Operating Experience on the Treatment on FGD Scrubber Blowdown From Existing Generating Stations

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Summary: Existing FGD installations in the United States have been addressing the treatment of FGD scrubber blowdown for many years. With the increased number of FGD projects planned in the United States, wastewater treatment is both a great concern and mystery for many utilities planning new installations.

This paper reviews operation practices and design considerations of Infilco Degremont (IDI) and Degremont Group installed FGD wastewater treatment systems worldwide.

INTRODUCTION

Amendments to the original 1990 Clean Air Act resulted in the initial SO$_2$ control requirements for coal-fired power plants in the mid-1990’s. These amendments initiated a new phase of installation of Flue Gas Desulfurization (FGD) scrubbers in the United States. The Clean Air Interstate Rules (CAIR), first filed by the EPA in 2004, required that more stringent requirements for SO$_2$ and NOx emission control be met in phases by 2010 and 2015.

The Degremont Group, has been a leading provider of FGD wastewater treatment systems worldwide since the first installation of FGD scrubbers, which incorporated the production of saleable gypsum, were installed in Germany in the 1980’s. With over 35 installations worldwide, the Degremont Group has developed an extensive working knowledge of the operation of FGD wastewater treatment systems. Infilco Degremont (IDI), the US based subsidiary of the Degremont Group, has installed three FGD wastewater treatment systems in the US and is presently designing numerous more.

WASTEWATER CHARACTERISTICS

The most important factor when considering FGD wastewater treatment is the influent characteristics of the FGD blowdown (wastewater). Table 1. shows the typical ranges of constituents found in FGD wastewater.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Typical Influent Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended Solids (TSS)</td>
<td>mg/L</td>
<td>250 - 20,000</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>15,000 – 35,000</td>
</tr>
<tr>
<td>pH</td>
<td>mg/L</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>mg/L</td>
<td>10,000 – 25,000</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>200 – 500</td>
</tr>
<tr>
<td>Ammonia (NH$_4$)</td>
<td>mg/L</td>
<td>20 – 60</td>
</tr>
<tr>
<td>Nitrate (NO$_3$)</td>
<td>mg/L</td>
<td>30 – 120</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>mg/L</td>
<td>300 – 5,000</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>mg/L</td>
<td>50 – 4,000</td>
</tr>
<tr>
<td>Sulfate (SO$_4$)</td>
<td>mg/L</td>
<td>3,000 – 5,000</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>mg/L</td>
<td>40 – 100</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>mg/L</td>
<td>20 – 200</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>mg/L</td>
<td>0.5 – 0.8</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>mg/L</td>
<td>1-10</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>mg/L</td>
<td>0.05 – 0.1</td>
</tr>
</tbody>
</table>
### TREATMENT SYSTEM DESIGN

The original process for FGD wastewater treatment developed by Degremont in Germany in the 1980’s had the following operations:

1. **Flow equalization**
2. **Primary clarification of suspended solids**
3. **pH elevation/\text{CaSO}_4\text{ Desaturation}**
4. **Sludge Recirculation to enhance desaturation**
5. **Heavy metal precipitation with organo-sulfide chemical addition**
6. **Coagulation with ferric chloride addition**
7. **Polymer addition to enhance flocculation of solids**
8. **Solids separation and thickening**
9. **Final Clarification**
10. **Sludge dewatering**

The operational feedback from installed facilities has led to numerous modifications to the original design, some which are discussed below:

1. **Due to the efficiency of the IDI’s patented DensaDeg clarifier, a primary clarification step is no longer required.** In general, primary clarification was determined to be unnecessary for FGD wastewater with TSS concentrations of less than 2.5 % when using the DensaDeg clarifier.

2. **Combining the Coagulation and Heavy Metal Removal tanks into one reactor**

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### CHEMICAL CONDITIONING

Chemical conditioning of the FGD wastewater is an important factor in meeting the stringent effluent limits set by Environmental regulators. Improper chemical conditioning will lead to operational difficulties and system failure.

**Coagulation**

The addition of iron or aluminum for coagulation and/or charge neutralization is a standard practice in wastewater and water treatment. The normal practice in FGD wastewater treatment is the addition of ferric chloride for coagulation. In FGD wastewater treatment, the process of iron co-precipitation is an extremely important in the removal of heavy metals from the wastewater. IDI’s review of operating FGD wastewater treatment plants has indicated that ferric chloride addition is not normally required, due to adequate amounts of iron being present in the wastewater. The source of this iron is the limestone Crushing Mill. The limestone Crushing Mill uses iron balls for the crushing of limestone and during the crushing process these iron balls are consumed, winding up in the scrubber.
Lime

The addition of lime slurry to FGD wastewater elevates the pH in the wastewater therefore facilitating the precipitation of tri and bi-valent metals into their insoluble hydroxide forms. The lime slurry addition also causes the elevation of calcium ions in the wastewater, which leads to additional CaSO$_4$ precipitation. Hydroxide precipitation is the main chemical process for the removal of heavy metals in FGD wastewater treatment. The main concern when selecting a lime supply is the concentration of impurities within the lime, especially Mg. High concentrations of these impurities will lead to additional sludge production, which will then lead to increase cost for sludge handling and disposal.

One of the more interesting operating experience’s concerning lime feed stock was a facility received a feed stock that was exceptionally low in Mg. The resulting sludge produced during this period was extremely heavy and basically was unable to be pumped out of the clarifier to the sludge holding tank. Once the facility return to the original feedstock the sludge became easier to pump.

Sulfide

Sulfide chemicals (TMT, Nalmet, Na$_2$S, etc.) are added to enhance the removal of heavy metals especially Hg. In most cases sulfide addition has not been necessary to achieve Hg limits of 25 ppb, but with newer permits requiring limits of 0.2 ppb in some states sulfide addition will be necessary. Organo-sulfide compounds (TMT, Nalmet) are not as efficient as inorganic sulfide compounds at the remove of Hg, IDI’s experience has indicated to achieve effluent limits of 0.2 ppb, that inorganic sulfide may be required.

Polymer

The flocculation of the suspended solids is required for the removal of the fine particulates present in FGD wastewater. To aid in the flocculation process a high weight, highly charged, anionic polymer with a dosage rate between 4 – 8 ppm is normal used. The polymer’s mode of action is the flocculation of CaSO$_4$ crystal into large flocs, which then captures the fine particulates by a sweeping action. In general, IDI’s designed FGD wastewater treatment systems are able to produce an effluent of < 2 NTU. One of the facilities had a discharge toxicity problem with an emulsion based polymer and had to change to solid polymer.

HCl

Hydrochloric Acid is added to the clarified water to lower the pH and limit the scaling potential of the wastewater before discharge. In some FGD facilities, the effluent is allowed to leave at elevated pH for neutralization of coal pile runoff. The first IDI system incorporated an in-line mixer for HCl addition followed by a gravity filter in short procession. The gravity filter twice plugged due to scaling and was finally taken out of service. IDI’s investigation into this issue determined that short residence time and inadequate mixing did not allow for proper neutralization. The new designs incorporate a separate effluent tank for pH neutralization with adequate mixing and residence time.

EQUIPMENT AND MATERIALS SELECTION

Due to the nature of the FGD wastewater;

i. High chloride concentration
ii. High solids concentration
iii. Abrasive and corrosive environment

Special attention to the materials of construction must be taken when designing and operating a FGD wastewater treatment system.

Piping

The first FGD wastewater treatment systems installed in Germany by the Degremont Group utilized Carbon Steel Rubber Lined (CS/RL) piping. IDI incorporated CS/RL piping into, our first installations in the United States. Fiberglass (FRP) and High Density Polyethylene (HDPE) piping have replaced CS/RL piping in newer installations. FRP and HDPE piping have some key advantages over CS/RL:
i. Lower Capital cost  
ii. Lower Installation cost  
iii. Easier Maintenance

When choosing between FRP and HDPE piping, the FGD wastewater treatment system designer and/or operator must choose between the ease of installation and lower capital cost of HDPE versus the higher structural strength and therefore lower pipe support requirements of FRP. While reviewing present FGD wastewater treatment systems, IDI discovered that PVC piping has also been used by plants to replace CS/RL piping for low-pressure applications, such as gravity process lines between FGD treatment reactor tanks.

Tanks

CS/RL tanks were used on the initial wastewater treatment systems in Germany and US. IDI installations have not seen any failures of the rubber lining in our installed process tanks. But, FRP tanks or carbon steel coated tanks have replaced CS/RL tanks on most if not all new FGD wastewater treatment systems, due to capital cost savings. The coating systems for carbon steel tanks in an FGD wastewater treatment application are very specialized.

Centrifugal Pumps

The standard slurry process pump in FGD wastewater treatment has been a belt driven, rubber-lined, centrifugal pump, which is designed to handle high solids that are abrasive, which are present in the FGD blowdown coming from the absorber. This type of pump is still utilized in most FGD treatment systems.

Sludge Dewatering

The most expensive unit operation in FGD wastewater treatment is sludge dewatering. The type of sludge dewatering equipment chosen for a power plant is dependent of two parameters:

i. Sludge Production

ii. Sludge Characteristics

Sludge production is an important factor when choosing the type of dewatering equipment. The higher the amount of solids produce the more likely a continuous sludge dewatering type of equipment (Belt Filter, Rotary Drum, etc.) will be used due to capital cost and operating ease. Smaller FGD treatment systems with low sludge production will more likely use a batch type system (Recessed Plate and Frame style), due to dryer sludge cake production. Table 2 shows the typical characteristics of filter press cake found in FGD systems.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Typical Influent Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Insoluble Solids</td>
<td>% wt</td>
<td>20 - 30</td>
</tr>
<tr>
<td>Calcium Sulfate (CaSO₄·2H₂O)</td>
<td>% wt</td>
<td>55 - 65</td>
</tr>
<tr>
<td>Calcium Carbonate (CaCO₃)</td>
<td>% wt</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Magnesium Hydroxide (Mg(OH)₂)</td>
<td>% wt</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Solids</td>
<td>% wt</td>
<td>50 – 65</td>
</tr>
</tbody>
</table>

Numerous TCLP analyses on FGD sludge cakes have demonstrated that the sludge has no unique handling or disposal requirements.

Disposal of FGD sludge cake has a major impact on the operating cost of a FGD treatment facility. While most plants dispose of their cake in either an onsite landfill or a local sanitary landfill, one of IDI’s facilities came up with a unique disposal method. The facility blends their waste cake with off-spec gypsum and then sells the blended cake to a concrete production facility.

The standard sludge pump in many applications in wastewater treatment for sludge dewatering has been air or mechanical driven diaphragm pumps. The initial Degremont Group FGD treatment systems in Germany used a mechanical driven diaphragm pump for sludge dewatering. This pump was a high-pressure pump, able to produce pressure up to 150 psig. It was thought this pressure was required for proper sludge dewatering. IDI utilized the same
pump in our first systems. The pump is extremely expensive and has high maintenance requirements, due to the rubber diaphragms being continuously ripped apart by sludge having high fly ash content. The operating facilities also indicated that 150 psig was not required for proper dewatering and did not seem to decrease the filter press cycle times. IDI’s newer designs incorporate the use of progressive cavity pumps for sludge dewatering. Progressive cavity pumps are extremely flexible in FGD applications they can be used to feed either continuous dewatering equipment or batch type equipment.

One of newer requirements that IDI is seeing at utilities is the installation of dry running mechanical seals instead of flushed packing. While, the mechanical seals eliminate the need for flushing water, they are extremely expensive and must be carefully installed.

OPERATING EXPERIENCES

IDI’s FGD wastewater treatment systems have been in operation for more than 10 years in the United States and the Degremont Group has installation operating in Europe for over 15 years. During this period IDI has expanded its database and developed valuable insight into the operations of FGD wastewater treatment plants.

Initial Start-up

The first hurdle that an FGD wastewater treatment system is going to face is the initial start-up phase. At most facilities the wastewater treatment system is started-up when the initial absorber goes into operations, followed by additional absorbers coming on-line at later dates. Therefore the wastewater treatment system may not see the design flow for a period of weeks to more than a year. Past experience has indicated that the facility will take about 2 – 4 months to reach steady state after each absorber start-up. During this period the system will see wide swings in loading and characteristics of the wastewater. The operator must monitor the system closely to ensure proper equalization and flow control of the wastewater, to achieve the operating performance required, during this phase of operations. Start-up will require additional manpower and process testing to ensure proper operations.

Normal Maintenance Requirements

Routine maintenance is a requirement of all operating systems in a power plant, FGD systems in particular require additional routine maintenance due to the operating environment and scrubber water characteristics. Instrumentation which comes into contact with the wastewater (pH, Temperature, Conductivity, etc., probes) may require cleaning and recalibrating weekly due to the high scaling potential of the water. Rotating equipment (Pumps and Mixers) should be checked yearly. Process tanks should also be checked yearly.

Manpower Requirements

One of the first questions asked by a future FGD system operator, “What are the manpower requirements to properly operate this system?”. To properly operate an FGD facility, including the scrubber, a dedicated staff must be trained. Operating an FGD system is more art than science, therefore rotating operators through the system will most likely lead to process failure and permit violations. The normal staffing level that IDI has seen at FGD wastewater treatment plants is two (2) – three (3) operators per shift, one (1) chemist and one (1) supervisor that can be shared with absorber. A dedicated maintenance team can be used for the FGD wastewater treatment plant but at most plants the facilities maintenance department is utilized. The most labor intensive area of a FGD wastewater treatment plant is the solids dewatering and handling systems, which may require 24 hour supervisor, based on the solids production at the facility.

SUMMARY

In summary, the treatment of FGD wastewater can be challenging, but with the proper system design, chemical conditioning, and operations a
treatment system can meet or exceed the permit requirements.

REFERENCES


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