POWER ENGINEERING

Ensuring Compliance with Proven ZLD: Capitalizing on EPA Incentives

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WFGD ZLD System at ENEL Sulcis, Italy, showing Brine Concentrator and Mechanical Vapor Compressor in the foreground. Photo courtesy: Aquatech International.

In September 2015, the Environmental Protection Agency put forward the final rule for Effluent Limitation Guidelines (ELGs), which establishes revised water discharge standards for the steam electric power generation industry. The final rule took the EPA a decade to develop and it finally became effective on January 4, 2016. The onus is now on the power industry as a whole to study the rule in light of their current (and future) water discharge practices. Experienced technology suppliers will play a key role on the pathway to compliance by applying commercially proven Zero Liquid Discharge (ZLD) solutions to overcome site-specific challenges.

Falling Behind and Catching Up

The previous set of steam electric ELGs had been in effect since 1982 without revision. After careful study, the EPA determined that the ELGs were "out of date" and that toxic pollution levels that were being discharged into America's watersheds were causing harm. The study reported that almost half of the waterbodies receiving power plant discharge exhibited pollutant levels that exceeded the limits established by the human health water quality criteria (EPA, 67840). At first glance, the term "out-of-date" can seem strange when discussing pollutant levels, since pollutants are pollutants and they cause harm whether in 1982 or 2016. However, the term "out-of-date" refers specifically to the advancements that have been made in air pollution control and flue gas desulfurization. These advancements have caused substantial changes to the nature of the waters discharging from the power plants to the local bodies of water. Three decades of technological leaps have left the effluent guidelines lagging behind.

While the effluent guidelines were stagnant, new water treatment technologies were being developed to treat these new types of waste waters.

The most significant technology to be born and mature with the industry was a process called Zero Liquid Discharge which is capable of completely eliminating water discharge to local watersheds.

ZLD has been applied to the power industry for almost 50 years with a proven track record.

The majority of ZLD systems operating within the power industry treat blowdown water from cooling towers and boilers, many of them recycling >99% of the blowdown water back to the cooling tower.

Not only does this eliminate a regulated discharge, but it also improves the water balance by reducing the make-up water volumes taken from local fresh water sources (especially important in arid regions).

The evaporation systems used in ZLD for water recycle consist of Brine Concentrators (Vertical-Tube Falling Film Evaporators) and Crystallizers (Forced-Circulation).

ZLD technology was pilot tested with Wet Flue Gas Desulfurization (WFGD) blowdown over 20 years ago. In the last decade, ZLD technology has been applied commercially to WFGD blowdown with great success.

The EPA has carefully studied the evaporative ZLD systems currently in operation on WFGD blowdown and is mandating ELGs as demonstrated by this technology for new discharge sources and power plants yet to be constructed

Table 1: Selection Success Factors

Selection Success Factors	Biological Approach	ZLD Approach
Proven Successful Technology	Yes	Yes
Commercially Operating References	Yes	Yes
Fully Automated Control	Yes	Yes
Physical Chemical Pretreatment Needed	Yes	***
ELG Compliance	Risk	Yes
High Purity Water Recycled	No	Yes
Handles Fluctuations in WFGD Blowdown Conditions	No	Yes
Qualifies under the EPA's Voluntary Incentive Program	No	Yes

Selection success factors when choosing between the two proven WFGD blowdown technology methods. ***Physical Chemical Pretreatment is required in some ZLD system configurations.

One important exception to this mandate is the more relaxed posture by the EPA towards existing plants.

The new ELGs establish numerical limits for several Pollutants of Concern (POC), including arsenic, selenium, mercury and nitrates.

Although the preference for evaporative ZLD is clear, the EPA set effluent limits for only these POCs to allow the use of another technology (physical/chemical/biological treatment) that is capable of reducing these pollutants but doesn't eliminate them.

Other pollutants of concern (including boron, bromide, chloride and TDS) are not controllable by physical/chemical/biological treatment and the final rule did not assign effluent limits for existing plants.

Window of Opportunity

Although the EPA decided not to make the effluent limits consistent with evaporative ZLD mandatory, a voluntary incentive program was established to reward existing facilities that pursue the best-practice of ZLD. This incentive comes in the form of a window of opportunity - a strategic delay in the implementation deadline. The guidelines are to take effect in the next NPDES cycle, beginning November 2018, which would give an existing facility approximately three years to develop and execute a compliance strategy based on physical/chemical/biological system.

Dry Salt

Dry salt generated by the WFGD ZLD System at Torrevaldaliga, Italy. Photo courtesy: Aquatech International.

Facilities that pursue this path are subject to the lighter regulations that limit only arsenic, selenium, mercury and nitrates. The incentive pathway would extend the implementation deadline to as late as December 2023 given that the steam electric power plant opts to adhere to more stringent ELGs (including a limit on TDS) which is consistent with evaporative ZLD as the treatment solution.

WFGD ZLD System

WFGD ZLD System at ENEL Sulcis, Italy. Chemical dosing systems in the foreground, Brine Concentrator the the left, Belt Filter Press at center, Softeners at upper right, and Crystallizer to Center-Right. Courtesy of Aquatech International.

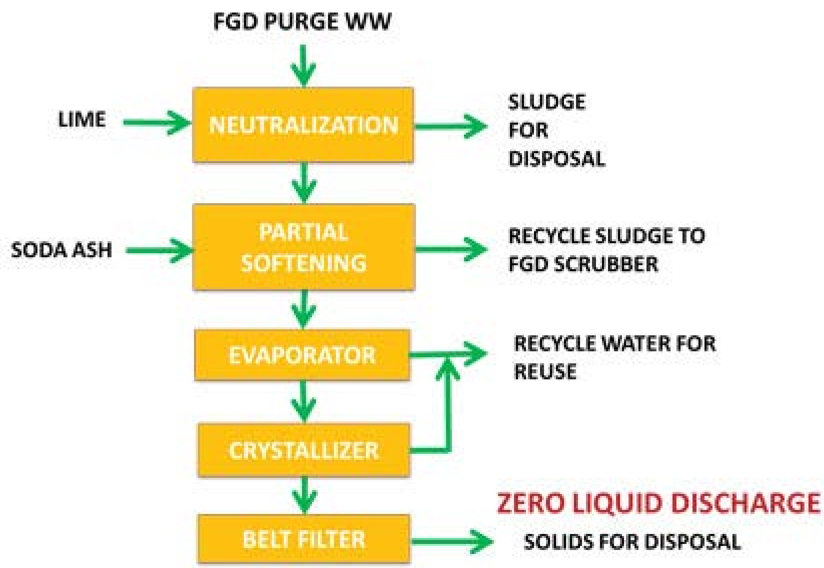
The existing facility is then given eight years (instead of three) to comply with the regulations, which not only defers the capital investment but also gives additional time for careful study and planning of the implementation strategy.

This is an especially significant opportunity for facilities that face additional Water Quality Criteria (WQC) above and beyond the limits established by the EPA. WQCs are established by state authorities for the protection of specific bodies of water. These criteria are driven by local factors that require special consideration for preservation of aquatic lifeforms and/or human use.

In many of these cases, evaporative ZLD may have been an immediate necessity to prevent the accumulation of halogens and dissolved salt content in the waterbody. In these instances, the incentive program offered by the EPA for delayed compliance is especially attractive.

Not only is the physical/chemical/biological treatment approach not able to control all of the POCs, but there are also expressed concerns about the efficacy of such an approach.

WFGD ZLD Block Flow Diagram



WFGD ZLD Block Flow Diagram showing the Softening Evaporation Crystallization Method. Photo courtesy: Aquatech International.

The EPA has documented power plant operators who have expressed concern about the stability of biological treatment systems due to high chlorides, temperature fluctuations and variability of the FGD wastewater. The EPA has dismissed these concerns. While this biological treatment has been proven effective on the POCs mercury, arsenic, selenium and nitrates, it has no impact on bromides, chlorides, boron or TDS.

The EPA has already acknowledged that evaporation can meet the established limits for Best Available Technology economically feasible (BAT). When these other POCs become numerically limited in the future, ZLD will become mandatory. Plants should strongly consider ZLD now to improve their standing in the future.

ZLD's Proven Track Record

The past decade has witnessed the rapid success of Zero Liquid Discharge in treating WFGD blowdown.

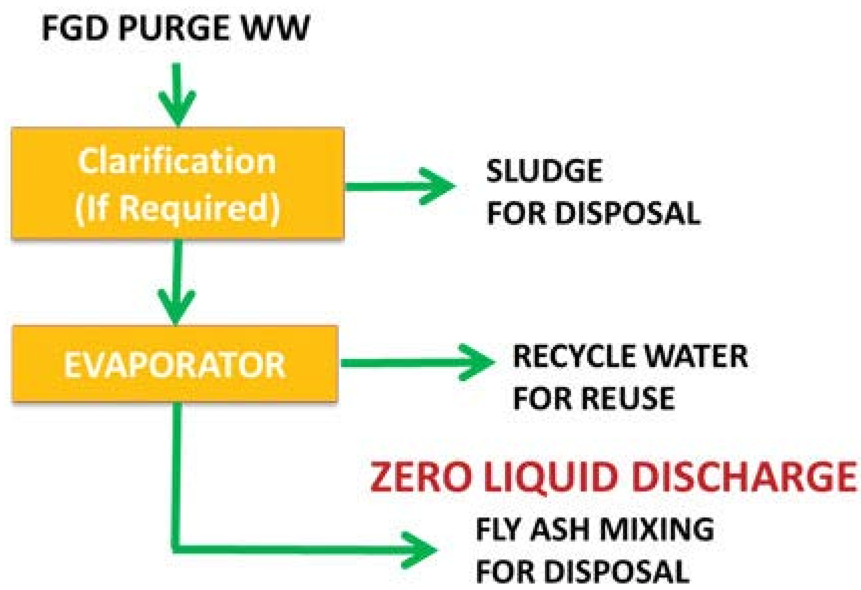
Although the EPA ELGs list several possible methods for achieving ZLD, there are only two ZLD methods that have been widely used and are commercially proven.

The two proven ZLD methods both utilize Brine Concentrators and Crystallizers to recycle WFGD water as high-purity distillate.

Each method produces a final concentrate that is not discharged as a liquid from the plant. The first method produces a dewatered solid from the Crystallizer (see Figure 1) and the second method produces a concentrated brine at a very low volumetric rate that is blended with fly ash for solidification. The final solids generated by each method are suitable for landfill disposal. Zero liquid discharge is achieved and Effluent Limitation compliance is ensured.

The nature of WFGD blowdown conditions are variable over time and are heavily influenced by the coal type being burned as well as other operating conditions (Mandigo, 2007).

WFGD ZLD Block Flow Diagram



WFGD ZLD Block Flow Diagram showing the Evaporation Solids Mixing Method. Photo courtesy: Aquatech International.

In a thermal evaporation process, the primary constituents that drive the design of WFGD ZLD system are the scrubber's TDS/chloride content, hardness levels (Calcium and Magnesium) and TSS/heavy metals.

Experienced ZLD technology suppliers will design the system not only for average concentrations, but will also consider maximum and minimum concentrations in each aspect of the design. ZLD systems have a strong ability to handle wide variations in water chemistry which makes them an ideal solution if/when facilities consider operational changes driven by market dynamics; the ZLD system can be designed to meet current and future demands.

The most utilized ZLD process in operation to date consists of physical chemical pretreatment, Brine Concentration, and Crystallization which directly produces a dewatered solid cake for landfill disposal.

A block flow diagram of this process is shown in Figure 3, courtesy of Aquatech International.

The physical chemical pretreatment portion of the ZLD process conditions the feedwater by reducing TSS, heavy metals, and partially softens the WFGD blowdown water.

Due to the variability of the wastewater, this pretreatment step adds robustness to the process making operation of the Brine Concentrator stable and reliable, like the Brine Concentrators that have been operating in power plants for decades.

While pretreatment does consume chemicals and produce a pretreatment sludge for disposal, it can be configured to recycle the sludge in the form of calcium carbonate back to the FGD system for recovery: thereby, reducing plant chemical consumption and sludge disposal.

The pretreatment also importantly removes a fraction of the hardness content such that the crystallization stage is accomplished at moderate temperatures and will consistently generate a sodium chloride based salt which is suitable for landfill disposal. (Without removing a portion of the hardness upstream, calcium chloride and magnesium chloride salts would be generated which are more problematic for disposal given their deliquescent nature.)

Aquatech has applied this process for six power plants. Five ZLD plants have been operating since 2008 (Marlett, 2012) and one has been operating since 2012 (Roy, 2015).

Photographs of such ZLD facilities at the ENEL plants in Italy are shown in Figures 2 and 3, courtesy of Aquatech International.

The second proven ZLD process utilizes Brine Concentration and Crystallization to concentrate the FGD wastewater such that a low-volume liquid concentrate is produced and is mixed with fly ash for landfill disposal. A block flow diagram of this process is shown in Figure 4.

This process consists of clarification to remove suspended solids upstream of the Brine Concentrator, if required. One important distinction with this ZLD method is that the salts present in the WFGD blowdown water are concentrated directly by the Brine Concentrator and softening is not required upstream, further improving the OPEX. Depending on the WFGD anticipated water chemistry variations as well as the amount of fly ash available for blending, a Crystallizer following the Brine Concentrator may or may not be required.

In either case, the evaporation system produces a low-volume brine concentrate that is mixed with fly ash. This reduces the load on the thermal evaporators resulting in lower energy consumption for the ZLD.

The City Water Power and Light ZLD system (Mandigo, 2007), Iatan Power Generating Station ZLD system (Mandigo, 2009) and Merrimack Station ZLD system (Scroggin, 2013) were designed for this configuration.

This ZLD method is preferred in some cases as it offers advantages in lower energy consumption and no chemical softening treatment, which reduces chemical OPEX and sludge handling requirements. The Merrimack Brine Concentrator is shown in Figure 6.

Conclusion

With the final rule now in effect, existing steam electric plants are best served by holistically considering their discharge practices (current and future levels) and studying the improvements that can be gained with Zero Liquid Discharge.

ZLD systems offer a proven and robust solution that have the ability to handle wide variations in WFGD wastewater pollutant concentrations as they change over time and ensure continuous ELG compliance.

Operating facilities that choose ZLD technology will not only mitigate their compliance risk but also capitalize on the implementation extension offered by the EPA as an incentive to those who select the preferrable ZLD.

With this in view, existing plants are best served by working with experienced ZLD technology providers who have demonstrated the ability to apply commercially proven ZLD solutions to wet flue gas desulfurization blowdown.

Author

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