#49

Duke Energy Carolina LLC's Strategy and Initial Experience of FGD Waste Water Treatment Systems

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ABSTRACT: In developing a flue gas desulfurization (FGD) retrofit program for its stations, Duke Energy Carolinas desired to have as much standardization in both the FGD and associated waste water treatment systems, as possible. The standardization/optimization process for the FGD systems has been presented earlier for Marshall, Belews Creek, Allen and Cliffside stations.[1]

This paper presents an assessment of the waste water treatment systems (WWTS) at each station in terms of the FGD purge characteristics, the effluent discharge requirements, overall treatment strategy and system designs employed. Initial experience and system performance for the completed WWTS at Marshall and Belews Creek are presented. Also, lessons learned are shared.

No two Duke Energy Carolinas stations will have the exact same system components. However, physical/chemical, anoxic/anaerobic activated carbon-based biological, and constructed wetlands processes were used in varying combinations for the four stations. Due to new selenium reduction requirements, it was necessary to include a biological treatment technology for Belews Creek and Allen stations that had not been previously proven commercially for FGD waste water applications. To reduce risk, it was appropriate to conduct pilot testing in parallel to the WWTS design/construction effort, in order to support the FGD startup schedule. Another design consideration included waste water quality varying over the life of the WWTS due to changes in coal type, limestone quality, and seasonal water quality. Equipment in the WWTS systems needed to be sized and configured to provide flexibility in treating changing waste water quality.

BACKGROUND

Duke Energy Carolinas committed to a multi-phase fleet-wide SO_2 emissions reduction program in compliance with the North Carolina Clean Air Program of 2002. They embarked on a program to retrofit wet flue gas desulfurization (WFGD) systems on 12 of their largest units over a 10 year period. Four of eight coal-fired stations (Marshall, Belews Creek, Allen and Cliffside Unit 5) will be retrofitted with WFGD systems by 2010. Individual stations will have multiple scrubber units, due to the size of the power plants and need for flexibility in operation of the multiple power units at each station. For the waste water treatment system (WWTS), each station will have a single system with adequate redundancy and backup capability. Characteristics of the stations retrofitted are indicated in Table 1.

Table 1: Stations in FGD Retrofit Program

Station	Approx. Total Net Capacity (MW)	WWTS Design Flowrate (gpm)	Expected FGD Startup
Marshall 1-4	2,090	542	2006
Belews Creek 1&2	2,240	600	2008
Allen 1-5	1,155	401	2009
Cliffside 5	560	100	2010

50,000 gpd.

vs. 35 gpm Merrimack.

Duke desired to have as much commonality between stations in both the FGD systems and the WWTS. Through a competitive bid process, the EPC selected the consortium of Siemens Water Technologies Corp. and a construction company (Marshall WWTS Consortium) to design, procure, construct and commission the waste water treatment system for Marshall Station.

For each of the subsequent stations after Marshall Station, the consortium of Siemens Water Technologies Corp. and Crowder Construction Company (WWTS Consortium) was selected to provide the FGD WWTS on a design, procure, construct and commission basis. On the Belews Creek and Allen stations, the WWTS Consortium subcontracted to GE Water Process and Technologies (Biological System Supplier) for their specialized ABMet® biological system for selenium reduction. The Biological System Supplier provided the proprietary selection of microorganisms, the activated carbon for the microbes to attach to and grow on, and specifications for the biological system. The WWTS Consortium provided the process and mechanical design for the biological system and performed the construction of the concrete biological reactors. On Belews Creek, a constructed wetlands treatment system (CWTS) follows the biological system, whereas on Allen there is no CWTS.

For Cliffside unit 5, the WWTS will include a physical chemical system. This system's primary components include an Equalization Tank, a Reaction Tank for the addition of ferric chloride, a Clarifier, Gravity Filters and a Filter Press dewatering system. There are no plans for a biological system in the Cliffside 5 WWTS, based on the projected removal efficiency by the solid removal system and the long term plans for discharging the wastewater back into a spray dryer to be in operation when a new unit comes on line in 2013.

TREATING THE PURGE

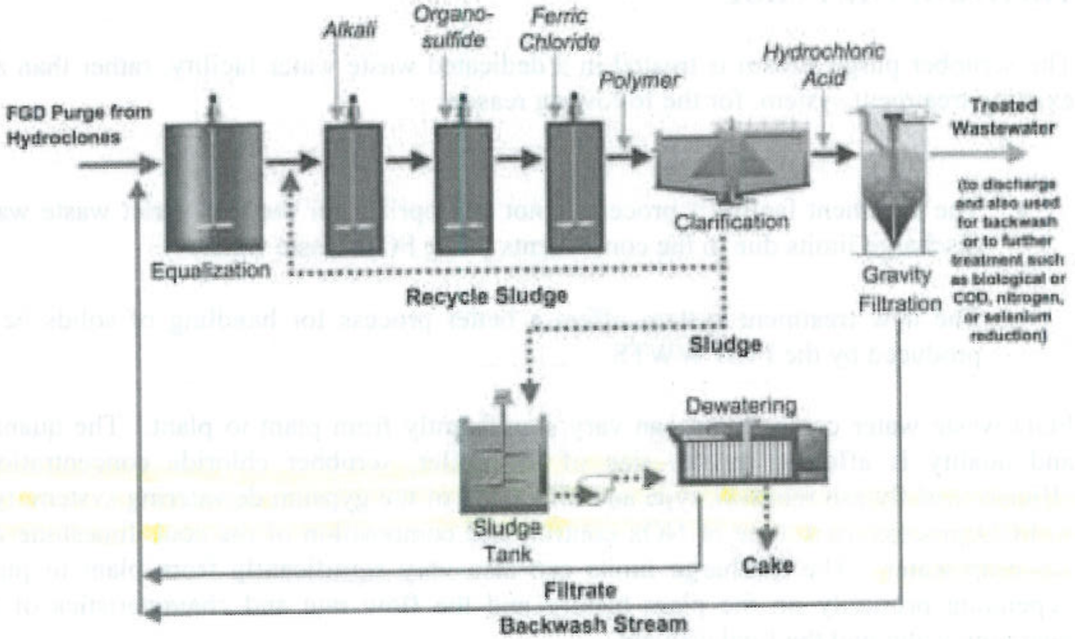
The scrubber purge stream is treated in a dedicated waste water facility, rather than any existing treatment system, for the following reason:

- The treatment facility's process is not appropriate for the very strict waste water discharge limits due to the constituents in the FGD waste water.
- The new treatment system offers a better process for handling of solids being produced by the FGD WWTS.

FGD waste water composition can vary significantly from plant to plant. The quantity and quality is affected by the size of the boiler, scrubber chloride concentrations, efficiency of fly ash removal, type and efficiency of the gypsum dewatering system, type of FGD process used, type of NOx control, and composition of the coal, limestone and make-up water. The discharge limits can also vary significantly from plant to plant, depending primarily on the plant history and the flow rate and characteristics of the receiving water and the final effluent.

The specific FGD waste water treatment system thus needs to be designed to meet the current waste water composition and discharge requirements, but also have some flexibility for meeting future requirements either as designed and constructed or with hopefully minor modifications or add-ons to the system. A basic building block in the WWTS has been an integrated physical chemical treatment system, as represented in Figure 1. This assumes the FGD purge originates from the hydroclones of the gypsum dewatering system. From a two stage hydroclone system, the stream will contain about 0.5 – 2% suspended solids (primarily gypsum and some fines of un-reacted or inert materials) and be directed to an equalization tank, which provides a means to even out the flow and chemistry of the purge.

Figure 1: Process Flow Diagram of Typical Physical Chemical Treatment System



The waste water is pumped to reaction tank #1 for addition of alkali (usually hydrated lime) for pH adjustment and gypsum desupersaturation of the waste water. Recycle of seed sludge from the downstream clarifier provides nucleating sites for crystal growth and aids in the desupersaturation process, which is important in order to prevent or reduce scale from forming on downstream equipment. Addition of an alkali also causes precipitation of abundant metals, such as aluminum, iron and manganese as metal hydroxides.

Some heavy metals will also precipitate as hydroxides in this reaction step; however metal sulfides have much lower solubility. Thus, in order to meet the low effluent requirements for heavy metals, organo sulfides are dosed into the stream in reaction tank #2 to further precipitate many of the heavy metals as metal sulfide (heavy metals are actually a subset of elements that exhibit metallic properties, including transition metals, metalloids, lanthanides and actinides.[2])

For flocculation an iron salt such as ferric chloride is added in reaction tank #3. The iron salt helps to form denser flocs, thus enhancing clarifier performance. In addition, the iron salt may co-precipitate other metals, some non-metals and some organic matter.

After the flocculation step, polymer is added to aid in coagulation of the floc in the clarifier. The waste water undergoes clarification using a solids contact clarifier, in this particular process design. After clarification, the pH is adjusted to neutral using hydrochloric acid (HCl), which is used rather than less expensive sulfuric acid (H_2SO_4) as sulfuric acid would add to the saturation of the treated effluent and could lead to scaling in other downstream equipment. If a low suspended solids level is required prior to discharge of the treated waste water, the effluent may need to pass through a gravity filter. The treated effluent from the gravity filter goes to the receiving water or to further treatment, dependent upon the discharge requirements. The backwash from the gravity filter would be returned to the equalization tank for reprocessing.

The clarifier sludge contains gypsum, inert materials, and precipitated metals and is usually about 15 – 20% solids by weight. It is normally pumped to an agitated sludge holding tank prior to being dewatered in filter presses. The sludge tank volume will be sized consistent with the utility's desire for filter press operations. Some utilities desire to only operate the filter presses on day shift and weekdays. In that case, the sludge tank will be sized to accumulate sludge for an entire weekend or holiday periods. The most common filter press being used for FGD waste water sludge is the recessed chamber type press (commonly referred to a plate and frame type). For very large sludge production, belt filter presses may be used. Solids discharge from the filter presses at 60 – 70 wt% solids and are disposed in non-hazardous lined landfills, either onsite or offsite.

The source of the nitrogen in FGD purge is usually due to ammonia slip from a Selected Catalytic Reduction (SCR) unit. Dependent upon the discharge permit for the power plant, additional treatment may be required downstream of the physical chemical treatment system. Some state or regional requirements (such as the Chesapeake Bay Initiative) limit total nitrogen in the discharge. Some states limit selenium on selected streams (North Carolina and Pennsylvania), and others limit the organic load created by use of dibasic acid or other organic acids in the scrubber operation. To reduce these contaminants to acceptable levels, a biological treatment system is added after the physical chemical system. Fixed film biological treatment systems are being used at Belews Creek and Allen stations primarily for selenium reduction. The physical chemical system is still needed to perform the intended tasks of pH adjustment, desupersaturation, suspended solids removal, and reduction of much of the heavy metals. If these tasks were not accomplished, the biological systems would not operate properly and could scale from saturated conditions or be overloaded from the suspended solids.

← No for Merrimack

Variations of the physical chemical treatment system may be used, including:

- System with a primary clarifier prior to two or three reaction tanks followed by a secondary clarifier – used when the total suspended solids are forecasted to be significantly greater than 2 wt%. However, it usually may be more cost effective to assure the second stage of hydroclones was included in the gypsum dewatering system, than to have a primary clarifier. Also, if more than 2 wt% solids are forecasted in the flow to the WWTS, this probably indicates some gypsum product is unnecessarily being lost with the waste water and the gypsum dewatering system should be optimized for recovery.

- System with only two reaction tanks, no primary clarifier, with a single clarifier following the last reaction tank.
- System with primary clarifier, four reaction tanks, secondary clarifier – original European design of the 1980s.[3,4]

For most applications, the most efficient and cost effective system has two or three reaction tanks and just a single clarifier following the last reaction tank.

DUKE ENERGY CAROLINA LLC'S RETROFIT PROJECTS

Since Duke's Carolina fleet is being retrofitted over a period of years and due to specific environments at each station, the design FGD purge characteristics and treated effluent discharge requirements vary from station to station as presented in Table 2.

Table 2: Design Basis Values: FGD Purge Chemistry and WWTS Discharge Requirements

Parameter	Marshall Purge	Marshall Discharge	Belews Purge	Belews Discharge	Allen Purge	Allen Discharge	Cliffside Purge	Cliffside Discharge
pH (S.U.)	5.6	5.3 – 9.0	5.6	5.3 – 9.0	5.6	5.3 – 9.0	5.6	5.3 – 9.0
Temp (°F)	123		124		133		133	
Flow (gpm)	542		600		401		100	
Surge (gpm)	720		720		480		150	
Constituents	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**
TSS	16,000	≤1,000	16,000	≤50	16,000	≤50	20,000	≤30
TDS	19,500		25,000		25,000		25,000	
Chloride	12,000		12,000	12,100	12,000	12,100	12,000	12,100
Oil & Grease	<1.0		<1.0		<1.0		<1.0	
Nitrate	NR		NR		NR			
COD					700			
BOD	NR		NR		467			
Ammonium			≤14		≤8			
Antimony	0.02		0.02		0.02		0.00	
Arsenic	0.36		0.49		0.28		0.61	
Barium	5.69		7.33		4.99		5.44	
Beryllium	0.013		0.013		0.035		0.06	
Cadmium	0.08		0.10		0.07		0.10	
Chromium	0.28		0.36		0.40		0.73	
Cobalt	0.34		0.42		0.37		0.30	
Copper	0.41		0.54		0.44		0.23	

Fluorine	39.62		39.50		52.2		63.6	
Lead	0.30		0.35		0.30		0.43	
Manganese	1.10		6.52		5.74		5.51	
Mercury	0.08		0.30	0.001	0.35	0.001	0.51	
Molybdenum	0.31		0.41		0.43		0.46	
Nickel	0.64		0.76		0.70		1.0	
Selenium	2.04		4.0	0.100	8.0	0.100	20.0	
Silver	0.01		0.06		0.07		0.05	
Thallium	0.01		0.2		0.22		0.17	
Vanadium	0.50		0.56		0.62		2.26	
Zinc	0.73		0.9		0.98		1.23	

Marshall Steam Station

Marshall Station is located on Lake Norman, approximately 35 miles northwest of Charlotte, North Carolina[5].

A detailed description of the Marshall station and its FGD system, purge characteristics and waste water treatment system can be found in an earlier paper[6]. However, we will summarize some of that information in this paper, so the reader is able to compare all four of the Duke Carolinas stations in the retrofit program.

With the discharge requirements identified for Marshall, chemical mass balance modeling of the FGD process was made by the EPC Consortium and Duke Energy to predict the FGD purge stream flow rate and composition. The design basis was for 2,040 ppb total selenium (Se) and 80 ppb total mercury (Hg). However, the modeling estimated the purge could contain up to 4,000 ppb Se and up to 300 ppb Hg and would need to be reduced to less than 200 ppb total Se and less than 0.5 ppb total Hg prior to discharge to the ash basin. Duke personnel evaluated a number of treatment approaches, including:

- Typical FGD WWTS physical/chemical treatment (as described above) with alkali, organo sulfide, and ferric chloride chemical additions.
- Carbonate complex precipitation
- Co-precipitation with iron
- Chelation with sodium sulfide or other chelating agents
- Constructed wetlands treatment system (CWTS)

A combination of a waste water solids removal system (WWSRS) and a CWTS was selected over the other treatment processes mainly because it met the anticipated waste water treatment needs at a significantly lower lifecycle cost. Meeting the targets of 200 ppb total Se and less than 0.5 total Hg took into account an anticipated 1:1 dilution factor for temperature and chloride control of the feed to the constructed wetlands. To provide appropriate protection from excessive suspended solids load on the CWTS, a waste water solids removal system (WWSRS) was designed, supplied, installed, and commissioned by the WWSRS Consortium. The WWSRS flow diagram is shown in Figure 2.

Figure 2: Marshall Station WWSRS Flow Diagram

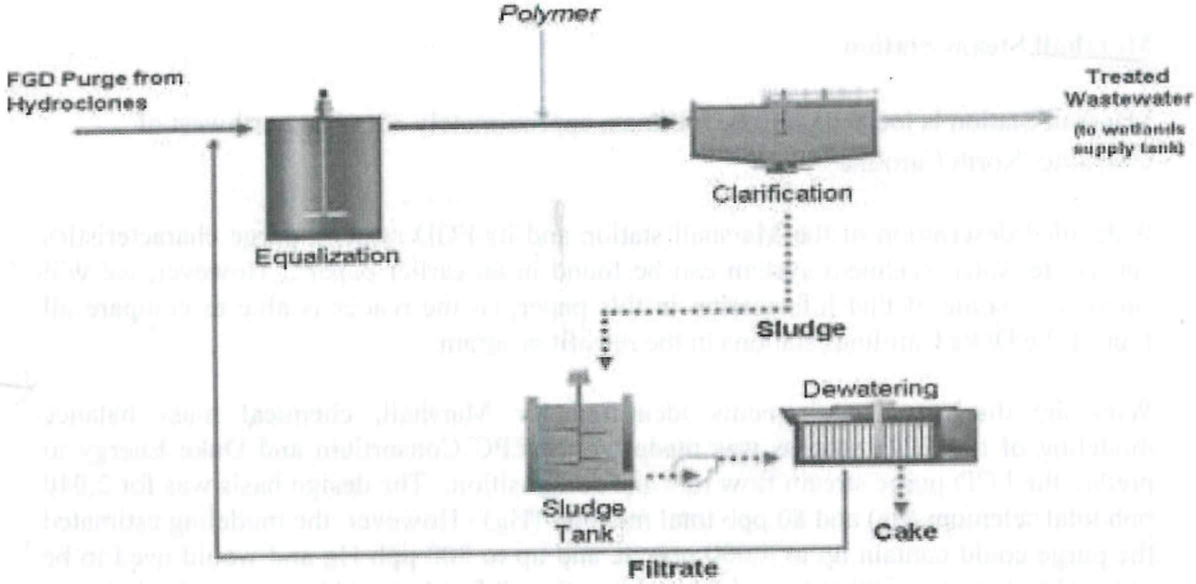
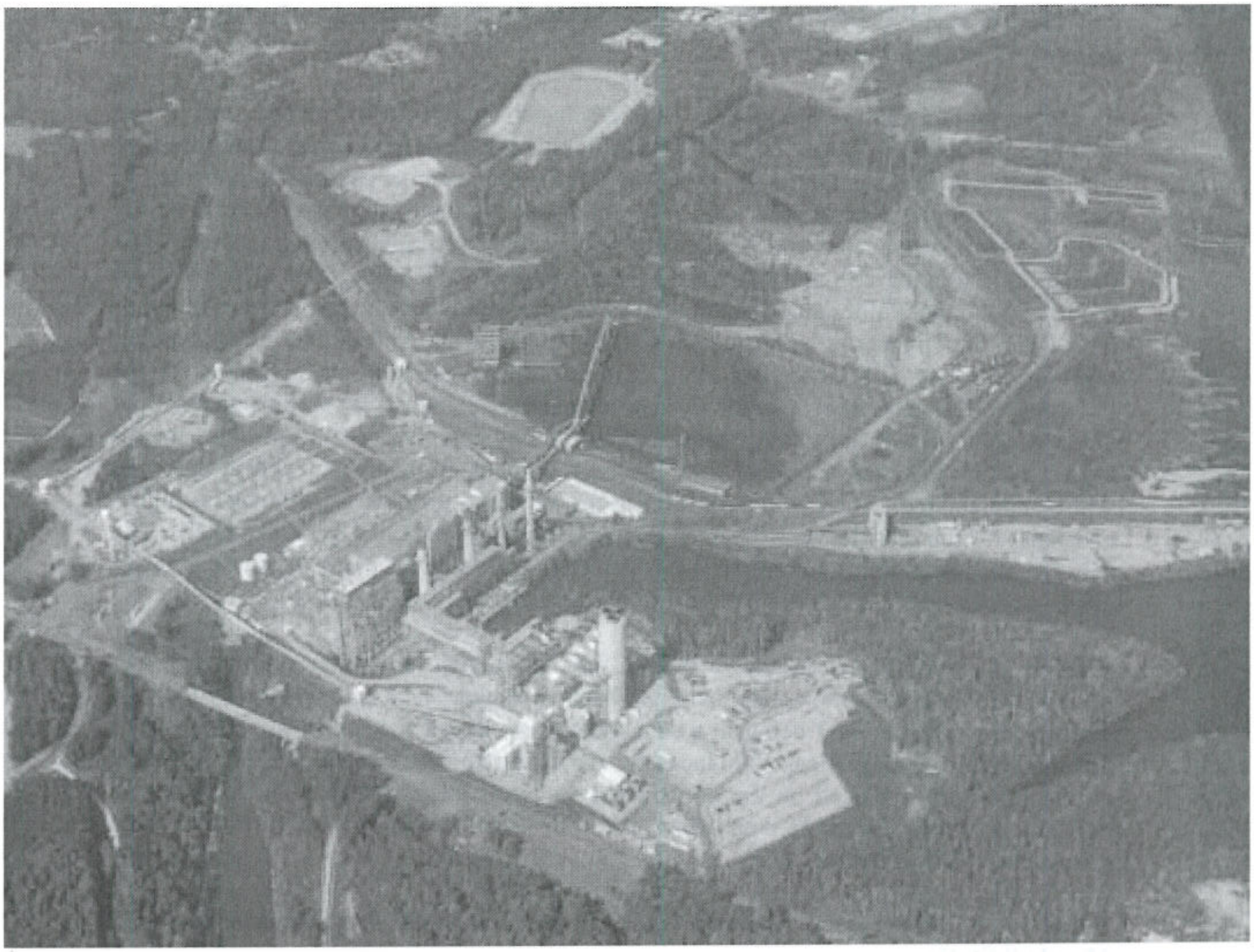


Figure 3: Marshall Station FGD System and WWSRS



The WWSRS is comprised of an Equalization Tank (EQ) taking an average flow at up to 542 gpm when all three absorbers are in operation and discharging a purge. The purpose of the EQ is to provide mixing of the waste water from the three absorbers and to provide an inventory of waste water to assure continuous flow to the downstream clarifier. The effluent from the EQ is pumped to a flocculating clarifier where suspended solids are settled out and discharged from the clarifier to the sludge holding tank. Polymer is injected into the line leaving the EQ, to enhance the formation of floc in the clarifier. No pH adjustment is made at any point within the WWSRS or the CWTS.

The overflow from the clarifier flows to the wetland supply tank and then is pumped to the CWTS about one mile away. Sludge is pumped from the sludge tank to a set of three recessed chamber type filter presses ("plate and frame type"). The sludge is dewatered to about 60 -70 wt% solids and discharged to a truck located below the filter press discharge. Filtrate from the filter presses is pumped back to the EQ. A Maintenance

Tank is also included in the WWSRS system to act as a backup to the EQ or the Sludge Tank or the clarifier (for short durations), when any of them requires servicing. The dewatered sludge is hauled to an onsite lined landfill. Figure 3 depicts the CWTS flow diagram for Marshall Station.

The Marshall FGD units were brought on line between October 2006 and May 2007. The WWSRS started up in December 2006, and although it experienced some normal start-up challenges (see Lessons Learned), overall it is providing excellent results as indicated in Table 3. A couple items of note – the suspended solids in the FGD purge to the WWSRS were lower than expected and removal in this system was higher than expected. The design basis was for TSS at 16,000 ppm in the feed and 1,000 ppm in the effluent of the WWSRS. Actual values are about 6,000 ppm in the feed and <50 ppm in the effluent of the WWSRS. This could be attributed to a difference of operation in the FGD absorber resulting in lower TSS as well as more efficient solids removal than forecasted for the two stage hydroclone system in the gypsum dewatering process. It can be expected that the hydroclones will wear over time and the TSS likely increase somewhat, thus a capability (in the sludge tank and filter presses) to handle higher TSS levels at that time will be appreciated. The lower TSS level in the WWSRS effluent is attributed to higher efficiency of the clarifier and polymer flocculating effect than had been expected. The net effect of lower solids coming to the WWSRS is that the filter presses operate at fewer cycles per day and less solids cake is produced for haul away and disposal.

Another positive impact in the WWSRS was the higher reduction of mercury and selenium in the clarification stage than had been expected. This is explained by more of the mercury and selenium being in a suspended form than expected in the design basis and thus able to be significantly reduced by clarification. The net effect of this situation is that less load is placed on the constructed wetlands allowing them to function as a polishing process. From the data below, the WWSRS removes 74% of the total Se and greater than 98% of the total Hg.

Table 3: FGD Targeted Average Waste Water Parameters at Various Stages at Marshall Station

Parameter	FGD Purge	WWSRS Effluent
TSS, ppm	6000	50
TDS, ppm	17700	16900
Hg, ppb	77	1.5*
Se, ppb	3100	820
Cl, ppm	7800	7700

* Most values were below detectable limits which varied from 0.2 to 2.0 ppb.

Waste water solids removal
system

Bioreactor Pilot Plant

During the period of May through December 2007, a pilot test of the fixed film biological treatment system to be used at Belews Creek and Allen Steam Stations for the removal of selenium and other metals was performed at Duke Energy's Marshall Steam Station. It was determined that an opportunity to test the technology on actual FGD purge waters would provide valuable operating experience for the startup of the Belews Creek WWTS and provide potential design improvements for the Allen WWTS, still under construction. The specific objectives of the study were to:

- Demonstrate the process;
- Determine optimal operating parameters;
- Establish process limitations with regard to inlet metal levels and achievable treatment targets.

Key results of the study are as follows:

- Selenium removal below 100 ppb (performance guarantee for Belews Creek and Allen) was achieved for the entire test period.
- Selenium removal below 21 ppb (Allen NPDES limit) was achieved 80% of the time.
- Selenium speciation had no impact on bioreactor performance, including organic forms such as SeCN.
- Effect selenium removal was achieved during significant changes in influent water characteristics.
- 100% nitrate removal is not required to achieve effective selenium reduction.
- The use of DBA in the FGD Scrubber reduced the amount of nutrient addition required.
- Station upsets and shutdowns had no significant impacts on performance.

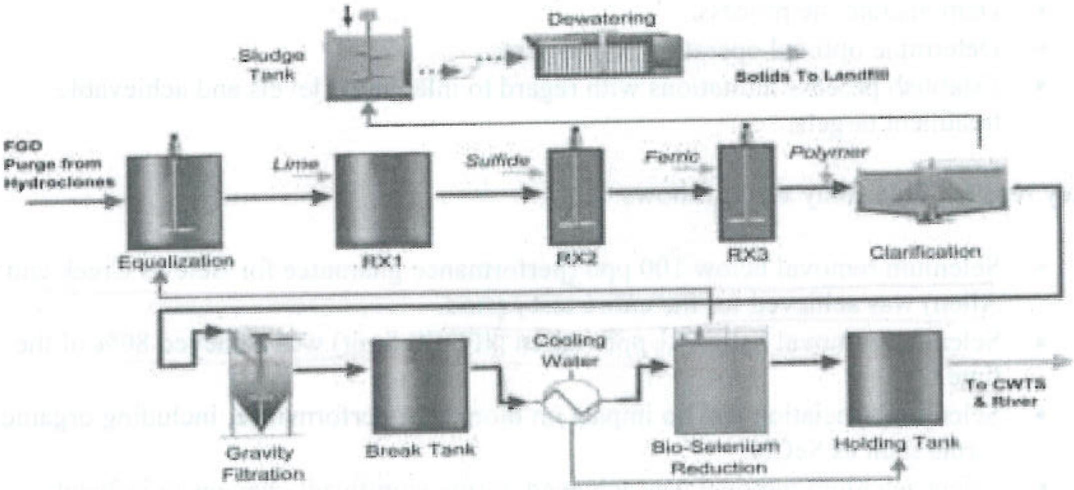
Belews Creek Steam Station

Belews Creek station is a two-unit coal-fired generating facility located on Belews Lake in Stokes County, North Carolina[7].

Duke Energy has made significant improvements to reduce emissions from the company's coal-fired plants. Both of the Belews Creek generating units have been equipped with selective catalytic reduction (SCR) devices to reduce nitrogen oxide emissions.

Belews Creek Station has more stringent discharge targets than Marshall Station, particularly for selenium and mercury. After evaluation of a number of treatment processes, it was determined to proceed with a combination of physical chemical treatment (basically like the typical physical chemical system in Figure 1) combined with a novel biological system utilizing specific strains of bacteria residing in a series of granular activated carbon filled bioreactors. Since this biological system was unproven in commercial operation, it was decided to also have a constructed wetlands treatment system following the biological system to act as a polishing step for final heavy metals reduction, if necessary.

Figure 4: Belews Creek Integrated WWTS

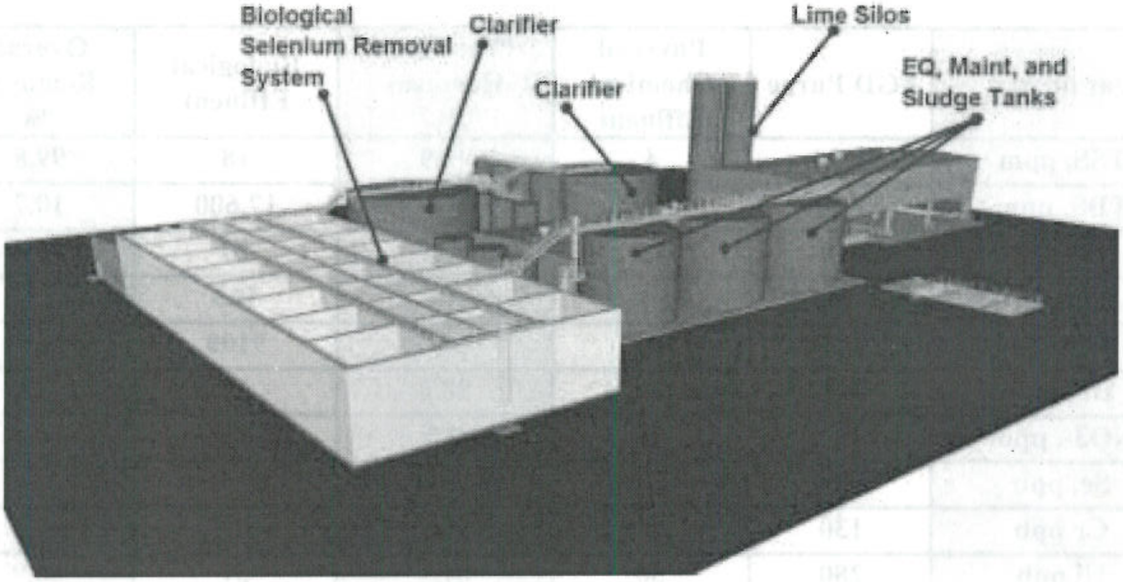


The process operations of the physical chemical treatment system and the CWTS have been described early in this paper.

The biological system is an anoxic/anaerobic, fixed-film, biological filter system. Activated carbon is used as a support media on which proprietary site-specific naturally-occurring bacteria cultures will grow and be retained within the bioreactor vessels. Activated carbon is used due to the very large surface area available for microbial growth. Moreover, much of the surface area is protected in crevices within each carbon particle, thus sheltering biomass from shear and abrasive forces. The biological system at Belews Creek operates in a down flow design.

The microorganisms require a food or carbon source. A molasses-based nutrient is used and is supplemented with micronutrients and other components shown to promote stable growth for the target microbial population. The nutrient can be added to the feed stream of each stage of the biological system. Belews Creek has a total of sixteen cells, two stages in series of eight parallel cells each,. DBA, which, Belews Creek Station will use periodically in the FGD, is another carbon source for the microorganisms. Periodically the bioreactor cells must be flushed, with post-treatment effluent, to allow the release of accumulated selenium, metals sulfides and other suspended solids that enter the cells from the influent solution, in addition to evolved gases, i.e. carbon dioxide and nitrogen.

Figure 5: Artist Depiction of Belews Creek WWTS



Throughout the process, online monitoring of pH and redox profile is done to ensure the health of the biological system and to aid in troubleshooting as required. The temperature of the influent to the BBTS should be maintained at 95°F by cooling in a heat exchanger.

For a more detailed description of the biological system, please refer to another paper being presented in this same session of the International Water Conference 2008.

Figure 6: Belews Creek WWTS

The Belews Creek WWTS began operation in support of the first scrubber absorber in February 2008 and began to receive full flow when the second absorber came online in

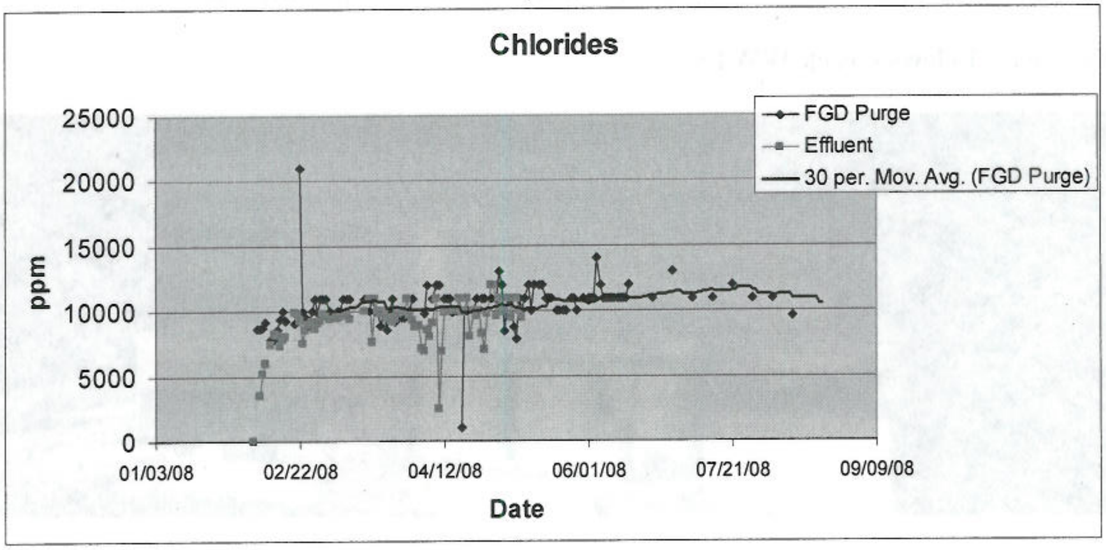
May 2008. The system has met expectations and is meeting the discharge requirements as indicated in Table 4.

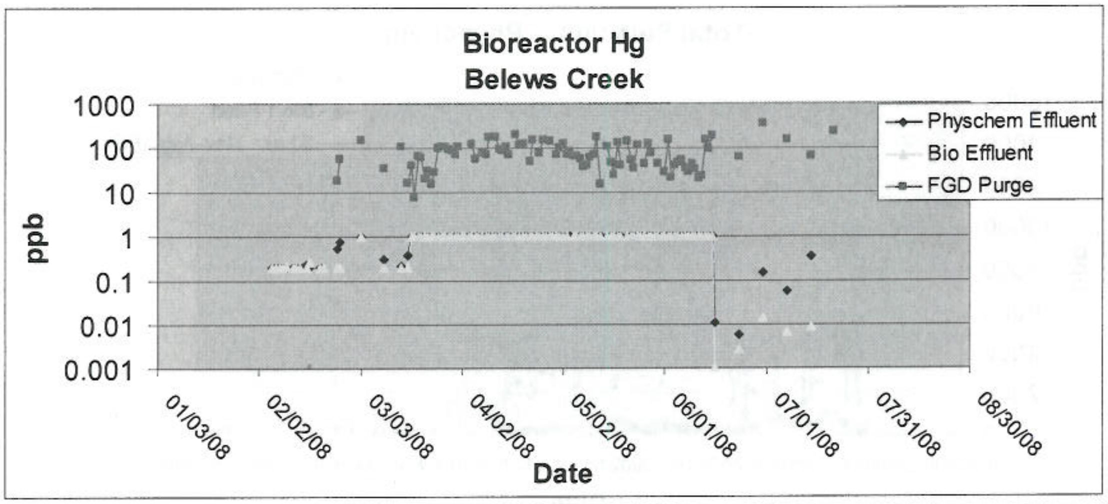
Table 4: FGD Waste Water Quality at Various Stages at Belews Creek Station

Parameter	FGD Purge	Physical Chemical Effluent	PhysChem Removal %	Biological Effluent	Overall Removal %
TSS, ppm	9600	4	99.9	18	99.8
TDS, ppm	19,700	18,200	7.6	17,600	10.7
As, ppb	510	11	97.8	29	94.3
B, ppm	210	---	---	163	22.4
Cl, ppm	10,500	---	---	9100	13.3
Hg, ppb	85	1*	98.8	1*	98.8
NO3-, ppm	9	9	0.0	0.5*	94.4
Se, ppb	5300	340	93.6	13	99.8
Cr ppb	130	10*	92.3	10*	92.3
Ni ppb	280	36	87.1	31	88.9
Zn ppb	260	12	95.4	11	95.8

* Detectable limit

Figure 7: Chemical Characteristics for Belews Creek Operations




Bioreactor Hg
Belews Creek
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0.1
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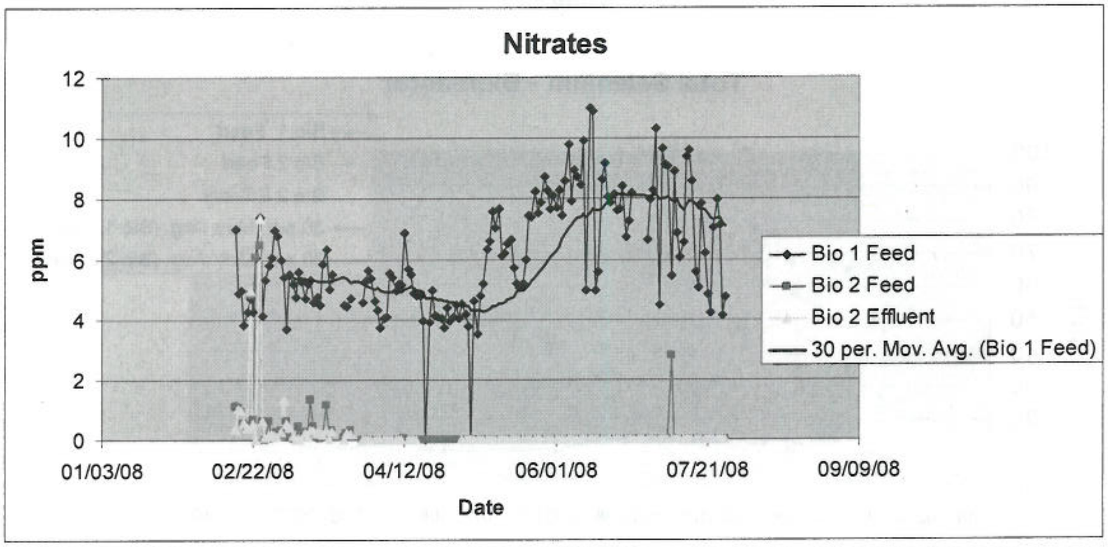
Physchem Effluent
Bio Effluent
FGD Purge


Nitrates
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10
8
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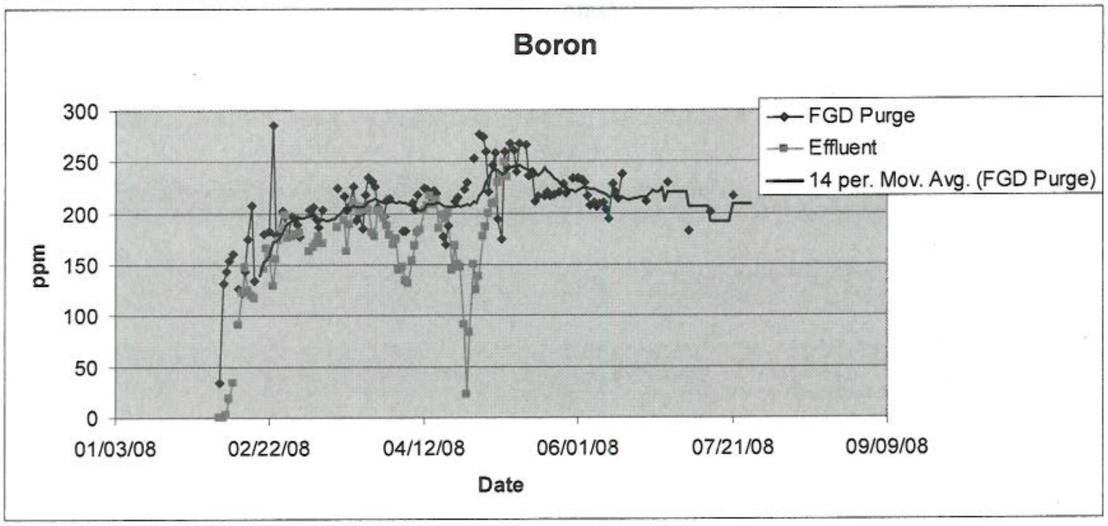
Date
Bio 1 Feed
Bio 2 Feed
Bio 2 Effluent
30 per. Mov. Avg. (Bio 1 Feed)


Boron
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FGD Purge
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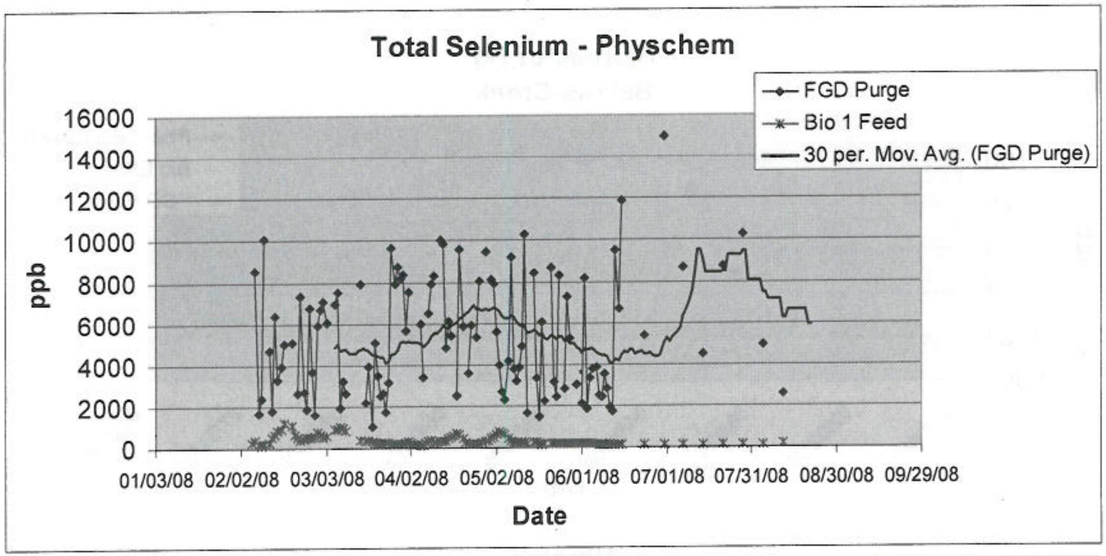
14 per. Mov. Avg. (FGD Purge)


Total Selenium - Physchem
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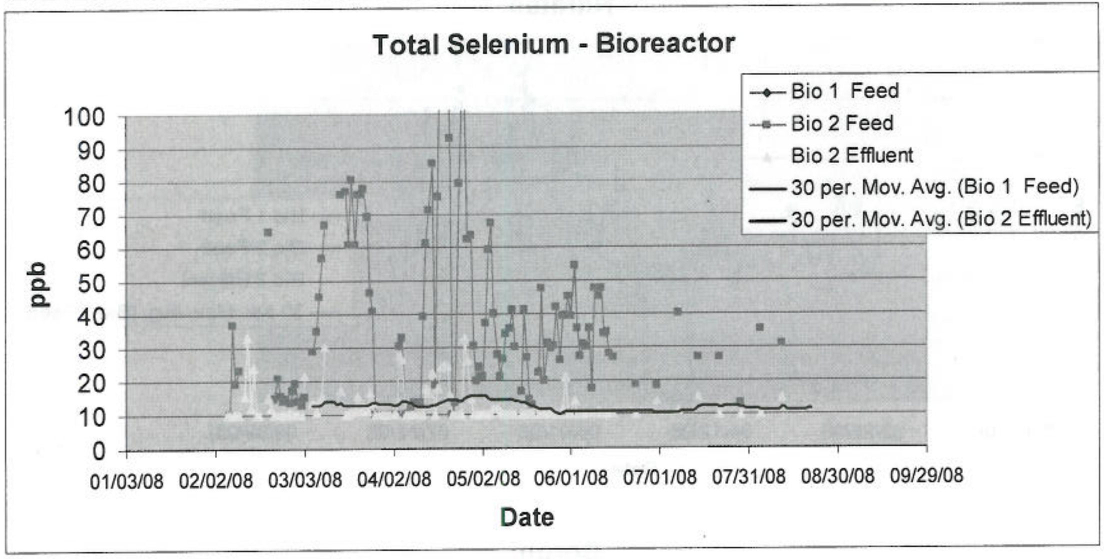
Total Selenium - Bioreactor
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Bio 2 Feed
Bio 2 Effluent
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30 per. Mov. Avg. (Bio 2 Effluent)
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80
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40
30
20
10
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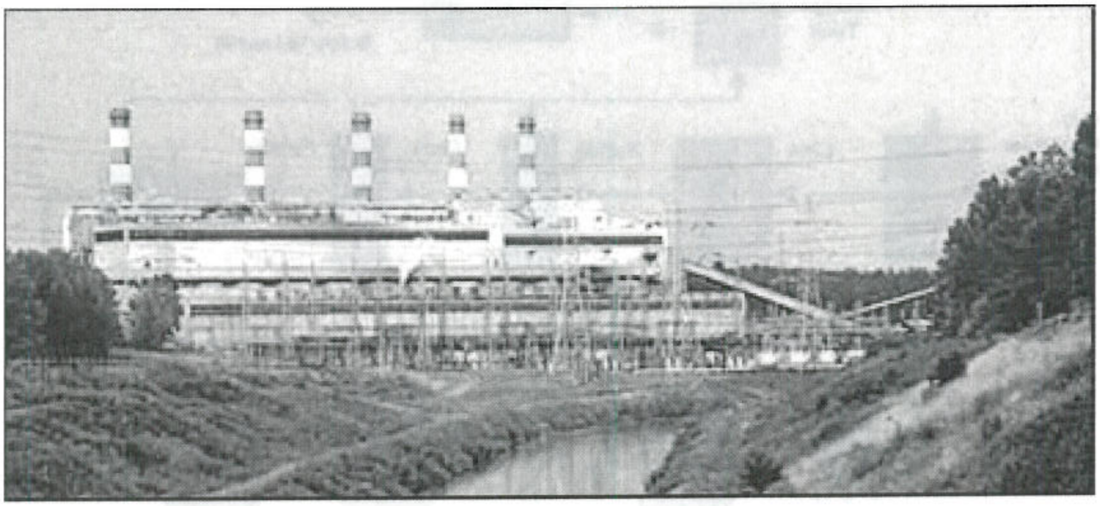
06/01/08
07/01/08
07/31/08
08/30/08
09/29/08
Date

Allen Steam Station

OUNDS, INC)

Located in Gaston County, North Carolina on the Catawba River, Allen station is a five-unit coal-fired generating facility[8].

Figure 8: Allen Station



Allen station has to meet stringent selenium discharge targets. Therefore, the waste water treatment system will be similar in design to the Belews Creek system, except at a 35% lower flowrate. However, at Allen the WWTS will not have a constructed wetlands treatment system following the selenium-reducing biological treatment system, based on successful pilot test performance of the biological treatment system. The Allen Station WWTS is currently under construction and scheduled for startup in early 2009.

Figure 9: Allen Station WWTS Flow Diagram

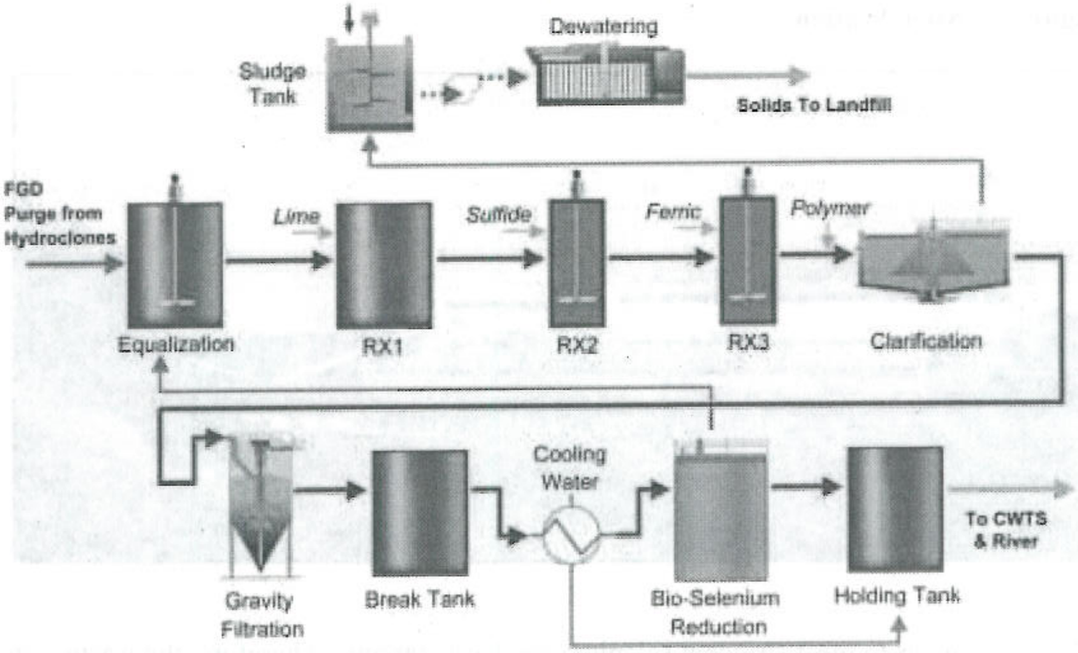
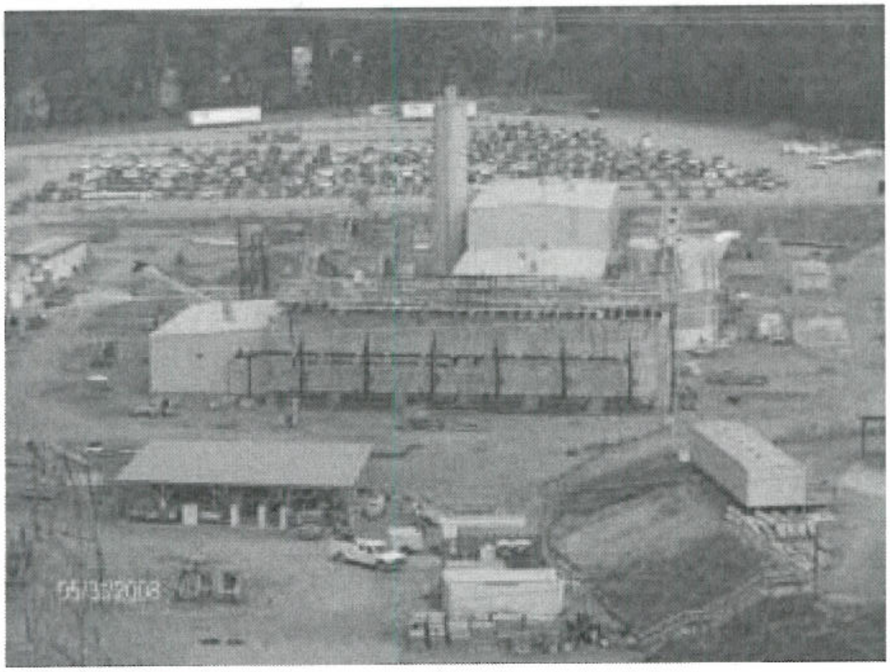


Figure 10: Allen WWTS Construction Site



Cliffside 5 Steam Station

Cliffside[9] station is a five-unit coal-fired generating facility with Units 1 – 4 located in Cleveland County, North Carolina. Although it is part of the same station, unit 5 is located in Rutherford County, North Carolina, one-half mile from the other four units. Due to their size and age, Units 1 – 4 will not be retrofitted with FGD, but rather retired.

Unit 5, Cliffside's largest unit, is equipped with a selective catalytic reduction (SCR) unit which reduces nitrogen oxide emissions. The retrofit with a wet limestone forced oxidation FGD system will complete the air quality control system upgrades for Cliffside 5. Thus a WWTS is required to treat the purge, however Cliffside 5 will be unique in some ways. Cliffside 6 has been approved by the North Carolina Public Utility Commission as a greenfield power plant near Cliffside 5, and will utilize a unique scrubber configuration. Cliffside 6 will have both a wet FGD and dry FGD with the purge stream from the wet FGD being used as liquid for the reagent to be sprayed in the dry FGD. The dry FGD will be sized to also use the purge from Cliffside 5's wet FGD as reagent makeup, thus eliminating the need to operate Cliffside 5's WWTS when the dry FGD is in operation. Thus, after Cliffside 6 becomes operational, Cliffside 5's WWTS will be layed up and be made available for scheduled outages when the dry FGD would not be operational.

Figure 11: Cliffside Station

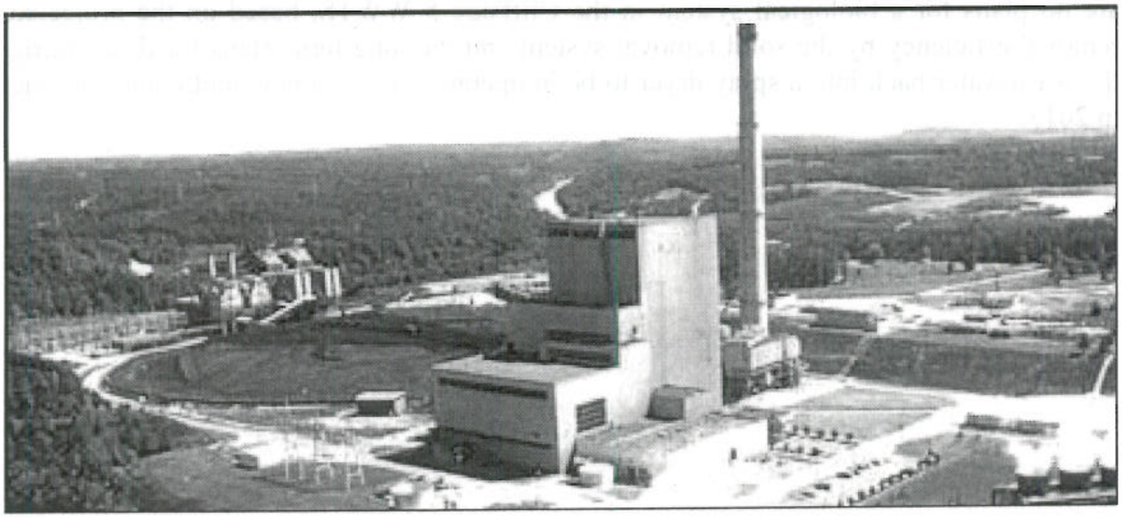
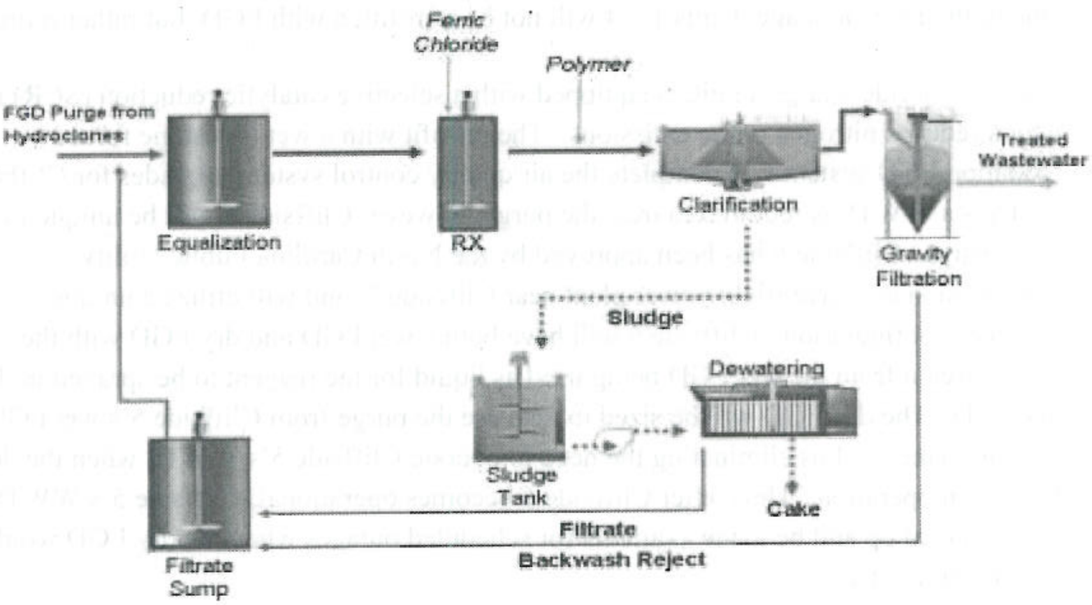


Figure 12: Cliffside WWTS Flow Diagram



For Cliffside unit 5, the WWTS will include a physical chemical system. This system's primary components include an Equalization Tank, a Reaction Tank for the addition of ferric chloride, a Clarifier, Gravity Filters and a Filter Press dewatering system. There are no plans for a biological system in the Cliffside 5 WWTS, based on the projected removal efficiency by the solid removal system and the long term plans for discharging the wastewater back into a spray dryer to be in operation when a new unit comes on line in 2013.

LESSONS LEARNED

The key lessons learned from these projects are:

- Selection of appropriate polymer is important for the clarification step. Since polymer effectiveness is not an exacting science, jar testing of similar waste water can assist in identifying the polymers that could produce the best success.
- Use of potable water in the polymer system is essential, rather than filtered service water, to prevent plugging of lines.
- Incorporate drive-through bays for filter press solids removal and chemical delivery trucks, if space allows.
- Scrubber units will start up at different intervals; so it is important to have a plan of operation of the WWTS under partial flow conditions, in order to maintain minimum levels in tanks, minimum velocities in pipes, and the chemistry of the treatment process. The chemistry of the FGD purge will likely change during the startups of the FGD units as their operation is adjusted towards optimization.
- Plant staff indicated they would prefer to have all pumps located indoors for access and maintenance.
- Access walkways on common levels throughout the plant and proved to be efficient.
- Mercury can be effectively removed in both the physchem and biotreatment operations without the use of organo-sulfides.
- FGD Purge water characteristics are difficult to predict and vary with scrubber design, station operations and the type of the coal burned. Scrubber vendor specifications of the FGD purge stream need to be critically reviewed to provide the most economical WWTS to meet requirements.
- Appropriate analytical procedures must be used in analyzing FGD purge/waste waters. Standard selenium methods yielded results 10 times higher than actual concentrations due to bromine interferences. Analytical interferences have been identified using standard methods for several of the constituent compounds.
- Extensive analytical analysis for the first several months of operation is critical in identifying normal FGD Purge water, system operating characteristics and system performance.
- Generation, FGD and WWTS are all integral to the efficient operation of a coal fired facility. None can effectively operate without adequate coordination between the functional groups.
- DBA has no adverse impact on WWTS performance.

SUMMARY

Proper treatment of the flue gas desulfurization purge stream is an essential part of a wet limestone forced oxidation FGD retrofit project, unless direct or mixed discharges are allowed for a power plant. Specific treatment steps, based on proven process technology, integrated into a system with the appropriate equipment components, controls, operator interfaces, flexibility of design, redundancy of equipment, and good control of the chemistry in the system will result in a reliable operation and ability to meet the plant's discharge requirements.

Operational experience to date shows that FGD purge streams can be effectively treated to reduce a range of metals, suspended solids and nitrates. Additional studies are required, in coordination with regulatory agencies, to develop valid standardized analytical methods to monitor the performance of these treatment systems.

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