Failure of Coal Ash Containment Facilities: Causes, Impacts, Remediation, and Lessons Learned

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ABSTRACT

Coal ash, in conjunction with other coal combustion residuals (CCR), constitutes the second largest waste stream in the United States. The major concern with the coal ash is its safe storage and disposal, as it contains trace contaminants that could migrate into the environment (air, soil, surface water and groundwater) posing risk to public health. The coal ash disposal facilities should be engineered for adequate structural integrity and waste containment to prevent contaminants spreading into the environment. However, until recently regulations allowed for coal ash disposal in unlined surface impoundments. This paper describes the failure of two recent coal ash disposal facilities, specifically the TVA Kingston Fossil Plant Coal Fly Ash Slurry Spill and the Dan River Coal Ash Spill. The aim of this study is to identify the causes for these failures, assess their impact on public health and the environment, and summarize the measures taken to remediate the spills. Overall, this study emphasizes the need for evaluating the geoenvironmental risk associated with the existing coal ash/waste disposal facilities and implementing sustainable closure/remedial measures. Besides maximizing innocuous beneficial reuse, the study underscores the need for design and operation of safe and effective containment systems for newly generated coal ash and other waste streams such as mine waste.

1 INTRODUCTION

Coal has been one of the primary sources of energy for generating power since ages. In 2015, about 33% of the total U.S. electricity generation was derived from burning coal (US EIA). In addition to generating electricity, combustion of coal produces several by-products called coal combustion residuals (CCRs). CCR includes bottom ash, fly ash, boiler slag and flue-gas desulfurization material. Coal ash consists primarily of oxides of silica, aluminum and iron and can further be classified based on particle size, chemical composition and other physical properties.

Over the decades, coal-fired power plants have been generating large amounts of coal ash and traditionally the coal ash was mixed with water to facilitate pumping it to large open pits usually regarded as ash basins. As the ash settles down in the basin the water that remains over the ash is released into the nearby surface water systems, subject to applicable discharge permitting criteria. This has been practiced as a part of coal ash storage and management over the years by most power generating facilities (Daniels, 2016). The storage of coal ash in an unlined disposal facility poses a threat to the groundwater, as the ash-laden water can leach out heavy metal contaminants and percolate into the subsurface.

Current coal ash disposal practices can pose a risk to the public health and environment. In addition, the inappropriate containment and storage of coal ash without adequate engineering inspection and safety measures increases the risk of facility failure. This study focuses on two of the most recent well publicized failures in the United States namely, the TVA Kingston Fossil Plant Spill that occurred in 2008 and the Dan River Coal Ash Spill in 2014. This study discusses the causes for these failures, outlines their impacts and enumerates the restoration plan with an engineering perspective. Finally, some of the major lessons learned from the investigation of these failures are highlighted.

2 TVA KINGSTON FOSSIL PLANT COAL ASH SPILL

2.1 Site Background

The Kingston Fossil Plant is a property of Tennessee Valley Authority (TVA) that generates power from coal combustion. The plant is located in Roane County, near the city of Kingston and the Watts Bar Lake coast in the state of Tennessee. Its construction started in 1951, and was considered to be the largest coal combustion energy plant, when it started its activities in 1955 (TVA, 2016). Since 1950's, the Kingston plant has been storing coal ash in containment ponds next to its headquarters near the Emory River. The containment ponds were initially built on the former flood plain of Swan Pond Creek.

In 1965, the initial provision pond had already reached its capacity and the new ponds were built for settling and storage of ash by subdividing the initial cell into smaller cells (Moore, 2009). The ash was mixed with water and sluiced to the sedimentation tank and thereafter the settled ash in the pond was dredged and transported to the storage cell. The dam safety monitoring system at the site performed visual inspection regularly and provided a detailed survey of the plant evaluating the safety issues, annually. In 2003 and 2006, a consulting company noted small slope failures in some of the containment dikes (Moore, 2009). The last inspection by the Tennessee Department of Environment and Conservation was held in August 2008, four months before the dike broke down. Interestingly, the last visual inspection of the containment pond was held a few hours before the failure, indicating no apparent problem (Moore, 2009).

2.2 Coal Ash Spill and Impacts

The incident at the TVA Kingston Fossil Plant occurred on December 22, 2008. The dike that held the disposed ash collapsed, causing the release of coal ash material to an area of about 300 acres in the Roane County, Tennessee, USA. An aerial survey of the affected area presented an estimate that more than tripled the first estimate of spill provided by TVA and EPA (1.3 million cubic meters), reaching over 4 million cubic meters (TVA, 2012). After the failure, the stored coal ash slurry crossed the Emory River, reaching the opposite shore of it covering about 1.2 square kilometers of the surrounding area, damaging the residences and the flowing watercourses nearby.

The mudflow caused by containment dike breakdown covered 12 homes stripping them completely of their foundation and causing damage to at least 42 other residential properties. The accident resulted in breaking a natural gas line that crossed the area, blocked a railway line, and destroyed one of the water supply systems and electricity supply lines. This incident was the largest coal ash spill in the history of US, exceeding by more than 3 times the sludge spill in Martin County in 2000, which shed 1.16 million cubic meters of coal ash slurry (TVA, 2012). A picture of the TVA incident is shown below.

Figure 1: Failure of the dike causing coal ash spill at Kingston fossil plant (Source: TVA, 2011)

2.3 Factors Influencing the Failure

The failure involved a number of contributing factors. In the EPA final report, the factors that promoted the failure of the dike that collapsed are listed. The dikes were built under the wet ash with a high void ratio and on a sensitive silt layer (slime) causing instability in the new dikes built over the existing dikes (TVA, 2012). The dredge cell area for the additional coal ash produced became smaller by introducing dikes one over the other. In order to fit the same volume of coal ash produced the height of the dike had to be increased. This increased the load on wet ash at the lower layers that rested on weak slime layer contributing to the failure of the dike. Several creep failures were also observed due to reduction in available strength in slimes.

The old ash disposed in the cell had high water content in the system, an unusually high liquid limit and relatively low undrained shear strength (TVA, 2012). In addition, the ash sent to the dredge cell had a high void ratio and low consolidation or densification by the weight of the ash from the upper layers (Walton and Buttler, 2009). Thus, the ash became highly compressible, leading to low resistance. The same report noted that TVA could have prevented the spill at Kingston Fossil Plant if it had made the recommended corrective actions as observed during the regular inspections.

2.4 Remediation/Restoration Plan

2.4.1 Infrastructure Repairs: Shortly after the rupture of the dike, the first measure adopted by the TVA was to remove the material from roads and railways, opening different ways to enter into the area. The damage caused to more than 900 meters of the railway has been rebuilt, reaching its original alignment and was released for traffic in January 2009. The electricity, water and gas systems that had been affected by the accident were restored in the same year (2008) (TVA, 2012).

2.4.2 River Flow and Ash Migration Control: After the failure of the dike, the migration of ash in the river was controlled by the construction of a barrier system. This reduced the flow of water in the spill area and prevented the migration of ash to downstream areas of the river. After few days following the failure, a provisory containment dike, using boulders as the main material was built. The main purpose of this dike was to avoid migration of the ash to the canal of the Emory River. In addition to its containment function, this dike was built to serve as a functional road during the process of removing the ash (TVA, 2012).

2.4.3 Dredging: The dredging of coal ash was performed in two stages during the remediation process. The Phase-1 was to remove the ash deposited in the riverbed by combined mechanical and hydraulic dredging methods to reduce possible flooding and migration of the ash to the downstream. An estimated 1.76 million cubic meters of coal ash was withdrawn. The Phase 2 of the dredging process was to remove the remaining ash in the river as well as reduce the impacts of coal ash along the natural river sediment. The volume of ash removed in this stage was 596,000 cubic meters and soon after the completion of this process, the Emory River was reopened to the public (TVA, 2012).

2.4.4 Dewatering Process of Ash: The process of dewatering the ash was performed simultaneously with the dredging process of the riverbed. The ash collected by hydraulic dredging was forwarded to the Rim Ditch, Sluice Trench and Ash Pond, so that ash could settle under gravity. After sedimentation, the material was excavated to Ball Field for air drying. After drying, the material was temporarily stored near the site before it was transported to the landfill. The excess water from the hydraulic dredging process was initially forwarded to the Rim Ditch. However, the excess water carried certain ash into the Rim Ditch. So, in January 2010 the water with some ash in it was forwarded to a filter press system for dewatering. It is estimated that at its peak operation, it dewatered about 635 m^3 of ash water (TVA, 2012).

2.4.5 Loading, Transportation and Final Disposition: The loading of dry material began in June 2009 through the railway system near the site. The ash was sent to the State of Alabama and disposed in the Arrowhead Landfill in Perry County. The transport and disposal continued until approximately 4 million tons were transported to the Arrowhead landfill. Although the destination was already set, the daily removal rate of ash (7650-15300 m^3) was higher than the daily rate of transport (6120-7650 m^3), and this required a temporary storage for the ash in stable cells near the power plant (TVA, 2012).

2.4.6 Containment and Removal of the Cenospheres: The management of contamination of cenospheres (floating ash) was initially performed with containment floats, and was suctioned with the help of truck mounted pumps. Approximately 52,000 cubic meters of liquid cenospheres was removed from the area (TVA, 2012).

2.4.7 Dust Control: Considering the problems that the air loaded with silica can cause on human health, a dust control system was immediately implemented in the impacted area. In the area of dredged stable cell, vinyl-acrylic solution was sprayed to suppress the generation of dust on site. For the rest of the area, TVA held aerial seeding of several species of grass, as well as application of fertilizers, to establish a temporary vegetation cover for about 86 hectares and helped reduce erosion in the impacted area (TVA, 2012).

2.4.8 Reconstruction of the Cell and Disposal of Ash: Due to the fast recovery of the impacted area, the disposal of the ash was initiated even before the stabilization of surrounding area. The maximum inclination adopted in the cell was 6H: 1V in order to provide greater stability to it (TVA, 2012). Due to concerns about the stability of underground already affected by the former failure, several monitoring systems (piezometers, slope inclinometers and settlement plates) were implemented to check the safety and stability of the cell. The ash was compressed to 90% of the maximum dry density with its moisture ranging from -2 to +6 of the optimum moisture content. During the construction phase in the winter period, problems in moisture control were observed during the compaction process (TVA, 2013). Accordingly, it was thought to incorporate 2 to 3% (by weight) of lime to the ash deposited in the cell, causing the lime hydration by consuming the excess water, and also enhancing the geotechnical properties of the soil (TVA, 2012).

2.4.9 Stabilized Containment Wall: To increase the stability of the landfill from seismic events, a soil berm was designed around the perimeter of the site, built over a system of stabilized bentonite-cement walls. The walls were built perpendicular to the perimeter of the landfill, with a function to transfer the impulses generated by a possible earthquake to the underlying bedrock (Kilgore, 2009; Bussey et al., 2012; Dotson et al., 2013). All foundation walls were embedded in shale from 0.6 to 2 meters, depending on location. The width of the stabilized area ranged from 15 to 30 meters, the walls being spaced 4.5 to 6.2 meters and with depths ranging from 12 to 21 meters. High performance backhoes were used for the construction of stabilized walls. The slurry used for the construction of walls was a mixture of slag cement and hydrated bentonite (cement-bentonite), which gains strength over time (Dotson et al., 2013).

2.4.10 Cover/Capping of Cell: The cover/capping was performed using a high capacity geocomposite (LLDPE) and 30 cm of cover soil. The use of this system was due to shortage of clayey soil for a compacted soil layer of low permeability. The cover system and the effects of its interface with the ash were analyzed to assess the drained and undrained static stability as well as the pseudo-static seismic conditions (Dotson et al., 2013). The surface drainage was addressed by grading the surface appropriately, allowing the rainwater drained to river (Dotson et al., 2013).

2.4.11 Surface Water Quality Control: A channel system was built around the impacted area to prevent the clean rainwater from entering into the contaminated area and become polluted. In order to avoid the entrainment of materials into the channels, daily cleaning was performed using backhoes. In addition, several monitoring programs were implemented to evaluate the river water, drinking water, air and soil quality near the affected area throughout the restoration period (TVA, 2012; Dotson et al., 2013).

3 DAN RIVER COAL ASH SPILL

3.1 Site Background

Duke Energy, headquartered in Charlotte, North Carolina (NC) is one of the largest electric power holding companies in the United States. In North Carolina itself Duke Energy owns 14 coal-fired power plants, one of which is the Dan River Steam Station (DRSS) located by Dan

River in Rockingham County near Eden, NC. The DRSS began its operation as a coal-fired power generating station in 1949 and was retired from service in April 2012. A natural gas power generating facility was constructed at the same site, few hundred yards away and began operations in 2012. The coal ash residue from DRSS was disposed of in the ash basin system located adjacent to the Dan River.

The primary ash basin was constructed in 1956 and was extended in length approximately 1200 feet east along the Dan River over two existing stormwater pipes in 1968. An intermediate dike was constructed on existing ash deposits in 1976, bisecting the basin into primary and secondary ash basins. The primary ash basin received sluiced ash from pipes through the plant. The secondary basin received decanted flow from the primary ash basin and the flows exit the basin through a decant structure in the secondary basin. The ash basin systems are unlined and are operated as an integral part of site's waste water treatment system. The flow from the secondary ash basin is controlled by National Pollutant Discharge Elimination System (NPDES) Permit. Two dry ash stacks are located to the north of the primary and secondary ash basins. These ash stacks consist of coal ash material dredged from the primary ash basin. Stormwater run-off from the ash stacks is contained within the ash basin system and flows to the secondary ash basin. The ash stacks are unlined and have a vegetative soil cap.

3.2 Coal Ash Spill

On February 2, 2014, a section of the 48 inch diameter stormwater pipe partly made of corrugated metal that ran beneath the primary ash basin collapsed releasing around 39,000 tons of coal ash and 27 million gallons of contaminated water into the Dan River (Duke Energy, 2014a). This coal ash spill was reported to be the third largest coal ash spill in the history of U.S. In a report, the United States Fish and Wildlife Service (USFWS) reported that the coal ash and ash like material were mixed with the sediments as much as 5 feet deep in places and as far as 70 river miles downstream within days following the spill. An immediate action was taken to stop the release and begin assessment of the environmental impact. A concrete plug was placed permanently at the outlet of both the stormwater pipes where the stormwater discharged into the Dan River. The ash deposits were removed from the immediate vicinity of the pipe failure and other downstream locations. Once the ash settled, few locations wherever identified, the ash was successfully removed.

On February 8, a coal ash bar about 75 feet long and 15 feet wide which had as much as five feet of ash or ash/sand mix over the natural stream bottom was identified and was subsequently removed resulting in the recovery of 15 tons of coal ash and native sediment. On July 7, Duke Energy recovered a coal ash deposit (258 tons of a coal ash/sediment mixture) at a site approximately two miles downstream from the steam station on a native sandbar delta at the mouth of Town Creek. The removal of around 2,500 tons of coal ash mixed with native sediment was performed by vacuum dredging at the Schoolfield Dam in Danville, VA in July 2014. In addition to these removal actions, a total of about 466 cubic yards of ash/sediment mix was removed from the water treatment plants at Danville and South Boston and properly disposed of along with dredged material from the Dan River (Dan River, 2014, 2015). A picture of the Dan River coal ash spill is shown below.

Figure 2: Coal ash spill at Dan River due to stormwater pipe collapse (Source: Duke Energy)

3.3 Impacts

The impacts of the Dan River coal ash spill on the natural resources and services were assessed as discussed below.

3.3.1 Surface Waters: The release of coal ash and contaminated water into the Dan River has significantly influenced the water quality. The evaluation of contaminant concentrations in the surface waters downstream showed an increase in the concentrations of copper, selenium, zinc, arsenic and lead exceeding the water quality standards and thresholds, in the days following the spill (Dan River, 2014). However, the risk associated with the contaminated water in the downstream for drinking purposes was mitigated soon.

3.3.2 Geological Resources: Geological resources include the soils and sediments located in upland and wetland areas closely associated with Dan River. The initial screening of sediment also indicated arsenic and selenium as a potential concern for sediments based on the exceedance of the threshold levels. The surveys between the release site and Kerr Lake headwaters indicated ash deposits of sufficient depth overlying native sediments to potentially impact stream habitats (Dan River, 2015). In addition, contaminated sediments serve as a source of continuing releases of hazardous substances to the water column.

3.3.3 Fish and Aquatic Wild Life: The aquatic habitat and wild life that includes fish, migratory birds, and aquatic plants that are dependent on the Dan River have been investigated by the release. The possible pathways for the exposure of aquatic biota to ash-related hazardous substances include direct contact with suspended or dissolved contaminants in the water column, direct contact with contaminated sediments, ingestion of contaminated sediment during foraging or feeding, and indirect contact through ingestion of contaminated prey species, including bioaccumulation (Dan River, 2015). The coal ash released into the aquatic environment can result in injury mainly by burial of native habitats and through destruction of habitat during removal actions to address larger depositional areas. The ash can coat the bottom in depositional areas, burying animals and their food; accordingly, there is a potential for physical burying of habitat that is important for aquatic life. Moreover, the concentrations of hazardous substances in surface water and sediments have been sufficient to cause injury to fish and other aquatic biota as well. It was also learnt that the ecological impact of the coal ash release towards the aquatic life was driven by the burial of aquatic habitat under coal ash rather than the contamination of surface waters due to heavy metals (Dan River, 2015).

3.4 Remediation/Restoration Plan

The disastrous coal ash spill into the Dan River spurred the state of North Carolina (NC) to impose strict regulations for coal ash management and its safe disposal. As per the Coal Ash Act in 2014, Duke Energy is required to close the coal ash impoundments at the DRSS no later than August 1, 2019. In this regard, Duke Energy has come up with a coal ash excavation plan that would assist in its work to close the ash basins at Dan River.

3.4.1 Excavation Plan: Phase I of the plan includes the excavation and removal of 1.2 million tons of ash from the ash stacks or the ash basins at Dan River Steam Station (Duke Energy 2014b). The Maplewood Landfill in Virginia located around 120 miles from DRSS has been identified as the ash storage site. The subsequent phase(s) of the coal ash management plan at DRSS would remove the remaining ash at the site and place it in a fully lined on-site landfill near the existing ash stacks, to facilitate the safe disposal of remaining ash (Duke Energy, 2016). Duke Energy has recently (10/26/2016) received the relevant permit from the NC state department for environmental quality to go ahead with the construction of a lined landfill at DRSS.

3.4.2 Dewatering Plan: The Dan River ash basins will be dewatered to facilitate the removal of ash and transport it to a lined landfill. The lowering of water level within each basin will improve safety factors of the dams by reducing the driving force on the upstream face of the dam (Duke Energy, 2015a). Similarly, dewatering will improve the physical properties of the retained ash, making it less susceptible to flow. The primary ash basin contains an undetermined amount of water which will be pumped to the secondary ash basin at a maximum drawdown rate of one foot over seven days. Following free water removal, vacuum well points will be installed in the ash along the dam to draw down entrapped water in the vicinity of the dam. The dewatering of secondary ash basin that contains approximately 20.7 million gallons of free water will be done similarly as done for primary ash basin (Duke Energy, 2015a).

3.4.3 Safe Basin Closure/Final Cap: The final measure to contain coal ash basins is to construct a final cap that prevents water from entering the system and leaching hazardous contaminants. Duke Energy considers the closing of ash basins by either placing the cap/final cover onto the dewatered ash or excavating the ash from the basin and placing it in a lined landfill. Both of these methods involve safe disposal of water from the basin without affecting the water quality of the water resources. Capping in place involves placing an engineered synthetic cover system over the dewatered ash in the basin with layers of soil and vegetation placed on top. The final cover prevents the rain water from entering into the basin. In fact this method would prevent the need for additional disposal locations, lowers transportation emissions and reduces other impacts on communities. If the excavation of ash is sought then, the feasibility of an on-site landfill is evaluated to help minimize community impacts. If the ash needs to be relocated off-site, the material is excavated, transported by truck or train and stored in a lined landfill that is sealed with a synthetic cover and a layer of protective soil and vegetation (Duke Energy, 2015b). However, in any case a regular monitoring of groundwater is essential in the vicinity of the basin or the landfill to check for the contaminant concentrations in groundwater.

3.4.4 Erosion and Sediment Control (E&SC) Plan: It is important to minimize the impacts to the community while excavating and relocating the ash off-site. Several measures are undertaken to control the dust at the site, including wetting exposed surface areas and maintaining ash at the proper moisture content to prevent dust. The transportation of coal ash to the off-site landfill is predominantly done by rail cars. The approved contractor will install the E&SC measures indicated in the plan such as site preparation activities, including mobilization, installing required site haul roads, installing rail load out spur for rail transportation, and install truck load out and truck wash for truck transportation (Duke Energy, 2015b).

3.4.5 Recycling of Coal Ash: Coal ash has some beneficiary aspects that provide a great opportunity to use it as a construction material. The pozzolanic nature of coal ash (particularly fly ash) makes it a good alternative for cement in construction materials. It is estimated that more than half of the concrete produced in U.S. contains coal ash for construction of structures such as roads, bridges and buildings and make them more durable. In this regard, Duke Energy has been contemplating several avenues for beneficial reuse of coal ash. In fact, Duke Energy had recycled around 63 percent of the coal ash produced in 2015 for beneficial reuse. The company continues to review other innovative technologies and conduct a comprehensive study to evaluate coal ash recycling market and available technologies (Duke Energy, 2016b).

4 Lessons Learned

The catastrophic failures discussed in this study are by no means natural hazards but are induced by some factors. There are many such un-engineered coal ash impoundments which are at a potential risk of failure. The failures discussed in this study set a good example for what needs to be accounted while managing and disposing of coal ash efficiently and safely. There are significant differences between the TVA and Dan River incidents, but there are also similarities that the agencies can utilize in channelizing their efforts to manage coal ash efficiently. The following are some of the important lessons learnt from the two incidents:

- Poorly maintained infrastructure was one of the main reasons for the failure of both the coal ash spills. In Dan River coal ash spill, there is an evidence of the failure of the stormwater pipe in the portion built of corrugated metal. Similarly, in the case of TVA facility the physical instability of the slope and the dikes were overlooked. Hence, it is imperative to check and assess for physical safety in terms of the integrity and stability of the containment system by performing static and seismic analyses to avoid such failures. Structural stability of the impoundments could be maintained by strengthening the containment features (e.g. dikes, MSE berms), and solidifying the load bearing ash to support the overlying load. Although the system is designed for a design life, there could be several factors during the course of its operation which can cause failures and hence timely inspection is indispensable.
- The Dan River spill is a prime example to show that, even without generating new coal ash, the coal ash left behind from decades of operation with inadequate storage can be

disastrous. The ash basins close to the surface waters could pose threat to the water quality in several ways. Firstly, direct discharge of contaminated water from the basin into the river can have adverse effect on the ecosystem of the river and could be carried over to humans. Secondly, the storage of coal ash without any containment barrier would pose threat to the groundwater quality with the leaching of heavy metal contaminants into the groundwater. Hence contaminant migration needs to be properly assessed based on seepage and contaminant fate and transport analysis to check for groundwater contamination. The major intervention in assessing these failures is possible by holistically evaluating the system based on risk associated with the system.

- Proactive remediation strategies which are cost effective and sustainable have to be employed to restore from the damages caused by these failures. Employing energy intensive remediation techniques would however solve the problem but adds greatly to other existing problems and exacerbates the situation. This would involve dewatering and clean-up of the affected site (sediments) using passive technologies and employing alternate sustainable materials in place of traditional materials during the process.
- It is necessary to consider the issues associated with coal ash impoundments based on the broader social, economic and environmental impacts. The environmental impacts shall be assessed in terms of the effects that the facility could have to the surrounding surface water systems, groundwater systems, soil and air. The contaminant transport needs to be assessed with an engineering perspective and needs to be minimized causing no risk to the environment and public health. The economic impacts of these facilities would sometimes be due to their influence on the surrounding property or the real estates. In addition, the economic impacts could also be from the use of materials for closure of the impoundments. Hence, the choice of materials can influence the cost and thereby the economic aspects associated with the facility. Finally, it is quite important to consider the community education and participation in decision-making.
- The end use of these coal ash impoundments should be planned similar to engineered landfills as there is a great opportunity for beneficial reuse of the land for several commercial and recreational purposes. Unlike MSW landfills, the surface impoundments provide great opportunity for reuse of space without posing any significant concerns with regards to the stability of the structures or the services built over it. However, there needs to be adequate monitoring employed at these sites to check for instabilities or any threat to the beneficiaries.
- Coal ash is a promising material in terms of its use in construction material, after being processed, to build more strong and durable structures. The encapsulated coal ash when used as a construction material can help reduce GHG emissions, diverge waste from going into landfill thereby reducing the need for landfill space, alleviates the need for primary raw materials preserving the natural resources. The recycling of coal ash has the most significant environmental benefits and it needs to be leveraged by innovative and technological systems.

The coal ash storage and disposal has been a concern to environmentalists for decades. However, it seems that these failure events made this problem gain adequate attention and the political momentum to create some new regulations for coal ash management. With the advent of NC Coal Ash Management Act, the US Environmental Protection Agency (EPA) has also imposed final rule providing a comprehensive set of requirements for regulating the safe disposal of CCRs (USEPA 2016). The final rule is based on extensive study on the effects of CCRs to the environment and public and the risks associated with them. The rule emphasizes on the structural integrity of surface impoundments to prevent any catastrophic failures experienced earlier. The rule also supports recycling of coal ash for beneficial reuse (USEPA 2016). The lessons learned and the new regulations would not only help US but other countries to develop such strategies for safe and effective management of coal ash.

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