Industry Perspectives on Integrating ELG and CCR Compliance through Wastewater Encapsulation: Challenges, Opportunities, and Technology Readiness

Kirk Ellison

Southern Company Services, 600 North 18th Street/14N-8195, Birmingham, Alabama 35203. kmelliso@southernco.com

KEYWORDS: Ash Transport, Brine, Encapsulation, Leachate, Paste, Solidification, Stabilization, Discharge Elimination

ABSTRACT
Pending regulatory challenges give reason to re-examine the status-quo approach for future coal combustion by-products (CCB) and flue gas desulfurization (FGD) wastewater disposal practices. The new Steam Effluent Guidelines (ELG’s) and CCB rules may end the discharge of ash transport water into impoundments and push the industry toward dry stacking of ash into lined facilities. Stringent treatment limits on FGD wastewater will be induced by ELG’s, forcing the construction of wastewater treatment facilities at most major coal-fired electric generating units. A potentially cost-effective alternative to CCB dry stacking and FGD wastewater treatment is under investigation. Passive deposition technologies, such as zero bleed water pastes, offer advantages for the integrated transport and disposal of CCB’s as well as difficult to manage FGD salts and brines from volume reduction technologies. Co-disposal is achieved when ash, brine, and binders are mixed and pumped into the landfill as a thixotropic paste and allowed to set into an encapsulated monolith. To bring this approach to commercial viability, the following work is ongoing: binder testing and development to prevent constituent leaching from encapsulated materials, evaluation of mixing, transport, and deposition technologies, development of contaminant fate and transport models for encapsulated materials, and development of landfill management best practices. Additionally, a demonstration scale research facility to create and test encapsulated materials has been established. This paper serves to give an industry update on the current state of the technology and its cost and outline a strategic vision for the commercialization of wastewater encapsulation.

REGULATORY BACKGROUND:

Much attention is currently being given to the EPA’s new regulations for Coal Combustion Byproducts (CCB). However, coal-fired electric generating units (EGUs) in the USA are facing many environmental compliance challenges due to additional regulations that are being proposed at the federal level. The first proposed changes to steam effluent guidelines (ELG) in over 30 years are stringent and will require companies to invest research and capital to comply if the rule is finalized in its current form. Both the CCB and ELG rules will have a significant impact on the way CCB’s and wastewater streams are disposed. At most coal EGU’s, the CCB rule will be an impetus to discontinue the use of wet ash impoundments. As a result, all future CCB’s will be disposed of in lined landfills. Additionally, the CCB rule is setting a precedent for protection of groundwater. This mindset will be carried into the future to ensure that new lined facilities are providing adequate protection of groundwater as well. As proposed, the ELG rule will require that ash transport water not be discharged, providing a second driver for discontinuing the use of wet impoundments and driving CCB disposal to lined facilities. In addition, the technology option chosen for flue gas desulfurization (FGD) wastewater treatment can have a major effect on future CCB disposal as will be discussed below.

The current practice of allowing all wastewater to be comingled before treatment and discharge will end with the implementation of the ELG rule. Instead, each waste stream from the plant is to be individually regulated. Of chief concern is the ability of FGD wastewater to be treated to the proposed low parts-per-billion and parts-per-trillion standards. FGD wastewaters have an extremely complex composition matrix, often complicated with high total suspended solids (TSS) and total dissolved solids (TDS). The waters have high concentration of calcium, magnesium, chloride, and sulfate. Additionally, these waters often contain high levels of nitrates as well as many heavy metals and metalloids like mercury (Hg), selenium (Se), and arsenic (As) in various forms and concentrations.

All of the commercially available treatment technologies that are being proposed for FGD wastewater treatment are costly and potentially susceptible to upset conditions that could lead to noncompliance. Additionally, all treatment processes will remove pollutants from the water and create a solid waste residual. These solids will need to be disposed of along with CCBs and need to be characterized to ensure proper disposal. Thus, as novel approaches to meeting the proposed ELGs are researched, moving toward the elimination of wastewater discharges is appealing.

POTENTIAL FOR AN INTEGRATED CCB & ELG SOLUTION:

A new technology path is becoming apparent. First, as noted, facilities will likely have to change their ash handling equipment to meet the requirements of the CCB and ELG rules. Additionally piping changes and improved water balances are needed to achieve compliance with the ELG rule. Therefore, it may make sense to integrate the systems for ash transport and disposal with the FGD wastewater handling and treatment
systems such that discharge is eliminated through wastewater encapsulation. Second, it may not make sense to use a thermal technology to evaporate FGD wastewater all the way to a brine or salt because all encapsulation recipes require some liquid to allow for proper mixing. Instead, at sites where the material balances allow it, a nonthermal option could exist where FGD wastewater could be directly mixed with ash and other additives and co-transported and disposed as a single material.

HISTORY OF ENCAPSULATION:
The concept of co-disposal of wastewater and CCB’s is not completely novel. The Pozzotec process is well established for the disposal of inhibited or natural oxidation scrubber sulfite solids. In this process, the interstitial water and sulfites are stabilized by adding lime and some fly ash. The material is typically mixed then stacked on a pad. It is then trucked to the landfill and placed with equipment similar to moisture conditioned ash. A similar approach can be taken for the express purpose of wastewater disposal by mixing fly ash, gypsum, and wastewater. The mixed material is then transported by truck to the landfill. However this approach has several drawbacks when the sequestration of constituents in wastewater is the primary goal:

- The liquid solid ratio is limited by what can be transported by truck (typically >20%). This increases the amount of CCBs needed and reduced the total volume of water that can be disposed.
- Benefits of a low permeability monolith reduced by material being constantly fragmented due to movement during transportation and placement in a landfill.
- O&M intensive
- Quality control of mix and placement difficult
- Potential regulatory issues around the continued use of stacking pads

PASTE AS AN ALTERNATIVE:
As coal fired facilities change their ash and wastewater disposal practices, Southern Company’s R&D group has surveyed other industries to see if significant strides have been made in solid and liquid disposal for similar applications. The mining industry was found to have made significant progress. Due to water shortages as well as concerns over wet impoundments similar to the power industry, mining operations have started to transition away from wet discharge slurries. The use of a technology, called paste, has been in use for over a decade. This technology, which is similar to flowable fill and mine backfilling, allows for the transport of solids with minimal liquid. The material is then pumped directly into a landfill. Due to the low water content, the material is able to pass a paint filter test and be considered a solid waste from a regulatory standpoint. In the mining industry, pastes are transported via pipeline up to several miles away. Finally, as the material (usually clays) is deposited, the thixotropic behavior of the material allows it to flow into the landfill passively.

Implementing paste for the use of wastewater and ash co-disposal allows the mix to be pumped directly into the landfill, which offers several advantages to traditional methods:

- Capital based solution that reduces O&M costs
- Reduced truck traffic and related safety and dusting issues
- Eliminates the need for stacking pads and related regulatory issues
- Costs of CCB and ELG compliance reduced due shared costs of the integrated approach

Additionally, paste has the following long term environmental benefits:
- Increased liquid solid ratio. Paste allows more wastewater to be co-disposed with CCB’s because there is no transport restriction, only the need to pass a paint filter test. Pastes made with CCB’s can contain up to 40% water and still pass the paint filter test. This allows for roughly double the amount of water disposal compared to traditional approaches.
- The monolithic structure of paste is superior to traditional methods. Void space is nearly eliminated allowing for a dense material to be created with low permeability. Additionally, any cracking that develops will be filled by the flow of subsequent layers.
- Quality control is improved because landfill deposition is passive. Mixes are controlled and optimized for deposition upstream at the point of mixing.

Therefore, it appears that the use of paste for the integrated disposal of CCB’s and wastewater shows promise and warrants further research. The approach could also hold promise purely as an ash transport and deposition technology at sites where the ELG rule isn’t relevant. However, in order to deem this approach as a technically feasible option, much more research is needed.

PATHWAY TO INDUSTRY ACCEPTANCE:
As new ash disposal practices as well as approaches to minimize and eliminate FGD wastewater discharges are explored, care must be taken to ensure that the landfill is retaining constituents of concern from ash and wastewater. There must be assurance that future disposal practices will be protective of the environment. Of chief concern is ensuring that groundwater and surface waters are protected.

Research on wastewater encapsulation has seen significant growth over the past three years. In order to commercialize this approach, continued research is needed in the following key areas:
- Sufficient wastewater volume reduction to allow for encapsulation
- Mix designs that:
  - Optimize wastewater disposal
  - Have acceptable resistance to leaching
  - Are economically viable
- Development of novel solidification agents, such as geopolymers, to reduce cost
- Stabilization additives to reduce leaching of constituents such as selenium.
- Additives to reduce infiltration, such as organosilanes to create hydrophobicity.
- Evaluate the effect of mixing and transport systems on the final behavior of encapsulated materials
- Pilot scale evaluation of encapsulation approaches and mix designs.
- Development of landfill management best practices for encapsulated materials.
- Creation of a numerical modeling framework to evaluate the fate and transport of constituents through a landfill of encapsulated materials.
KEY CHALLENGES:
Southern Company has been supporting work in these key areas. At this stage, the following challenges have emerged:

- **Volume Reduction**
  - At many sites, particularly those burning Illinois Basin Coal, the FGD wastewater stream is a larger volume than can be mixed with the available CCB’s (both ash and gypsum) onsite, even using paste.
  - In order for encapsulation to be feasible, wastewater volume must be reduced. This will require enhanced cycles of concentration in the scrubber as well as additional concentration, either with membranes or potentially thermal volume reduction technologies at some sites.
    - Membranes and thermal technologies, such as brine concentrators, are difficult to operate and have been shown to have significant issues with scaling during treatment of FGD wastewater.

- **Heavy Metal & Halide Retention**
  - Although much work has been performed to ensure solidification and stabilization, leaching test show that some heavy metals as well as halides may still be mobile. More data is needed at the field scale to determine the true behavior of encapsulated materials.
  - If a volume reduction technology is needed, the solidification and stabilization of the concentrate will become more difficult to accomplish.

- **Cost**
  - The need for volume reduction as well as additives to enhance solidification and stabilization could drive encapsulation away from being economically favorable compared to other wastewater treatment and ash handling approaches.

- **Loss of CCB beneficial use**
  - At sites with large wastewater volumes, all of the fly ash and gypsum may be required if volumes cannot be further reduced.

KEY BENEFITS:
Although challenges have been identified, there are promising results for this approach, particularly at sites burning low chloride and sulfur western coals, such as Powder River Basin, that also produce Class C fly ash.

For sites burning western Coals:

- Encapsulation of FGD wastewater can be achieved with minimum to no additives.
- Material hydraulic conductivity regularly observed to be lower than landfill liner requirements of $1 \times 10^{-7}$ cm/s.
- Leaching tests, such as TCLP and LEAF 1315 show minimal leaching of constituents of concern.
  - Concentrations of metals and halides are inherently low in FGD wastewater at sites burning western coal.
- Paste transport systems allow for mixes containing up to 40% wastewater to pass a paint filter test and be pumped passively into a landfill.
Beneficial use of CCB’s minimally affected due to the inherent low wastewater volumes of a site burning western coal.

**DECISION CHART**

In order to establish where the use of an encapsulation approach is feasible, the chart below has been developed so that the appropriate questions, and resulting research tasks, can be established.

![Diagram of decision chart for wastewater encapsulation]

**Table 1: Decision chart for wastewater encapsulation. Start at top left.**

**FUTURE WORK:**

In order to answer outstanding research questions and continue to push the development and commercialization of wastewater encapsulation, Southern Company is building a research facility that will be located alongside the Industry wide collaborative Water Research Center at Georgia Power’s Plant Bowen.

The research facility, shown below, will be operational in May 2015. Automated control systems will be used to control mix designs. A bank of silos will be used so that CCB’s and wastewater from any site can be evaluated. Additionally, different mixes and pumps can be brought in for evaluation of their effectiveness in transporting encapsulated materials as a paste.
This pilot scale facility will allow for the following:

- Production of solidified material in significant quantities through pasting as well as other methods such as stacking so that the best landfill transport and placement method can be determined.
- Placement of materials into a pilot scale landfill to evaluate runoff, leachate, and geotechnical properties for different recipes and placement methods.
  - Field sampling and instrumentation will provide data on water infiltration as well as the geotechnical properties of the material. This will provide feedback for recipe development and modeling efforts.
- Long term fate and risk evaluation will be accomplished by using established geosciences practices in numerical modeling. Data from pilot studies will be used to give best available projections for future leachate quantity and quality for various scenarios such that implementation and best practice decisions can be made.

In addition to providing a site to perform field scale research, it is hoped that this solids research facility will provide a point for collaboration within the power industry and serve as a test ground for vendors who may have innovative mixer and pump designs that warrant evaluation.

CONCLUSIONS:
As required compliance with the ELG and CCB rule draws near, it is important to find cost effective integrated solutions. Southern Company sees value in promoting ash pasting as an alternative to FGD wastewater treatment technologies. Whether electric
utilities choose to employ encapsulation technologies for effluent guideline compliance or not, it is expected that the need for reduction or elimination of wastewater discharges will become ever more prevalent over time. As pressures increase around water quality and water consumption, these drivers will become stronger. Therefore, it is prudent for the industry to continue to evaluate and develop encapsulation approaches and ensure they provide a technically, economically, and environmentally feasible option for liquid and solids wastes from coal fired facilities.