Ash Pond Replacement Therapy

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ABSTRACT

Regulatory agencies are scrutinizing coal-fired power plant coal combustion product management and associated wastewater discharges. Possible regulatory requirements cast doubt on the long-term viability of impoundments for wastewater treatment and ash disposal. This paper conveys information on: regulatory drivers, information collection needed to evaluate alternative wastewater management strategies, water reuse to reduce the amount of water needing treatment, and process engineering concepts for ash pond replacement systems. Example ash pond replacement treatment systems, one of which was recently placed in service, are described.

INTRODUCTION

For decades, a standard of practice for ash management in coal-fired power plants has been to use river water to sluice ash from the power block to a large earthen pond or impoundment where the ash settles out; return the water to the river; and dispose of the solids permanently in the impoundment. Regulatory agencies are scrutinizing coal-fired power plant ash management practices and wastewater discharges. Possible regulatory requirements cast doubt on the long-term viability of impoundments for wastewater treatment and ash disposal.

CH2M HILL is supporting multiple power plant clients through evaluating alternatives to ponds, developing water reuse schemes to reduce the flow requiring treatment, and developing systems to replace ponds and meet tightening discharge requirements – from design, through procurement, services during construction, and startup. Insights from these experiences are presented in this paper.

DRIVERS

Environmental accidents like the Tennessee Valley Authority Kingston ash pond failure, which released 1.1 billion gallons of fly ash slurry over a 300-acre area, have raised the level of scrutiny that regulatory agencies and non-government organizations are placing on coal-fired power plant ash management. Power plants face both regulatory and non-regulatory drivers to replace ash ponds.

REGULATORY DRIVERS - Regulatory drivers include solid waste and wastewater regulations. Others, such as air toxics regulations, also affect wastewater management.

The Environmental Protection Agency (USEPA) is currently considering federal regulations under the Resource Conservation and Recovery Act (RCRA) for managing coal combustion residuals (CCRs), imposing additional lining and structural integrity monitoring and test requirements on ash pond dams. The USEPA issued a proposed CCR rule in June 2010. The rule contained two possible regulatory scenarios–regulating ash under RCRA subtitle C or RCRA subtitle D. In either scenario, composite liner systems, leachate collection and removal, and groundwater monitoring would be required on new and existing ponds. There has been extensive public debate on these requirements over whether the requirements should be set at the federal or state level. Updates and further information are available at http://www.epa.gov/osw/nonhaz/industrial/special/fossil/ccr-rule/index.htm.

Many power plants are facing, or already have, strict limits on contaminants in their wastewater discharge. Currently, these are primarily driven by regional water quality-based limits. Examples of limits in place on power plant wastewater discharge include low part per billion limits on selenium for several plants in North Carolina, part per trillion limits on mercury in the Great Lakes Region, and nutrients limits in the Gulf of Mexico and Chesapeake Bay watersheds. Water quality-based limits may become more common and more stringent as more receiving water bodies are listed as impacted or impaired due to metals, nutrients, or salinity. Salinity may present the most challenging condition, as it is costly to remove. Over 1,700 water bodies in the U.S. are considered impacted by total dissolved solids, conductivity, chlorides, or sulfate (per USEPA's Reach database at http://epamap32.epa.gov/radims/).

The USEPA is also working to tighten coal-fired power plant wastewater discharge limits by updating the Steam Electric Utility Effluent Limitation Guideline (ELG). The draft ELG will be issued in November 2012, and the final rule in April 2014. The ELG imposes Best Available Technology (BAT) limits on wastewater streams. The ELG also provides the minimum requirements for all wastewater discharge permits issued to power plants in the industry after the rule is final. This would suggest that plants would get ELG-based requirements as their permits are renewed after 2014. Assuming a 5-year permit cycle, this would mean 2014 to 2019. However, permit limits are already tightening due to the June 2010 memo from USEPA directing USEPA regions to immediately begin setting BAT-based limits for new permits in the industry using best professional judgment.

Through recent draft permits, such as that issued by USEPA Region 1 to Public Service New Hampshire's Merrimack Station in September 2011, and through publically available information from the USEPA, a sense for the likely ELG content can be gained.

A main focus of the ELG is flue gas desulphurization (FGD) scrubber wastewater. The treatment technologies being considered by USEPA in setting BAT limits include physical/chemical treatment, biological treatment, and zero liquid discharge (ZLD) treatment (USEPA, 2009). Potential ELG limits on FGD wastewater are seen in the Merrimack draft permit (Table 1). It should be noted that the 10 µg/L selenium limit would likely necessitate biological treatment or ZLD.

Other wastewater issues that the USEPA is considering include: banning discharge of fly ash transport water, reducing or eliminating bottom ash transport water, treating leachate, and tightening restrictions on cleaning wastes from both chemical and non-chemical cleaning (USEPA, 2011).

Table 1. Internal Monitoring Points on FGD Wastewater Limits from Merrimack Draft Permit (USEPA, 2011)

Parameter	Average Monthly	Daily Maximum
Arsenic, µg/L	8	15
Cadmium, µg/L	—	50
Chromium, µg/L	—	10
Lead, µg/L	—	100
Copper, µg/L	8	16
Manganese, µg/L	—	3,000
Mercury, µg/L	—	0.014
Selenium, µg/L	10	19
Zinc, µg/L	12	15
Chlorides, mg/L	—	18,000
TDS, mg/L	—	35,000

OTHER DRIVERS - Power plants may also choose to evaluate ash pond replacement due to factors other than regulatory drivers. A key driver is risk management. Companies may choose to replace ponds to avoid the risk of pond failure, and the monetary and public perception costs associated with a pond failure. Replacing ponds also manages the risk inherent in the uncertainty of future regulations.

Water scarcity may lead facilities to change from wet to dry ash transport and other water-reduction changes. As ponds near capacity, the permitting of new ponds may be challenging, thereby pushing plants to install landfills for ash and other CCRs rather than new ponds. Space constraints may drive some power plants to close ash ponds to make use of the area.

DATA COLLECTION TO EVALUATE ALTERNATIVES

The following steps describe an efficient and effective process for planning wastewater management changes:

1. Identify wastewater management objectives
2. Identify information needed to meet the objectives
3. Fill gaps in needed information
4. Evaluate and choose alternatives

With these activities completed, the chosen alternative can be progressed through full-system design, construction, startup, and operation.

The progress of these steps will be dictated by a plant's compliance schedule. Some facilities will face very aggressive schedules driven by permits that necessitate overlapping treatment testing and design stages. This typically increases overall project costs. Other facilities can work at a more comfortable pace with proper early planning to verify compliance strategies, schedule, and goals.

The alternative to such a planning effort is facing ash pond closure without the information needed to make good decisions.

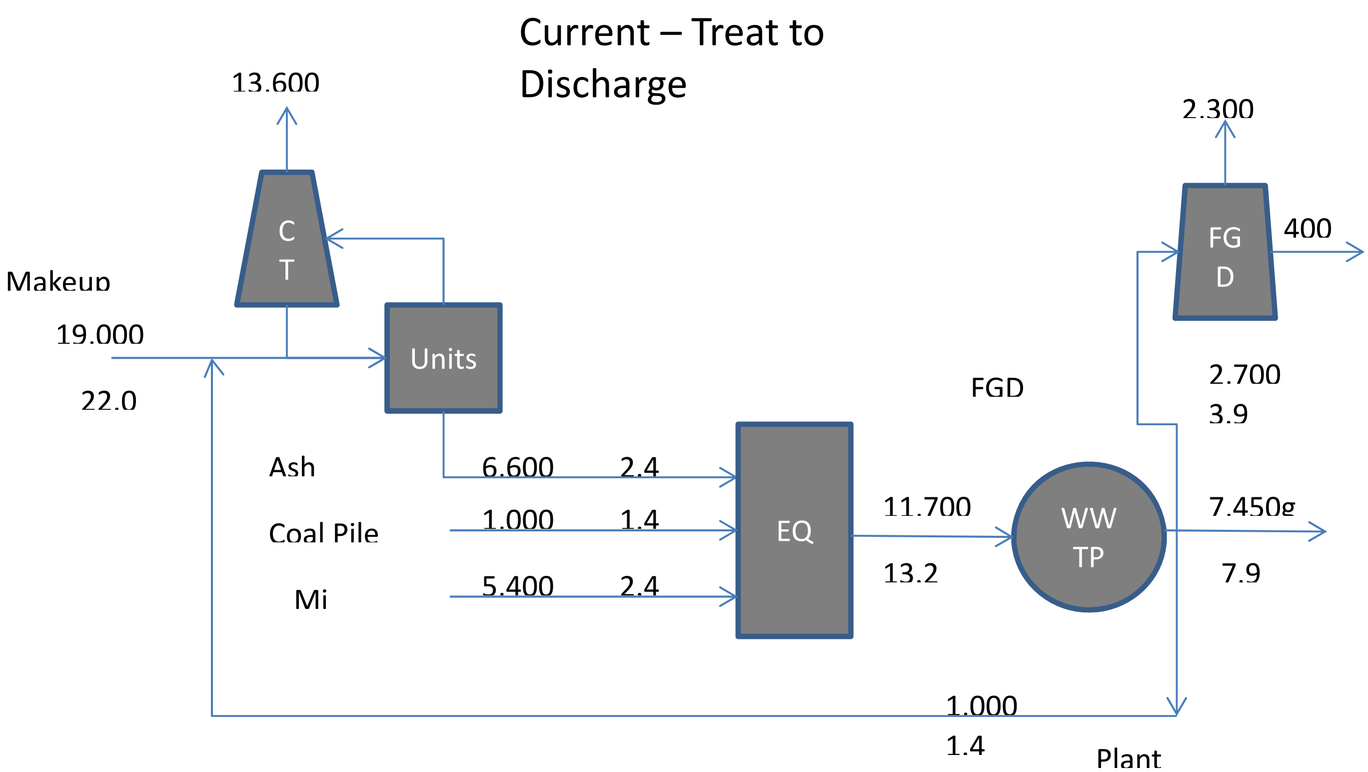
IDENTIFY WASTEWATER MANAGEMENT OBJECTIVES – Wastewater objectives will likely include compliance with current and anticipated regulations. Other goals that should be considered include water use reduction, fitting any new equipment into a limited footprint, and site-specific community stakeholder goals. Clearly stated goals are needed to make the planning process effective. There should be a schedule aspect to each goal clarifying when it is to be met.

IDENTIFY INFORMATION NEEDED TO MEET GOALS – The goals set will affect the information that is needed to evaluate and choose the best approach to reaching those goals. For example, a goal of compliance with discharge limits will require an understanding of current and future regulatory activity, expected limits, and compliance schedules; understanding current, historic, and projected wastewater characteristics to evaluate which (if any) constituents will require treatment; if treatment is needed and what types of treatment alternatives exist; what affects these treatment systems; and flow information, including peak and average flows and solids content.

Because treatment costs and footprint are typically directly related to flow and mass loading of solids, treatment evaluations should also include evaluating water reuse or recycle options to reduce the amount of water and solids that must be treated. Water reuse evaluation requires an understanding of the water use quality and flow requirements.

Understanding water stream flow and composition at key points in the power plant is essential to water and wastewater planning. This information is typically captured in flow and mass balances. An example of a flow balance developed for a plant is shown in Figure 1. Because both peak and average flows are important to designing the system, both are tracked in the flow and mass balances. The water constituents that must be understood depend on the possible wastewater management alternatives. Evaluation of water recycling or reuse requires an understanding of corrosive salts such as chlorides. If thermal zero liquid discharge alternatives will be evaluated, additional water quality data will be needed–especially data regarding calcium, magnesium, sulfate, and chlorides.

Figure 1. Example Flow Balance Evaluating Water Reuse Options
Note: Peak flow in gallons per minute (gpm), average flow in million gallons per day (mgd).



The outcome of this step should include an aggregation of information collected, flow and mass balances, design basis for wastewater treatment or reuse, and information identified as needed but not available (data gaps).

FILL DATA GAPS – Once the information needed to evaluate wastewater approaches is defined and data gaps identified, these gaps must be filled. Without filling the data gaps, the alternatives evaluation must be based on assumptions; this can result in incomplete or inaccurate evaluation.
If upcoming regulatory limits are unknown, a discharge limit study should be completed to identify future compliance requirements. This study can be completed by the utility staff or a consultant with broad wastewater discharge

permitting experience. The study should involve working with the regulators who write the plant's discharge permit. A time element should be included in this evaluation, to understand when various limits are expected to be imposed. These evaluations will result in some uncertainty on limits or schedule that must be documented and factored into the planning process. For example, if a plant faces a limit on nutrients 10-15 years in the future, but metals limits in 3 years, a treatment system could be built with only solids and metals removal as a first step. The treatment system could then include provision for future addition of biological-based nutrient removal.

Developing a sufficient understanding of a plant's water and wastewater for compliance planning typically requires flow monitoring, sampling, and constituent analysis.

Often, a plant's flow information is limited to average or approximate flows, which are sufficient for permit applications or operation of a large ash pond. However, because tank-based treatment systems are less able to handle large flow swings, the instantaneous maximum, minimum, and average flow, flow frequency, and periodicity must also be understood. An example is bottom ash sluice water at the Case Study site. Bottom ash is sluiced twice a day for a total of 4 to 12 hours per day, resulting in several surges of flow to the wastewater system.

Gathering peak flow information may require reviewing historical flow meter readings, or evaluating pump curves and run time logs. If such historical information is not available, flow monitoring, using either temporary or permanent meters, may be required. Visual flow approximations are also possible, but should be used only for flows that are not critical to the basis of design.

Runoff flows are typically estimated based on design rainfall intensity times runoff area times a runoff coefficient. It is important to understand the time period over which this water flows to the wastewater management system. At some plants this will be a matter of hours or even minutes. At other plants the flow is attenuated by constructed ponds or natural ponding.

In gathering flow information and building a flow diagram, documentation of information sources, assumptions, and calculation methods are essential to avoid mistakes and re-work. It is also essential to discuss the collected information frequently with plant staff to ensure the data makes sense, is complete, current, and is the best available information.

Sampling and analysis of water constituents must address not only regulated pollutants but those water constituents that affect treatment of those pollutants. One example is the effect of nitrates on selenium treatment by anaerobic biological processes. Sampling should be completed to characterize not only typical wastewater conditions, but also anticipated extreme conditions such as equipment washes. Typical conditions may be difficult to characterize at some plants due to the range of coals fired. In these cases, understanding which conditions result in maximum wastewater concentrations and mass loads of parameters of concern is important to scheduling wastewater characterization sampling and establishing an accurate design basis.

Wastewater characteristics are typically tracked in data tables and material balance spreadsheets. The wastewater management approach should dictate the sophistication of the tool used. For physical/chemical treatment processes, flow, total suspended solids, and site-specific metals may be sufficient and can be tracked in a spreadsheet. When planning a thermal ZLD system to manage wastewater, the interactions of water constituents and the resulting scaling or corrosion can best be understood by combining plant flow balances with water chemistry models. The number of operating scenarios at a plant can also drive the data management system level of sophistication.

ALTERNATIVES EVALUATION – An alternatives evaluation should be completed progressively, starting with low-cost options and moving to higher-cost options only if needed. This progression includes:

1. Negotiating more favorable permit conditions
2. Modifying existing chemistry to meet treatment objectives
3. Using tank-based physical/chemical treatment
4. Adding a low-cost passive treatment system if biological treatment is needed

5. Using tank-based physical/chemical treatment followed by in-tank biological treatment
6. Exploring the use of low-cost ZLD mechanisms
7. Using thermal ZLD as a last resort

The evaluation of alternatives to meet a plant's goals should include a combination of waste stream elimination, segregation, and treatment. Fly ash transport water is a high-flow, high-solids stream with relatively high trace metals concentrations. Fly ash water can be nearly eliminated by conversion to dry fly ash transport systems. (Note: Typically, even with dry fly ash transport there remains some water impacted by fly ash, such as from fly ash silo area washdown or from wet sluice systems operation during plant startup, which must be managed.)

Those streams with tight regulations or that may adversely affect water reuse should be segregated and managed separately. An example is FGD wastewater, which has chloride concentrations that would make reuse impractical in any system with metal susceptible to chloride corrosion. FGD wastewater is likely also to be regulated with in-plant limits as opposed to end-of-pipe limits on combined streams. These factors may make segregation and separate treatment of FGD water more cost efficient then treating FGD water after it is combined with other streams.

Although fly ash transport water and FGD wastewater contain the majority of wastewater contaminant loading from a typical coal-fired power plant, there are numerous other wastewater streams that require management. Remaining streams to be considered for treatment include landfill leachate, process area washdown, and bottom ash transport water, either from a single-use bottom ash sluice system, or blowdown from a recirculating system.

Alternatives are evaluated based on site-specific quantitative and qualitative criteria. Typical criteria could include: cost, treatment feasibility (is technology proven, able to meet limits, and expandable), reliability (able to deal with upset conditions), compatibility with future limits, process safety, regulatory and public acceptance, other environmental impacts (air emissions and solid waste), operability, constructibility, and space requirements. Pertinent criteria are used to narrow the alternatives to a select set for further evaluation. The quicker alternatives can be screened, the less the evaluation will cost. When alternatives are eliminated the logic should be documented clearly so others outside the core project team (such as company management, regulators, or others picking up a project that has been put on hold) can easily understand the project objectives, design basis, assumptions, alternatives under consideration, evaluation criteria, and reasons for eliminating alternatives. Proper documentation avoids re-work and misunderstandings.

Many wastewater treatment or reuse options will warrant bench-scale or pilot-scale testing before selection. This testing will help verify that the selected treatment scheme can effectively meet the wastewater management objectives. This testing will also identify operational challenges and set design criteria for the full-scale system.

REDUCING FLOW REQUIRING TREATMENT

The cost and size of wastewater treatment is directly related to the flow of wastewater. Equipment sizing is driven by peak flow, while most operating costs are driven by average flow. Therefore, wastewater reduction should be part of any pond replacement evaluation. Other drivers, such as a water conservation goal, may also lead to water reuse.

Wastewater treatment flow reduction at a power plant relies on identifying and matching wastewater streams for reuse and for best water uses; and using a power plant's inherent evaporative processes.

IDENTIFYING WATER REUSE OPPORTUNITIES – In general, high-volume, relatively low-quality water uses are the best for wastewater reuse. Such water uses include FGD makeup water, wetting ash that is to be landfilled, ash transport water, and cooling tower makeup. These uses should be paired with relatively good quality, large-flow wastewater streams. Wastewater quality can be described by its suspended solids and salt content. Suspended solids are relatively easy to remove, so salt content typically becomes the reuse-limiting factor. High salt concentrations can cause scaling or corrosion. Higher-quality wastewater streams include cooling tower blowdown, bottom ash transport water, seal water, boiler blowdown, and water filter backwash.

Wastewater and reuse flows must be matched so that water needs are consistently met. If flows are not well matched (for example, a water need is constant, but wastewater production is intermittent), equalization storage will be required.

Use of wastewater for ash wetting offers a good opportunity to dispose of very poor-quality water. This approach can be used in near zero liquid discharge systems where wastewater flow is reduced to an amount that can meet the wetting needs of landfilled ash or FGD solids. Evaluation of the effects of using wastewater as wetting agent would require reviewing the characteristics and management of leachate from the ash landfill.

WATER REDUCTION USING A POWER PLANT'S NATURAL EVAPORATION – ZLD systems rely on evaporators and crystallizers to reduce wastewater volume and use heat to evaporate water. Power plants have natural evaporation that can be used to reduce wastewater flow without large capital investments. Cooling towers and FGD systems evaporate large amounts of water and are good candidates to include in a water reuse and flow reduction approach. For example, most clean wastewater streams could be sent to the cooling tower for reuse followed by use of cooling tower blowdown as FGD makeup water; this leaves only FGD blowdown requiring treatment.

PROCESS ENGINEERING CONCEPTS FOR TANK-BASED SYSTEMS TO REPLACE ASH PONDS

Once the plant's wastewater management goals have been identified, the wastewater characterized sufficiently, and alternatives evaluated and selected, the new system to replace ash ponds can be designed. To design a system that meets plant discharge limits and other goals and is constructible and operable, the following key concepts should be considered.

DESIGN FOR PRESENT, PLAN FOR FUTURE – Designing a treatment system that meets current requirements, but cannot be adapted to future requirements, will ultimately waste time, money, and effort. As ash pond replacement systems are planned, likely future requirements must be understood and accommodated to the extent possible. The designs should include either the means to meet the future limits from the onset, or the ability to easily expand to meet them. Designing for future expansion requires an understanding of what future treatment system changes will entail. This may include increased capacity, changes in influent water chemistry, tightening discharge limits, or reuse of the treated effluent to meet future water use restrictions.

Designing for expansion means saving room for future treatment processes, but there are other considerations as well:

- Electrical and other utilities supplying the treatment plant should be designed to serve future needs, or designed with the ability to be expanded to meet those needs
- Control systems should be designed with sufficient excess input and output points
- Electrical and control conduits to remote areas should be sized to hold future power and control wiring

A very simple, but extremely valuable design approach for meeting future expansion is to include tees in treatment system piping at appropriate points for future tie-in without requiring extended treatment system down time.

Future treatment unit hydraulics should also be considered and planned for higher operating levels in current treatment tanks to facilitate gravity flow to future additions.

The plants featured in the Case Study presented later in this paper, were designed to discharge effluent, but included elements to accommodate future effluent recycle for reuse if future regulations require excessively costly additional treatment. The wastewater is treated beyond current discharge requirements to higher quality than current plant makeup water, and connections are provided to a future reuse water storage tank and distribution system.

DESIGN FOR OPERABIILTY – A successful treatment system design meets a plant's wastewater management goals and is easy to construct, operate, and maintain. Some tips for designing operability and maintainability into an ash pond replacement system are listed below:

- Consider safety and accessibility in all aspects of design. System reviews (often called hazardous operations reviews, or process hazard analyses) should be completed, with input from construction and operations staff, during the design process. An example of designing with safety and accessibility in mind is including steps and catwalks rather than ladders.
- Provide in-line redundancy for equipment that will need periodic maintenance. This includes key pumps, strainers, and instrumentation such as pH meters. In-line redundancy will allow maintenance with minimized plant downtime.
- Provide instrumentation and automation to understand flow and key water quality parameters at all points of interest for process monitoring and control.
- Reduce pipe cleaning requirements through thoughtful design. Some power plant wastewater can be scaling or high in suspended solids. To minimize solids deposition and prevent freezing, design sufficient flow velocity to minimize solids deposition and slope gravity lines so that they are self-draining. Include flush points and automated flushing in high-solids lines such as clarifier underflow and sludge lines for quicker pipe clearing and reduce plant downtime for cleaning. Clarifier underflow, sludge, or other high-solids streams should have short pump suction lines. Running sludge pumps continuously and alternating between wasting and recycling will maintain continuous sludge line scouring.
- Reduce maintenance and replacement requirements by careful materials of construction selection. Chloride corrodes the steel used in most commonly available treatment equipment and instrumentation. Special alloys, fiberglass reinforced plastics, or unreinforced plastics will be required if chlorides are present. It is important to remember that chlorides and other ions will cycle up if water is reused.
- Design tank effluent lines with dip tubes (Figure 2) to reduce short-circuiting. Dip tubes allow an influent-high / effluent-low flow path through the tank, preventing heavier solids from remaining in tanks (as occurs if tank effluent was high in the tank). This also reduces solids deposition in effluent piping (if flow is stopped, solids fall down the dip tube back into the tank).