1-gallon, acid cleaned polypropylene vessels. The vessels are then capped and allowed to stand for a period of approximately one hour to allow settling of the bulk of the solids. Samples are then filtered using a transportable positive filtration unit which employs acid cleaned pump tubing and “one-use” 0.45 µm clean-rated capsule filters. The settled effluent is filtered directly into the respective sample bottles.

During the filtration, the “clean hands” individual is restricted to handling only the sample bottles and none of the sampling equipment and supplies which potentially could be contaminated from the surroundings. The “dirty hands” person is tasked with handling the equipment and materials.

The host plant’s laboratory is used to conduct the filtrations providing a moderately clean and isolated area. Clean, non-metallic, and disposable supplies are used as much as possible. All other equipment and supplies requiring re-use are thoroughly acid washed and rinsed with copious amounts of ultra clean DI water before and after use.

The sample bottles are shipped directly to the site in a protective cooler from the analytical laboratory. The bottles are pre-cleaned in the analytical laboratory and double bagged, prior to shipment. The shipment includes a chain of custody and gel bags for safe and cold shipment for return to the laboratory from the field. The bottles include

both plastic and glass and some contain preservative depending on the analysis (see Table 1.) The preservative is added in the laboratory prior to shipment and after cleaning.

Samples collected during this initial phase of the SESS study will be analyzed for dissolved elements using USEPA Method 200.7 which utilizes Inductively Coupled Plasma Spectroscopy. It is not as sensitive, as EPA method 200.8, which uses Inductively Coupled Plasma Mass Spectroscopy, however 200.7 is rugged enough to handle the WFGD effluent samples, which contain high amounts of TDS, while providing sufficient sensitivity to quantify most of the requested elements down to single digit ppb levels.

Dissolved mercury will be determined using two different methods, USEPA SW-846 7470 and EPA 1631E, to see if there are analytical advantages to using EPA 1631E for this application. Method 7470 is a cold vapor atomic absorption (CVAA) based method and commonly used for detection of ppb and ppm levels of Hg. Method 7470 and similar CVAA methods have been extensively used since the 1990's to analyze samples for mercury. Still today, CVAA based methods are readily used because they are proven and most laboratories have extensive experience with them. Conversely, EPA Method 1631E is relatively newer in comparison and is more commonly associated with analyzing simple water samples with low (ppt) mercury concentrations. 1631E is an extremely robust method and is the method of choice at most specialty metals laboratories for analyzing complex matrices, even containing ppb and ppm levels of mercury. It delivers accurate and precise results without sacrificing any significant sensitivity, even on difficult samples. CVAA based methods can suffer analytical interferences from some of the analytes present in scrubber effluent, especially at the concentrations present. Thus it is possible that some of the effluent samples collected during the study could present analytical problems. EPA Method 1631E uses cold vapor atomic fluorescence (CVAF). Atomic fluorescence is known to have fewer interferences, offer better accuracy, tighter precision, lower detection, and improved linearity versus atomic absorption. However, CVAF is slightly more expensive, less routine, and analytically more challenging. Its application is growing in popularity, however CVAA based methods are still readily used at most environmental laboratories.

The SESS scrubber effluent sampling and analytical program is fortified with a rigorous QA/QC plan. Field blanks are collected and analyzed routinely. They are comprised of ultra-pure, certified DI water, subjected to any and all of the sampling and filtration steps. The field blanks help to assess any potential sample contamination from the sampling procedure and sampling supplies. Samples are analyzed under USEPA Level 3 QA/QC protocol which specifies additional QA/QC samples to be included with the routine samples and field blanks. These are included to thoroughly assess accuracy, precision, sensitivity, and contamination. The QA/QC samples include method blanks, matrix spikes, matrix spike duplicates, sample duplicates, certified reference materials, laboratory check samples, independent calibration verification samples, continuing calibration verification and blank samples. Sample results are reported in a standard laboratory report package with all supporting QA/QC results included.

During each sampling program, a representative feed coal sample is collected to provide some relative contribution of the elements from the coal. The coal is analyzed for ultimate and proximate parameters, plus major ash elements, and trace elements. See Table 2 for details. In addition, a questionnaire is submitted to each plant soliciting important process and operational information. Combined, the coal data and plant questionnaires will provide supporting data and information which will be used in the interpretation of the scrubber effluent data.

**Table 2.** Analytical - Coal

<b>Parameter</b>	<b>Units</b>	<b>Method</b>
<b>Proximate</b>		
Moisture	% - as received	D 2961
Ash	% - dry	D 3174
Volatile Matter	% - dry	D 3175
Fixed Carbon	% - dry	D 3172
<b>Ultimate</b>		
C, H, N	% - dry	D 5373
S	% - dry	D 4239-02
Oxygen	% - dry	D 3176
Ash	% - dry	D 3174
BTU	BTU/lb – dry	D 5865
FSI		D 720-91
Cl	mg/kg – dry	D 4208 / SW-846 9056
<b>Major Ash Elements</b>		
Na <sub>2</sub> O, Al <sub>2</sub> O <sub>3</sub> , SiO <sub>2</sub> , P <sub>2</sub> O <sub>5</sub> , SO <sub>3</sub> , K <sub>2</sub> O, CaO, TiO <sub>2</sub> , Fe <sub>2</sub> O <sub>3</sub> , MnO <sub>2</sub> , MgO, SrO, BaO,	%	D 6349
<b>Trace Elements</b>		
Be, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, V, Zn, Li, Mo, Sn, Tl, Ag	mg/kg – dry	D 6357
As, Se	mg/kg – dry	D 4606/ D 6357
B	mg/kg – dry	D 6357 modified
Hg	mg/kg – dry	D 6722
F	mg/kg – dry	D 3761/SM 4500

## Results

To date, four SESS scrubbers have been sampled, samples analyzed, and results were collected. All associated effluent, coal, and plant questionnaire data were collected. Table 3 includes the wet scrubber effluent data.

Two additional programs were recently completed in July and are awaiting analytical results. Two more test programs are tentatively scheduled for completion in the upcoming months.

**Table 3. WFGD Effluent Data**

		<b>Plant A</b>	<b>Plant B</b>	<b>Plant C</b>	<b>Plant D</b>
<b>Parameter</b>	<b>Units</b>	<b>Result</b>	<b>Result</b>	<b>Result</b>	<b>Result</b>
pH	s.u.	5.47	7.13	6.63	6.75
Temperature	°C	42.5	32 (2 hrs later)	30.3 (2 hrs. later)	37.3 (2hrs. later)
BOD <sub>5</sub>	mg/L	2,310	< 2.0	< 2.0	1,770
TSS	mg/L	89,800	12,700	136,000	33,200
TDS	mg/L	65,300	17,100	8,190	18,400
Cl <sup>-</sup>	mg/L	37,000	4,730	1,370	4,490
Alkalinity	mg/L	752	236	100	3,000
Carbonate	mg/L	< 2.17	< 5.0	< 5.0	< 5.0
Bicarbonate	mg/L	752	236	100	3,000
COD	mg/L	4,380	2,460	1,070	6,660
TOC	mg/L	1,650	299	6.42	44.9
NH <sub>3</sub> (N)	mg/L	18.1	4.42	< 0.10	< 0.10
TKN	mg/L	48.4	21.8	< 0.20	9.91
F <sup>-</sup>	mg/L	18.1	30.9	15.3	20.6
Br <sup>-</sup>	mg/L	191	41.6	6.59	37.9
NO <sub>3</sub> <sup>-</sup>	mg/L	16	73.4	57.4	0.495
NO <sub>2</sub>	mg/L	< 0.125	< 2.50	< 0.4	< 5.0
SO <sub>4</sub> <sup>2-</sup>	mg/L	1,160	3,920	3,490	2,320
<b>Dissolved metals</b>					
Al	ug/L	882	379	191	255
Sb	ug/L	59.9	24.2	5.8	15.7
As	ug/L	520	69.2	20.1	81.1
Ba	ug/L	2,730	90.6	180	37.6
Be	ug/L	< 1.98	< 20.0	< 0.281	< 20.0
B	ug/L	692,000	288,000	222,000	36,800
Cd	ug/L	406	153	119	2.41
Ca	ug/L	8,820,000	1,010,000	742,000	41,700
Cr	ug/L	38.6	2.94	166	5.79
Co	ug/L	190	98.6	< 20.0	< 50.0
Cu	ug/L	45	< 50.0	< 20.0	46.4
Fe	ug/L	< 188	101	< 200	68.8
Pb	ug/L	< 28.4	14.8	< 10.0	12.9
Mg	ug/L	5,230,000	2,410,000	1,130,000	345,000
Mn	ug/L	36,800	27,200	< 20.0	< 50.0
Mo	ug/L	276	663	12.8	895
P	ug/L	204	153	18.9	84.3
Ni	ug/L	1,920	624	313	41.1

<b>Se</b>	ug/L	3,870	1,210	1,290	2,530
<b>Ag</b>	ug/L	< 13.4	< 50.0	< 20.0	< 50.0
<b>Sr</b>	ug/L	37,400	6,320	5,000	71.9
<b>Na</b>	ug/L	2,700,000	181,000	77,500	98,800
<b>Tl</b>	ug/L	< 86.1	< 50.0	< 20.0	< 50.0
<b>Sn</b>	ug/L	< 25.6	< 25.0	< 25.0	< 25.0
<b>Ti</b>	ug/L	< 9.24	< 500	< 200	5.13
<b>V</b>	ug/L	163	148	5.42	357
<b>Zn</b>	ug/L	5,460	483	2,590	12.5
<b>Hg (CVAA)</b>	ug/L	0.11	< 1.0	210	3.46
<b>Hg (CVAFS)</b>	ug/L	0.54	0.058	195	0.468

## Discussion

### *Selenium*

The effectiveness of WWT systems on removing selenium is highly dependent on the species of selenium present. Three of the four wet scrubbers sampled in this program are limestone force oxidation (LSFO) scrubbers. The oxidation process converts sulfite to sulfate but it also will oxidize selenium from selenite to selenate. Selenite is easier to remove than selenate and can be removed through iron precipitation in the WWT, whereas, selenate can not be removed by such a conventional process. Selenate must be either reduced to selenite or elemental selenium<sup>2</sup> to be removed by iron precipitation or another approach must be employed.

One treatment, the ABMet® process, has demonstrated success in effectively removing selenium from WWT streams. It is a biological based treatment. Although it has demonstrated effective performance in removing selenium, it is challenging to keep the process active, due to varying nature of scrubber effluent and organic content composition. As such, this process is not widely employed as few plants have selenium discharge limits that would require this type of treatment, but it remains a viable option.<sup>4</sup> The ABMet® process can treat WFGD effluent with a selenium concentration of up to 10 ppm and reduce it to 25 ppb.<sup>5</sup>

In the four scrubbers sampled by SESS, selenium was determined to be in the 1 to 4 ppm (mg/L) range. Plant A had the highest concentration at 3.9 ppm. All four plants had similar selenium concentrations in the coal at of 2 – 3 ppm (mg/kg). Plant A did report the use of dibasic acid in their wet scrubber for enhanced SO<sub>2</sub> removal. Dibasic acid can affect the speciation of selenium<sup>6</sup>.

For the initial phase of this study it was determined to delay any selenium speciation analysis until more is known about the speciation methodology. For example, EPRI is currently conducting studies investigating issues related to speciation analysis<sup>2</sup>. As a result only total selenium concentration is determined.

### *Arsenic*

Arsenic concentrations in the wet scrubber effluent ranged from approximately 20 up to 500 ppb for the four scrubbers. However, only one (Plant A) of the four scrubbers contained a scrubber effluent greater than 100 ppb.

### *Mercury*

It has been suggested that plant discharge mercury limits will be lowered to ppt levels. This is significant considering no commercial treatment technology can currently reduce mercury to these low levels.<sup>2</sup> Furthermore, mercury is difficult to treat in WWT streams with high concentrations of chlorides present and generally requires a sulfide based chelating agent.<sup>4</sup> Chloride concentrations in excess of 10,000 ppm are common to WFGD effluent.

Dissolved mercury ranged from approximately 50 ppt up to about 1-3 ppb for three of the four SESS scrubbers. However, for one of the scrubbers (Plant C), the mercury concentration was significantly higher at approximately 200 ppb. The reason for the significant difference is undetermined. It is possible that this was an outlier due to a problem in the sampling or analysis. However, QA/QC samples did not reveal any contamination or measurement issues.

Plant C also had the lowest chloride concentration. The low concentration of chloride (1,370 ppm) suggests that the scrubber effluent is being turned over routinely (i.e. more open water balance) not allowing analytes (e.g. mercury) to concentrate, however Plant C scrubber effluent is about 200 times greater in mercury than the other plants (A, B, and D). Possibly the high mercury concentration is related to mercury adsorbed to ultra fine solids suspended in the sample. Plant C did contain the highest level of TSS (136,000 ppm) of all four plants but most of the TSS should have been removed by field filtration through the 0.45 $\mu$ m filter. Plant C did burn a coal that contained approximately 200 ppb (mg/kg) mercury, which is twice the concentration of mercury in coals burned at Plants A, B, and D. It is unclear that this alone could account for the difference. It is not unreasonable to think that Plant C flue gas is comprised of a larger portion of oxidized mercury entering and being captured in the wet scrubber but again it is highly speculative that this alone could account for the significant difference in concentration. It does suggest that mercury behavior and concentration in scrubber effluent is difficult to estimate and depends on many factors, such as mercury speciation and fine solids that are present. As such, it is recommended to measure mercury in all cases and not to rely simply on engineering estimates.

As expected, the analytical methods comparison did identify some potential concerns with using Method 7470 for this application. For Plant A, the result determined by Method 1631E was approximately 5 times higher than Method 7470. The method 7470 matrix spike and matrix spike duplicate recovery for Plant A was significantly low (~40%) which indicates matrix interference and a recovery problem. Method 1631E spike recoveries for Plant A were within acceptable recovery limits (80 – 120%) thus providing more confidence in the 1631E results. For Plant C, the two methods did show good agreement at 7.4% relative percent difference (RPD), although the concentration of mercury in the Plant C sample was 200 ppb, which is a concentration easily quantified by

both methods. For Plant B, Method 7470 could not quantify the result below 1 ppb and for Plant D, the two analytical methods differed significantly by a factor of 10. The reason for the difference for Plant D has not been identified. The QA/QC for Plant D was within acceptable limits for both methods which suggest some other reason than analytical. One possible difference for the Plant D sample could be attributed to the field filtration, however this is only speculative.

### ***Boron***

Boron is a difficult element to remove and requires WWT processes such as evaporation, ion exchange, and reverse osmosis. All of these are costly and prone to scaling. In addition, boron is one of a number of elements of increasing regulatory interest.<sup>2</sup>

For three of the SESS scrubbers (Plants A, B, C), boron ranged from approximately 200 to 600 ppm. Plant D was much lower at about 36 ppm. During internal communications with SWT, they indicated there is limited data on boron because it is seldom included on WWT specifications. Their in-house data contained only a handful of data points ranging from approximately 4 to 600 ppm.

### ***Plant Operations and Other Observations***

Plant A had generally the highest concentration for most of the analytes, but operationally the plant water cycle is significantly more of a closed loop than the other plants which over time would concentrate the analytes.

Plant D is a lime, natural oxidation wet scrubber and operates at a higher pH level than much different than Plants A, B, C which are more conventional LSFO wet scrubbers. However, even with the different scrubber chemistry, the wet scrubber effluent profiles were generally similar with only a few differences (e.g. TSS, B).

For Plant A and Plant D, BOD<sub>5</sub> results were above detection limit and approximately 2,000 mg/L which suggests indirectly significant organic material available for degradation. This is not unexpected for Plant A which adds dibasic acid, however for Plant D the result is somewhat unexpected, however, contributions of BOD are possible via the alkaline reagent.

Some WFGD systems can experience foaming which impairs the scrubber systems to detect and control slurry level in the absorber. Some of the analytes in Table 1 are used as indicators of WFGD foaming specifically when they are present at specific concentrations. These include ammonia, nitrate, and nitrite which are byproducts of biological activity.<sup>7</sup> However all of these were present at low concentrations and none of the plants sampled were experiencing foaming, making it difficult to confirm any correlation. Note that Plant A has a history of foaming conditions and was currently adding a defoaming agent at the time of sampling.

### ***Comparison to Data in the Literature***

After an extensive search, only a few data sets were identified for comparison. Arsenic, mercury, selenium, chlorides, and TDS concentrations determined at the four SESS scrubbers were generally comparable to the ranges reported by Czuchna for the Mayo Station.<sup>8</sup> As well, concentrations were comparable to typical concentrations presented by Elliot at the 2007 APC Round Table and Expo.<sup>9</sup>

### **SUMMARY**

Preliminary results were reported from the SESS WFGD effluent sampling program. Some preliminary findings and observations were discussed for selenium, arsenic mercury and boron based on coal, operating conditions, and considerations for WWT. Two additional SESS scrubbers were recently sample and an additional two are scheduled to be sampled over next several months.

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## **KEY WORDS**

WFGD effluent, wet scrubbers, wastewater treatment, mercury, arsenic, selenium, boron, chlorides