WFGD Effluent Characterization Study Update and Considerations for MATS, CCR, and ELG

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ABSTRACT

*Foster Wheeler (FW) will present a number of comparisons using new and past study data. This data will be compared to: Proposed regulatory limits, Data used in support of the ELG rulemaking, and to various related issues, exposing a number of key considerations. This will help operators as they begin the process in evaluating waste water treatment (WWT) technologies most applicable for their plant to treat scrubber waste water. Of note this presentation is a continuation in a series of MEGA Symposium presentations given in 2008, 2010, and 2012 regarding the FW study.

** In March 2014, a subsidiary of the Foster Wheeler AG Global Power purchased the assets of the Siemens Environmental Systems and Services, the former Wheelabrator Air Pollution Control (WAPC) Company located in Pittsburgh, Pennsylvania.*

INTRODUCTION

A series of air, solid waste, and waste water regulations will cumulatively impact how water is utilized and how waste water is treated at coal and oil fired power plants over the next few years.

The initial effect will result from the Mercury Air Toxics Standard (MATS). This will target emission reductions in flue gas mercury, particulate, and hydrochloric acid. Many plants will upgrade and install Selective Catalytic Reduction (SCR) systems, particulate control equipment, and/or Wet Flue Gas Desulfurization (WFGD) systems to help achieve higher removals. In turn, this will result in enrichment of sorbents, fly ash, scrubber solids, and most specifically WFGD water as these help to scrub the various pollutants from the flue gas. Enrichment with increased levels of nitrogen, mercury, selenium, arsenic and other metals will result.

In December 2014 at about the time for MATS compliance to begin, the Environmental Protection Agency (EPA) targets finalizing new solid waste regulations. The new regulations are referred to as the Coal Combustion Residue (CCR) rule. It is specific to the disposal of plant solid wastes including fly ash, sorbents, WFGD solids, bottom ash, and boiler slag. The CCR rule's overriding theme is dry disposal. Often power plants mix process solids with water to ease in handling. A few known examples are the sluicing of fly ash and the ponding of WFGD slurries. However, the CCR rule will phase in restrictions to these practices and force plants to reconsider the fate of such waters. It's logical to assume that the CCR rule will shift plants toward increased recycling of plant waters in other processes. Much of these waters will likely be reused in the WFGD, which is a large consumer of plant water.

MATS and the CCR rule will indirectly impact water within power plants, but the last of the three regulations, the Steam Electric Power Generating Effluent Limitation Guidelines (ELG), will directly impact water bodies and Publicly Owned Treatment Works (POTW) by imposing strict waste water limits on plant discharges. ELG will affect a number of waste water streams including fly/bottom ash transport water and coal combustion residual leachate; however, the primary target will be WFGD waste water due to its complexity and volume.

ELG rulemaking is expected to be finalized around the fall of 2015. It will be phased in through National Pollutant Discharge Elimination System (NPDES) and Pre-treatment permit renewals starting in 2017 up through 2022. ELG limits will be *in addition to* and will not replace the existing NPDES and Pre-treatment limits. ELG is constructed based on performance of a number of waste water treatment technologies. It designates a handful of these technology options as "preferred". There are numerical discharge limits for mercury, selenium, arsenic, and nitrate-nitrite nitrogen for WFGD waste water. ELG also offers incentives to plants through additional years of compliance that adopt a Zero Liquid Discharge (ZLD) plant strategy.

WFGD effluent or purge is the influent stream sent to WWT. WFGD effluent is discharged from the scrubber to reduce and maintain the scrubber operating chlorides and solids. It is complex, variable, and its treatment is challenging. Once it enters the treatment process it is commonly referred to as WFGD waste water. It is upon its discharge from WWT that it is subject to meeting compliance.

ELG's strict discharge limits will challenge selection of WWT technology and overall compliance strategy. As such, it is important to characterize WFGD effluent to properly align the treatment technology with the compliance limits. FW's study is targeted to ensure the limits are not overreaching or unattainable. This and other industry studies are essential in helping to identify gaps in technical information and raise awareness on issues so utilities have a complete and full understanding of all the considerations before investing millions of dollars in technology.

FOSTER WHEELER STUDY

FW launched its WFGD effluent R&D program in the spring of 2008. The program was initiated for a number of reasons including the development of an internal WFGD effluent chemistry database in anticipation of future waste water regulations. Around this time, FW was in the initial stages of a WFGD installation intensive period, which ultimately translated into over 14GW of scrubbers from 2006 through 2012. This large number of WFGDs provided FW the opportunity to build a substantial study population.

The full study design and methodology is described in detail in the proceedings papers of the 2008[1] and 2012[2] MEGA Symposiums. Preliminary results and trends were provided in 2008[1] and 2010[3]. Then in 2012[2] a full summary of the study data was presented. The summary included averages as well as data minimums, maximums, medians, and percentiles. Results were also presented at other non-MEGA conferences including the 2011 Electric Power Conference[4] and the 2013 WPCA Duke Energy Waste Water Workshop[5]. The Electric Power presentation was a joint paper with Siemens Water Technologies (now Evoqua Water Technologies) exploring a number of case studies for optimization of WFGD with WWT.

At the time of 2012 MEGA paper[2] the FW study had comprised six years of sampling, covered 15 power plants, 15 different wet scrubbers and 18 unique total sampling events (note that three of the plants included a second sampling event, as it was decided to include a second point from these plants since they were under significantly different process conditions or equipment upgrades). See Table 1.

Table 1. Summary of FW Study Sampling Events as of MEGA 2012

Plant	Sample Date	Sample Point[A]	Coal[B]	SCR[C]	Particulate Control[D]	WFGD Type[E]	Additives[F]
A	2008	RWD	EB	No	ESP	LSFO	DBA, AF
A	2009	SHOF	EB	Yes[G]	ESP	LSFO	DBA, AF
B	2008	WWFT	EB	No	ESP	LSFO	No
C	2008	TUFT	Ill	Yes & SNCR	ESP	LSFO	No
D	2008	BP	Ill	Yes	ESP	LNO	No
E	2008	CPT	EB	Yes	ESP	LSFO	No
F	2009	SHOF	EB	Yes	FF	LSFO	No
G	2009	ST	PRB	No	FF	LSFO	No
H	2009	ET	PRB	Yes	ESP	LSFO	AF
I	2010	AB	EB	Yes	ESP/FF	LSFO	AF
I[H]	2010	AB	EB	Yes	ESP/FF	LSFO	AF
J	2010	AB	Ill	Yes	FF	LSFO	DBA

K	2011	AB	EB	Yes	ESP	LSFO	No
L	2011	AB	EB	Yes	FF	LSFO	DBA, AF
L[H]	2011	AB	EB	Yes	FF	LSFO	DBA, AF
M	2011	SHOF	EB	Yes	ESP	LSFO	No
N	2012	AB	EB/PRB	Yes	ESP	LSFO	AF
O	2012	AB	PRB	Yes	ESP	LSFO	AF

A: RWD = Return Water Drain, SHOF= Secondary Hydroclone Overflow, TUFT = Thickener Underflow Tank, BP= Bleed Pump, CPT = Chlorides Purge Tank, ST = Supernate Tank, ET = Equalization Tank, AB = Absorber Bleed
B: EB = Eastern Bituminous, Ill = Illinois, PRB = Powder River Basin
C: SCR = Selective Catalytic Reduction, SNCR = Selective Non Catalytic Reduction
D: ESP = Electrostatic Precipitator, FF = Fabric Filter
E: LSFO = Limestone Forced Oxidation, LNO = Lime Natural Oxidation
F: DBA = Dibasic Acid, AF = Antifoam
G: Plant A installed SCR
H: Different limestone than first sampling episode

Since 2012, FW has re-sampled three of the Plants (M, N, and O) multiple times and Plant H was re-sampled and characterized for a few select parameters. Some of this new data will be included in following discussions.

The strength of the FW study is that it is fairly representative of WFGD effluent across the power industry. It includes numerous scrubbers and different process conditions such as different coals and upstream air pollution control equipment. WFGD systems were characterized from a wide geographical range, which reflects many different sources of water and limestone. The following highlights some of the key study variation.

- States: Florida, Colorado, Kentucky , Pennsylvania, Maryland, West Virginia, Illinois, Virginia, New Hampshire, Wisconsin
- Coals: 8 Eastern Bituminous, 3 Illinois Basin, 3 PRB, and 1 PRB blend
- Particulate control equipment: 11 ESPs and 4 FFs
- Scrubber Additives: 3 WFGD systems using DBA

REGULATORY LIMITS AND EPA RULEMAKING

FW compared study data with proposed regulatory limits for WFGD waste water and with EPA supporting data and information used in ELG rulemaking.

The WFGD limits are included in Table 2. These include numerical discharge limits for arsenic (As), mercury (Hg), selenium (Se), and nitrate-nitrite nitrogen (NO_3/NO_2 as N).

Table 2. Proposed Discharge Limits for WFGD Waste Water

Parameter (units)	Daily Max	30 day Ave.
As (µg/L)	8	8
Hg (µg/L)	0.242	0.119
Se (µg/L)	16	10
NO_3/NO_2 as N (µg/L)	170	130

The EPA supporting data and information for rulemaking was downloaded from the publicly available website, www.regulations.gov. A docket within the website includes all the related EPA white papers, field studies, contributed industry data, vendor feedback, and public comments. Of specific interest to the authors were the following EPA documents.

- Incremental Costs and Pollutant Removals for Proposed Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category[6]
- Technical Development Document for the Proposed Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category [7]
- Sampling Data Used as the Basis for Effluent Limitations for the Steam Electric Rulemaking[8]

RESULTS & CONSIDERATIONS

Observed in the EPA analyses was considerable focus on plants adopting physical chemical (phys-chem) WWT systems used in combination with an anoxic/anaerobic bioreactor. This seemed logical as a first pass considering the EPA indicates[6] that 36 of the 117 plants currently discharging WFGD waste water already have some chemical treatment technology in place. Phys-chem systems are relatively effective at reducing mercury and arsenic; however, they require the addition of a bioreactor (or other technology) to reduce selenium and nitrate-nitrite nitrogen down to ELG discharge limits. There are a number of competing technologies for selenium and nitrogen reduction; however, most of the EPA literature and data refers to the use of an anoxic/anaerobic bioreactor. As such, this will be the point of reference in the following discussions for nitrogen and selenium removal.

Consideration 1: Nitrogen

In the EPA's Technical Development Document[7], they detail an average industry WFGD effluent. This is essentially a quantitative profile with average concentrations calculated for each of the constituent parameters. It is referred to in the document as the *Average Pollutant Concentrations in Untreated FGD Waste Water*. The EPA indicated it is based on their independent sampling programs and also from self-monitoring data submitted by individual plants. The EPA also included a qualitative description to highlight the degree of stream complexity. The agency wrote, "*As shown in the table, FGD waste water contains significant concentrations of chloride, total dissolved solids (TDS), nutrients, and metals, including bio accumulative pollutants such as arsenic, mercury, and selenium*." The industry average nitrate-nitrite nitrogen concentration was reported at 75 mg/L.

The EPA also quantified a typical waste water profile for treated WFGD effluent with a phys-chem system in its Incremental Cost Document[6]. Essentially they presented an influent profile for an anoxic/anaerobic bioreactor that would be installed downstream of a phys-chem system. The EPA described this stream as the *Expected FGD Waste Water Characteristics for Design of the Biological Treatment Stage***.** The EPA referenced site visits, sampling episodes, and long-term industry monitoring data in determining the profile concentrations. The average concentration for nitrate-nitrite nitrogen for this treated stream was 58 mg/L with a minimum of 13 mg/L and a maximum of 160mg/L. A small level of nitrate-nitrite nitrogen reduction is realized across a phys-chem system so 58 mg/L is consistent with a phys-chem influent concentration of 75 mg/L as detailed in the Technical Development Document.

In comparison, the FW WFGD effluent study average is 75 mg/L nitrate-nitrogen as presented in MEGA 2012 proceedings paper[2]. Study minimum and maximum were 0.5mg/L and 191 mg/L nitrate-nitrogen with eight of the plants greater than 75mg/L. *Note that FW measured only nitrate-nitrogen and not nitrate-nitrite nitrogen. However, the results are comparable as nitrite concentrations are mostly insignificant in WFGD effluent.* Since 2012, the FW re-sampling events at plants M, N, and O, determined an average nitrate-nitrogen concentration of approximately 115 mg/L with some individual samples ranging up to nearly 200 mg/L. This range of concentration is relatively similar to concentrations included from these plants in the 2012 average.

Overall there is a fair amount of correspondence between the EPA and FW data for nitrogen levels in WFGD effluent. However, this is not the case when comparing the sampling data EPA used in their basis in determining ELG nitrogen discharge limits.

The EPA Sampling Data Document[8] is a compilation of ELG compliant data formatted in an Excel Workbook. Each sheet in the workbook contains data from one of the proposed ELG waste water technologies. The workbook includes a sheet with data collected from two full scale anoxic/anerobic bioreactor systems operating downstream of phys-chem treatment systems treating actual WFGD effluent. These are the sites and the data that the EPA used in determining ELG limits. The data set includes about 30 data points covering a range of two years. All of the bioreactor effluent data contains nitrogen concentrations below the nitrate-nitrite nitrogen limits outlined in Table 2. The data set also includes corresponding influent concentrations for the compliant days at various stages, starting with the WFGD effluent purged from the scrubber and concentrations for the waste water after various treatment points. Surprisingly for these compliance days, the average WFGD effluent concentrations were only 32 mg/L and 17 mg/L nitrate-nitrite nitrogen for the two plants. On the EPA docket there was also plant submitted data[9, 10] that did show higher WFGD effluent levels up to 200 mg/L nitrate-nitrite nitrogen, but none of those data included bioreactor effluent data below ELG limits. For most of these data the discharge concentrations were only reported to less than values of 10 or 1 mg/L which are approximately 5 to 50 times higher than the daily ELG maximum limit of 0.17 mg/L. Hence for the days where ELG compliance was demonstrated for nitrogen, the corresponding WFGD effluent nitrate-nitrite nitrogen levels were nearly two to four times less than the FW 2012 study average, four to eight times less than new FW data, and two to four times below EPA's own documented industry average for untreated WFGD effluent.

Like other pollution control equipment, anerobic/anoxic bioreactor technology includes some design constraints, with many of these are focused on the complexity of the waste water stream. A leading supplier of the technology detailed some of these design limits on their website[11]. These included maximums for chlorides, TSS, temperature, plus operating ranges were identified for pH, batch flow, and ORP. In addition, there were some descriptive considerations included for TDS. So to assess the degree of treatment difficulty presented by the waste water from the two EPA sites, a relative comparison is outlined in Table 3 comparing site levels with supplier design limits and industry averages for TDS and chloride levels. It is clear that the waste waters from the two EPA sites were somewhat less complicated than typical WFGD effluent observed across the industry.

Table 3. Dissolved Solids and Chloride Levels

	Supplier Design Specifications	EPA Site 1	EPA Site 2	EPA Industry Average [A]	FW Study Average as of 2012	New Data from FW Study 2012-14 Plants M, N,O
TDS (mg/L)	No limit given, supplier states proven at levels > 35,000	10,324	15,714	28,600	34,000	32,175
Cl (mg/L)	25,000	4,000 [B]	10,641 [C]	7,740	12,317	8,500

A: Technical Development Document for the Proposed Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category
B: Estimated concentration determined from site supplied data from different time period.
C: Concentration determined from site supplied data from different time period.

The authors did uncover a reference[12] in the literature where a utility is using an anaerobic/anoxic bioreactor to treat WFGD effluent close to the EPA industry average. In addition, this utility is treating down below the ELG discharge limits for nitrate-nitrite nitrogen. However, there is a dilution step with landfill leachate prior to entering the anaerobic/anoxic bioreactor which reduces the nitrogen load. Their data shows an untreated WFGD effluent concentration of approximately 65 mg/L nitrate- nitrite nitrogen. Upon treatment from the phys-chem plant, the nitrogen level was reduced to approximately 43 mg/L and then 22 mg/L upon dilution with landfill leachate before entering the bioreactor. One consideration is that a similar approach could be adopted by plants with large volumes of landfill leachate or impoundment waste water, especially with the CCR rule making more displaced waters available for "dilution" prior to treatment. However, dilution before treatment is often not economical and so such a concept would require a detailed FEED study to determine if the volumes and costs would make this a viable option.

Consideration 2: Mercury

In the Sampling Data Document[8] the EPA included performance data from three phys-chem treatment systems for mercury and arsenic similar to data from the two sites for nitrogen. However, in this case the data was being used by the EPA as their basis for determining mercury and arsenic ELG limits. The ELG compliant discharge data included corresponding WFGD effluent concentrations or (I.e. influent to WWT). Mercury concentrations were in the hundreds of ppb (µg/L) for all three sites entering their phys-chem systems. Discharge levels were well below ELG limits reaching ppt (ng/L) levels. However, there were a number of aspects to the data that were of particular interest to the authors. First, the influent data represented total mercury and not dissolved. Second, one of the EPA plants was plant K in the FW study. Plant K's dissolved mercury concentration was determined to be less than 1 µg/L as measured in 2011. Therefore, the hundreds of ppb of mercury entering the phys-chem systems were essentially mercury associated with solids and not dissolved mercury. This was confirmed upon detailed review of the site sampling reports[13, 14, 15] for all three plants, where both total and dissolved concentrations were reported. Significant partitioning of mercury to the solids for plant K is also confirmed by other evidence such as the plant ORP levels are consistently in the range of 160 to 200 (*personal communications*). Plant K has also exhibited exceptional flue gas mercury removal in the past and has not experienced re-emission.

For plant mercury abatement strategies this is the ideal scenario or in other word mercury in mainly oxidized form enters the WFGD where it is captured, solubilized, and then partitions to the solids. The plant not only realizes high flue gas mercury removal but excellent WFGD waste water mercury removal as solids are easily removed with precipitation and clarification steps.

All three plants detailed by the EPA exhibited almost the same influent profile such that the mercury was predominantly partitioned on the solids with all three plants realizing high mercury removals across their phys-chem systems. This clearly indicates that the scrubber played a leading role in mercury removal in these waste water treatment systems. All three sites did achieve a relatively high degree of dissolved mercury removal across their phys-chem systems averaging 96.78%, but their solid mercury removals averaged 99.96%.

Therefore, the following questions arise: Do these three plants represent the industry? Can all plants expect similar performance? Typically, these plants burn predominantly eastern bituminous coal or a majority mix of eastern bituminous coal. They operate at mid to high chloride levels in their scrubbers at a range of 7,000 to 20,000 mg/L. They likely see mainly oxidized flue gas mercury making removal easy with the WFGD. Their higher operating chlorides then help to inhibit re-emission chemistry and to promote partitioning of the dissolved mercury to the solids. Plants that burn PRB or Illinois Basin coals or even plants with higher levels of dissolved mercury may struggle to achieve the same level of performance with their phys-chem systems.

FW's dissolved mercury study average reported in 2012 was approximately13 µg/L; however this average was distorted due to an outlier plant that had a concentration of nearly 200 µg/L of dissolved mercury. If this high point was removed, the average was significantly reduced to around 1 µg/L. Even so, there were a handful of plants in the FW study that did have dissolved mercury concentrations higher than 1 µg/L. The EPA reported a significantly higher industry average of 78 µg/L dissolved mercury in their Technical Development Document[7]. So this at least concludes that there are a number of plants operating with dissolved mercury levels somewhat higher than the three plants that the EPA used as a basis for rulemaking. As such these plants with higher dissolved mercury are likely to experience a step up in the degree of treatment difficulty. Scenarios like this would typically translate into higher doses of sulfide chemicals in the phys-chem systems to help chelate the increased levels of dissolved mercury. Also this may necessitate installation of supplemental filtration to help remove the fine coagulated mercury solids occasionally formed by using increased levels of waste water chemicals.

As mentioned previously, phys-chem systems will require the addition of a bioreactor for full ELG compliance. Bioreactors do provide supplemental removal for mercury and arsenic, so this should help to offset the performance deficiencies in phys-chem systems that do not solely achieve ELG compliance levels. However, this may not be as simple for all plants that have higher dissolved mercury, as these plants may have other limiting factors to consider as well. Such is the case of Plant H in the FW study. This plant illustrates the difficulty in balancing flue gas mercury removal for MATS, WFGD chemistry, and WWT performance for ELG. Plant H applies a bromide salt to their coal to help promote mercury oxidation and subsequent capture with the WFGD. However, as reported by others[16, 17], the addition of bromine can have detrimental effects such as increased levels of dissolved selenium in the WFGD scrubber liquor. FW sampled this plant in 2013 and dissolved selenium levels were significantly higher than FW measured in the past and before routine addition of bromine began at the plant. The concentration of selenium will not be reported here due to the sensitivity in the data, but nonetheless, it should be noted that the level measured in 2013 would represent a significant challenge to an anoxic/anerobic bioreactor. In addition, the nitrogen level at this plant is around 200 mg/L. A consultant hired by the plant in 2009 to explore upgrades for enhanced mercury removal with the plants phys-chem waste water treatment expressed reservation over the size and complexity of installing a bioreactor to this plant due to the high nitrogen levels. His reservation did not even take into account the current increased levels of dissolved selenium. The plant's phys-chem system has already been modified a number of times since installation to resolve operational problems and enhance overall performance. However, the additional hurdles of ELG will significantly challenge WWT at this plant and may force additional considerations beyond simply installing new WWT technology. This may force changes to alter the scrubber chemistry necessary in maintaining both flue gas and waste water performance. Plants like Plant H may have to modify upstream air pollution control (e.g. upgrade ESPs or SCRs) or possibly add sulfide chemicals or activated carbon to the scrubber to enhance scrubber ORP levels plus other options

Consideration 3: Zero Liquid Discharge

Up to this point, the authors have presented considerations with WFGD effluent and treatment with phys-chem-biological systems. As aforementioned, this approach seems likely as the popular choice since many plants already have chemical treatment systems installed. However, there still remain key questions and uncertainties for certain WWT technologies at some of the plants. Conversely, there are a number of different Zero Liquid Discharge (ZLD) approaches that would eliminate the concerns with waste water discharges. Plus ELG is incentivized with additional years until compliance for plants adopting a ZLD strategy; therefore these approaches are worth consideration. Two such ZLD approaches will be briefly discussed.

The first approach employs vapor compression crystallization technology. There are a number of international systems[18] treating WFGD waste water with this technology and one in the US[19]. All of the referenced systems are being supplied from one vendor. This vendor's technology does require pretreatment with a phys-chem system for solids reduction, gypsum desaturation, and softening. Reservation exists among the industry to adopt vapor compression crystallization technology due to the operating complexity and overall cost. However, it should be noted that there are efforts underway to simplify and lessen costs associated with this approach and one vendor is reporting[20] they can operate with minimal to no pretreatment. This technology does offer the attractive feature of generating a high quality sodium salt byproduct which likely has beneficial use for deicing and/or as a feedstock for making chemicals. In addition, these systems generate a clean distillate, free of TDS, which can be re-used within the plant where clean water is required.

The second approach has been applied at a number of plants globally[21] for treating waste water. It involves the repurposing of spray dryer technology common in air pollution control for waste water evaporation. The concept is relatively simple and consists of a spray dryer which utilizes a slipstream of plant flue gas to provide the motive force and thermal input to dry a waste water stream. As WFGD effluent contains high ppm concentrations of calcium and chloride, a predominantly $CaCl_2$ based salt byproduct is formed in the drying process which is either captured in the existing flue gas train or a stand-alone dedicated particulate control equipment. This is schematically represented in Figure 1.

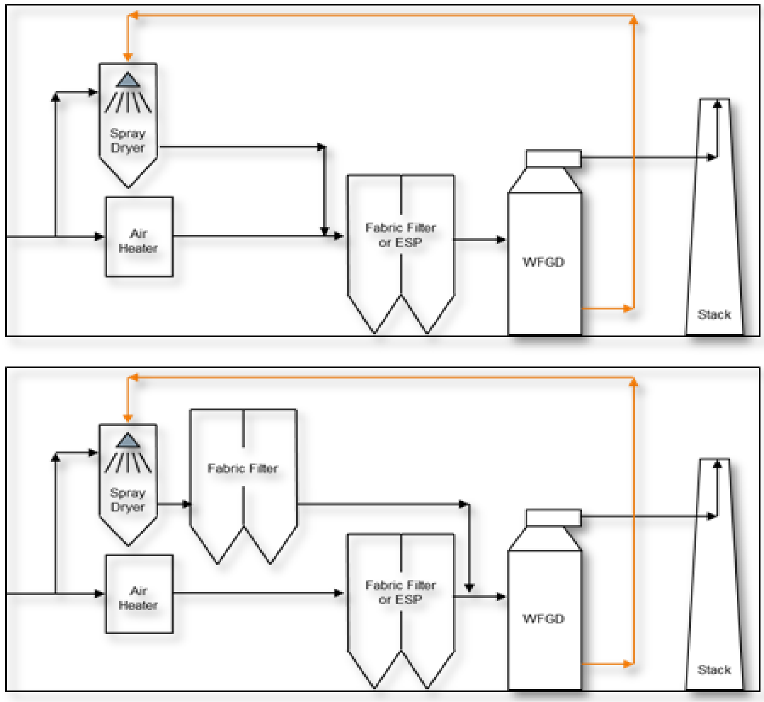

Figure 1. Spray Dryer Configurations

This approach presents a number of challenges including the possibility of severe equipment corrosion since it is salt intensive. However, with proper engineering, spray dryers have proven to overcome this issue as they have been successful in drying solids in excess of 25% as $CaCl_2$ in the Waste-to-Energy Industry over many decades. Utilizing high pressure sprays for evaporation does require optimization to ensure proper seeding and drying of solids to ease material handling issues since salt based solids can readily absorb moisture and solidify. Although, the biggest hurdle may be that the high percentage of salts can have a detrimental effect on leaching characteristics of fly ash (if the two streams are co-mingled). However, even this may be overcome as there have been discussions[22] on effective fixating techniques for disposal. There may also be beneficial uses for the byproduct such as deicing applications due to the high percentage of salts.

Spray dryers do offer an attractive element of eliminating the heavy chemistry burden and monitoring demands presented by many WWT technologies. Finally, spray dryers and particulate capture equipment are familiar to power plant operators who are knowledgeable on their operation and maintenance. Many of the leading air pollution control suppliers, including FW, offer spray dryer technology.

SUMMARY

FW presented a number of comparisons using WFGD effluent study data to benchmark some of the published WWT performance highlighted in the ELG rulemaking. From these, a number of key considerations for physical chemical WWT systems in combination with a bioreactor were evaluated and discussed. Questions were also raised in trying to applying of some of the EPA field study results to plants with different operating conditions. A number of ZLD approaches were presented to highlight different strategies for compliance.

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KEY WORDS

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