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FGD Wastewater Treatment Still Has a Ways to Go

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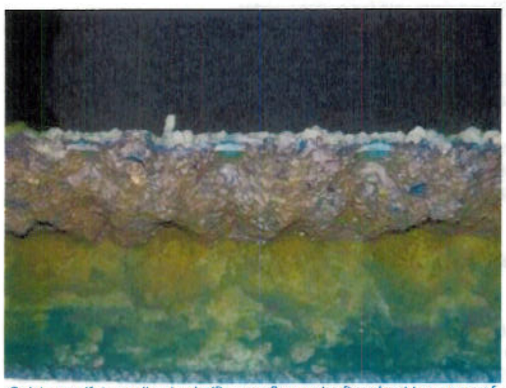
The power industry should jointly address questions about FGD water treatment and share the lessons it has learned so far.

By Thomas Higgins, Silas Givens and Tom Sandy - CH2M Hill

The composition of flue gas desulfurization varies widely, based on scrubber type and coal and limestone used. Coal contributes acidic gases, such as chlorides, fluorides and sulfate. Coal also contributes volatile metals, such as arsenic, mercury, selenium, boron, cadmium and zinc. Nonvolatile compounds such as silica and iron from coal tend to end up in the bottom ash.



Calcium sulfate scaling in clarifier overflow weir after about two years of operation. Photo courtesy of CH2M Hill.
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Limestone contributes clay minerals such as aluminum to the FGD wastewater and the clays tend to contribute the inert fines that are among the reasons wastewater is purged from the scrubber. The other most common reason for purging wastewater is the buildup of chlorides, which are typically limited to 12,000 milligrams per liter (mg/L), based on the metallurgy used in the scrubbers. With corrosion-resistant metallurgy, chlorides can be handled up to 35,000 mg/L, reducing wastewater production.

CH2M Hill contacted the Electric Power Research Institute (EPRI), FGD wastewater treatment equipment vendors and scrubber manufacturers to obtain information for typical FGD wastewater composition. These results are compared to values collected at eight operating FGD systems. Four of the samples were of wastewater that had undergone settling before the collection point; these were not analyzed for total constituents. For the other four sites, total and soluble (filtered) analyses were performed.

Wastewater Treatment Lessons Learned

Figures 1 and 2 depict a wastewater treatment scheme developed by CH2M Hill to treat FGD wastewater and remove heavy metals. In this particular plant, CH2M Hill desaturated the wastewater of sulfates and removed the bulk of the insoluble suspended solids prior to tertiary treatment of heavy metals and arsenic using a chemical/physical treatment process. Additional treatment could be provided (for example, anoxic biological treatment) for selenium, nitrates and organics.

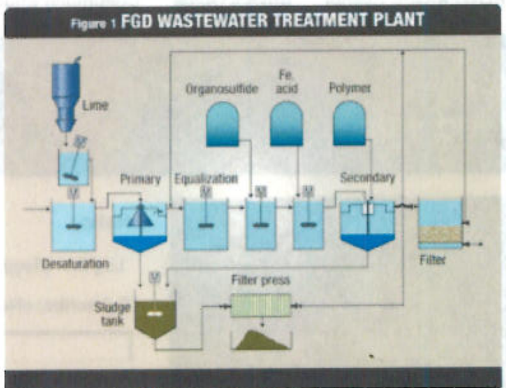

Figure 1 FGD WASTEWATER TREATMENT PLANT

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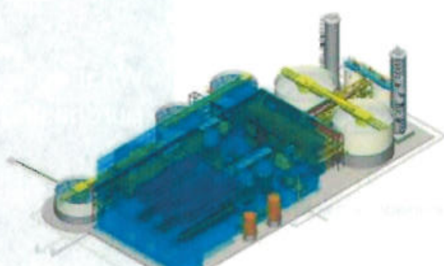

Figure 2 FGD Wastewater Treatment Facility Designed by CH2M HILL

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Because of the highly complex nature of FGD wastewater, several stages are required to treat the wastewater blowdown from the FGD scrubber to meet National Pollutant Discharge Elimination System (NPDES) requirements for surface water discharge.

FGD wastewater treatment typically consists of the following steps: calcium sulfate desaturation, primary clarification, equalization, trace metals precipitation and flocculation, secondary clarification, filtration and solids dewatering.

The desaturation process reduces the concentration of dissolved sulfate in the FGD wastewater. This is best achieved by adding enough lime to raise the influent pH to approximately 8.5 resulting in the precipitation of calcium sulfate. Raising the pH higher would result in precipitation of calcium carbonate, using up lime and increasing the volume of sludge requiring disposal.

The calcium sulfate scaling potential is high and must be considered in the design. The above shows the effect of calcium sulfate scaling on a clarifier weir after a couple of years of operation.

Traditional wastewater treatment provides equalization first. However, calcium sulfate solubility increases as the temperature decreases. CH2M Hill has modified the conventional practice of providing equalization to treat the higher temperature wastewater (typically 115 F to 130 F) before it cools and solubility increases. By providing desaturation first, the water is treated to its lowest solubility. By providing equalization after desaturation, the water cools to a lower temperature, where calcium sulfate is more soluble, reducing downstream scaling potential. Also, by having equalization after primary treatment, low-sulfate waste streams such as filter press cloth washwater can be sent there, further reducing the concentration of calcium sulfate.

By recycling sludges to the desaturation tank, the concentration of solids is increased, providing additional precipitation sites for calcium sulfate precipitation, reducing scaling on tank walls and weirs. This crystallization also has a benefit of producing denser solids, improving settling in the primary clarifier and subsequent dewatering.

Primary Clarification

Primary clarification is provided to remove the bulk of the suspended solids present in the FGD wastewater and to remove calcium sulfate solids produced in the desaturation reactor. Primary clarifiers also can serve as thickeners for the resulting sludge and for sludge storage. Loading is based on the overflow rate (the flow of water over the effluent weirs divided by surface area).

The concentration of expected solids in the FGD wastewater will determine if primary clarification is needed. If the FGD system uses primary hydroclones only and wastes, then the total suspended solids (TSS) of the FGD wastewater is likely in the 4 percent to 7 percent range and primary clarification is needed to meet a low TSS effluent limit and reduce solids loading on metals removal processes. If the FGD system uses primary and secondary hydroclones and wastes the overflow from the secondary hydroclones, then the TSS in the wastewater is likely to be consistently less than 2 percent and primary clarification can be eliminated.

Primary clarifiers can store sludge, reducing the volume of sludge storage tankage required. To accommodate the dense

The wastewater's scaling nature and high solids content make sludge piping design critical. Using gravity flow between desaturation and primary clarification results in pipes that are self-draining when the flow is stopped. Piping should be designed for easy cleaning and replacement and should include automated flushing of sludge lines and pumps when turned off.

The rate at which sludge is produced and dewatered varies during the drying cycle. If this is matched by varying the flow of sludge pumps from the clarifiers or if the flow is constant and the pumps are cycled on and off frequently, there will be a tendency for velocity in the sludge lines to be less than needed to keep solids in suspension. By recirculating sludge from the filter press area back to the desaturation tank, the sludge withdrawal from primary clarifiers can be maintained at a constant line-cleaning flow.

Selenium Removal

Modern forced-oxidation FGD system wastewater contains selenium, predominately in the selenate form. While selenite can be somewhat removed by iron co-precipitation, selenate is soluble and is not removed in the treatment processes mentioned earlier. Effective treatment requires reduction to selenite or to elemental selenium.

Treatment of FGD wastewater is complicated by the presence of high concentrations of sulfate, which is very similar to selenate, and nitrates, which compete with the selenate to serve as oxidation sources. In addition, keeping a biological treatment process active is challenged by the variability of the wastewater composition and organic content. Additional work is needed before these treatment processes can be reliably employed.

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nature of the sludge, primary clarifiers should be designed more like thickeners than clarifiers, with a high torque mechanism and steep bottom slope. Sludge solids can typically be between 10 percent and 15 percent solids. Recently, in a plant employing sludge recirculation to desaturation, sludge underflow approached 25 percent solids when sludge was stored for a few days without dewatering. Reducing the sludge inventory by increasing the frequency of dewatering reduced this volume to a more reasonable 15 percent.

Equalization is provided for situations in which the total daily flow is delivered to the treatment plant intermittently and to more evenly distribute flows and composition of internal recycle flows such as filter press filtrate, gravity filter backwash and filter cloth wash. Mixing keeps any remaining solids in suspension.

Equalization can be placed before or after primary clarification. If performed before clarification, as in most other types of wastewater treatment, the clarifier and associated equipment can be sized to handle peak daily flow rather than instantaneous peaks. One advantage of placing equalization after primary clarification is the ability to desaturate the incoming wastewater while hot.

Unlike most wastewater treatment plants, the waste TSS concentrations are near those of clarifier sludge. As a result, primary clarifier underflow to dewatering is a significant portion of the waste flow. Returning the sludge dewatering filtrate to equalization, if located before primary clarification, would require retreating this relatively clean water and increasing the size of the primary clarifiers.

Tertiary treatment is target-pollutant-specific. Metals can be treated through chemical, physical and biological means. Iron co-precipitation removes cationic metals and arsenic and also assists in solids removal through flocculation of negatively charged particles. Adding organosulfide precipitants lowers the levels of cationic metals such as mercury.

Iron, typically from ferric chloride, is added to coagulate suspended solids. Recirculating sludge to this reactor results in improved metals removal and the formation of a denser sludge that improves settling, reduces the need for polymer addition and improves mixed sludge dewaterability. To avoid solids shearing, this and other mix tanks should be designed with large-diameter, variable-speed mixers. Reactor residence time is based on pH control and the mixer should be more like a flocculator than a rapid mixer.

An acid such as hydrochloric acid is added to control pH within the range required for this treatment process. Hydrochloric acid is preferred over sulfuric acid, as the water is near saturation for calcium sulfate. What's more, sulfuric acid can result in calcium sulfate scaling, particularly if filtration is used for polishing.

Enhanced Metal Precipitation

If additional cationic metals removal (particularly mercury) is required beyond what can be done with iron co-precipitation and filtration, organosulfide can be added to enhance these metals' precipitation. Mercury is particularly difficult to remove in FGD wastewater due to the high concentration of chlorides, which can form soluble complexes. To counter the solubility of mercury and other cationic metal chloride complexes, FGD wastewater can be treated with a cationic metal-binding polymer such as an organosulfide.

Polymer is added to aid in removal by subsequent settling. Anionic polymers are typically used, because the previous addition of iron and lime can give the resulting solids a net positive surface charge. It is recommended that polymer be used only if necessary. After sludge recirculation is well established, the use of iron alone should be sufficient to produce a well-settling solid.

Solids that pass through the primary clarifiers and have been generated in the chemical reaction tanks can then be removed by settling in secondary clarifiers. Some of the sludge should be recirculated to the mix tanks to seed a crystalline precipitate to improve settling and dewatering.

Filtration may be required to meet TSS limits and is required to meet parts-per-billion metal limits. Gravity dual-media filters are recommended to follow the secondary clarifiers. The advantage of gravity filters is the lower shear produced by gravity feed. Filter sand is subject to scaling, so if a filter is installed, special care is needed to limit scaling and to monitor and replace media early, rather than after scaling causes filter media cementation.

The solids removed in the treatment processes must be dewatered. If solids are to be landfilled, a regulatory limit of "no free liquid" in the dewatered sludge probably will be imposed. In FGD systems that produce a high solids wastewater, solids dewatering becomes a significant portion of cost and plant size. It is also a critical step and must be designed to leave the over power plant's reliability unaffected.

Residuals management strategies must be considered, given the volume and mass of solids produced. FGD wastewater solids tend to be thixotropic when dewatered to 40 percent to 50 percent solids. In this state, they tend to take the shape of their container and are difficult to remove after transport. Increasing the solids content to 60 percent during dewatering reduces the potential for thixotropy and also reduces the danger of free water forming during transport.

The most common wastewater treatment sludge dewatering technologies are centrifugal dewatering, pressure filtration using belt press and pressure filtration using a plate-and-frame filter press. FGD wastewater fines could also be stabilized for disposal by mixing with a stabilizer such as fly ash. Of the available sludge dewatering technologies, plate-and-frame presses maximize dryness and are the most likely technology to achieve the "no free liquid" requirement. These presses also maximize sludge compaction, reducing the cost of subsequent disposal. The addition of polymer with the other two technologies results in less attractive sludge landfilling characteristics. While belt presses are less expensive to buy and can be fit into a smaller and less expensive building, the additional conditioner costs offset the savings in a few years.

Pumps for Filter Press Operation

Various pumps have been used for filter press operation. It is desirable to rapidly fill the press, then reducing flow as the pressure builds and the water is extracted. Using two variable-speed centrifugal pumps in series provides a cost-effective combination of flow capacity and pressure. The pumps must be programmed to limit flow at low pressure and build speed as the resisting pressure increases. Positive displacement pumps are not economical when combining the need for high flow and high pressure, and require considerable preventive maintenance.