The Tennessee Valley Authority's Kingston Ash Slide: Potential Water Quality Impacts of Coal Combustion Waste Storage

A testimony to the Subcommittee on Water Resources and Environment,
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by

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1. Introduction

On December 22, 2008, the retaining wall broke on a waste retention pond at the Tennessee Valley Authority (TVA) Kingston Fossil Plant, Tenn., and an estimated 4.1 million m^3 of coal ash slurry was spilled onto the land surface and into the adjacent Emory and Clinch Rivers (TVA , 2009). This was the largest coal ash spill in US history. The coal ash sludge spilled into tributaries that flow to the Emory River and directly into the Emory River itself (Fig. 1), which joins to the Clinch River and flows to the Tennessee River, a major drinking water source for downstream users. With funds provided by the Dean of the Nicholas School of the Environment of Duke University, in January 2009 our team began a preliminary investigation of the potential environmental and health effects of the spill. This preliminary work (Vengosh et al., 2009; Ruhl et al., in revision) has thus far revealed three major effects: (1) The surficial release of coal ash formed a sub-aerial deposit that contains high levels of toxic elements (arsenic concentration of 75 mg/kg; mercury concentration of 150 μg/kg; and radioactivity (radium-226 + radium-228) of 8 pCi/g). These pose a potential health risk to local communities as a possible source of airborne re-suspended fine particles (<10 μm). (2) Leaching of the coal ash sludge in the aquatic environments resulted in severe water contamination (e.g. high arsenic content) in areas of restricted water exchange such as the Cove area, in a tributary of the Emory River. Further downstream, in the Emory and Clinch rivers, much lower levels of metals were found due to river dilution, but with metals concentrations above the background upstream levels. (3) High concentrations of mercury in downstream sediments of the Emory and Clinch rivers indicate physical transport of coal ash in the rivers. The high concentration of mercury and sulfate in the downstream river sediments could impact the aquatic ecosystems by formation of methylmercury in anaerobic river sediments.

A recent survey of the amount of coal ash generation in the United States revealed that 500 power plants nationwide generate approximately 130 million tons of coal ash each year, 43 percent of which is recycled into other materials. The remaining 70 million tons are stored in 194 landfills and 161 ponds in 47 states (Lombardi, 2009). An EPA study (USEPA, 2007) identified 63 coal ash landfills and ponds in 23 states where the coal sludge is associated with contaminating groundwater and the local ecosystem. One of the major potential hazards of coal ash storage in ponds is the continuous leaching of contaminants and their transport to the hydrological system. As such, the TVA coal ash spill provides a unique opportunity to evaluate the large-scale impact of coal ash leaching on the environment and water resources.

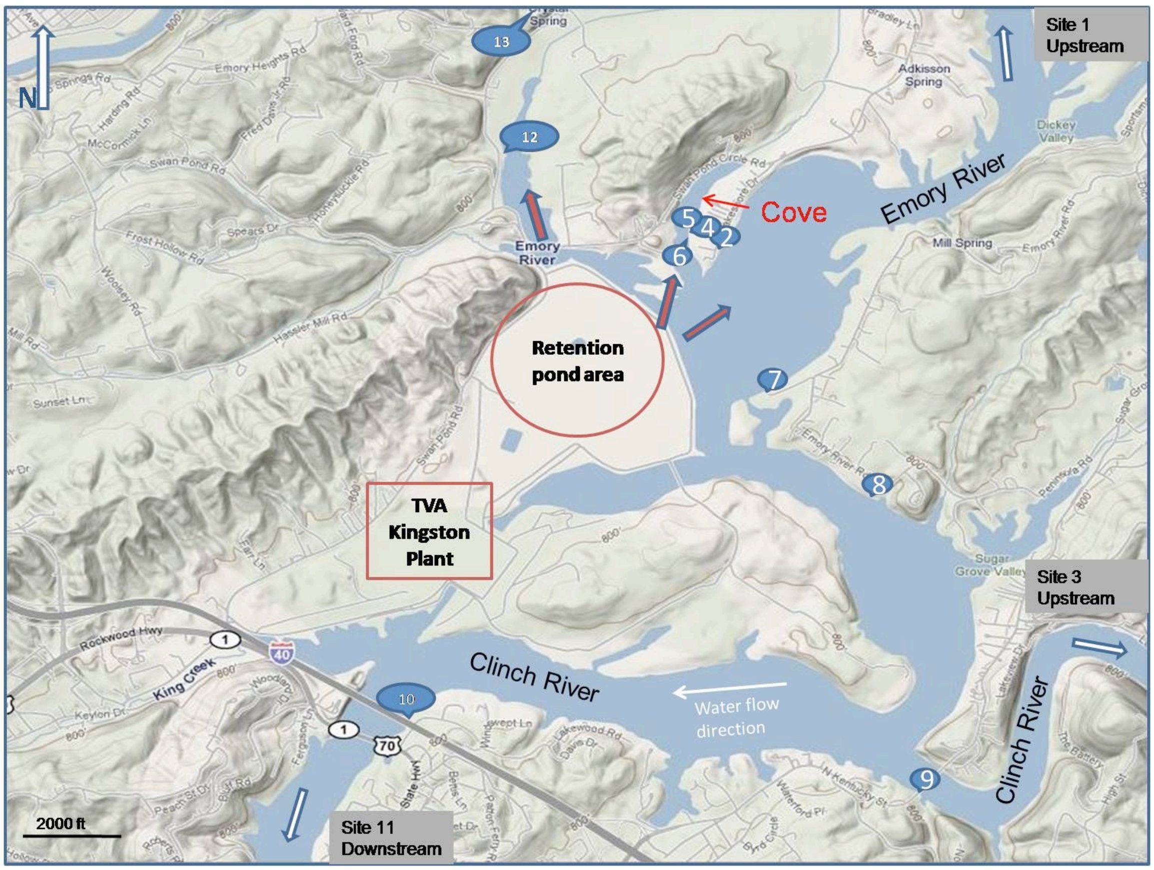

Figure 1: Map of the sampling sites of the TVA coal ash spill in Kingston, Tenn. From Ruhl et al. (in revision). Numbers refer to sampling sites in the vicinity of the TVA coal ash spill.

2. Fieldwork and analytical work

Coal ash sludge, sediments from the rivers, and water samples from tributaries, Emory and Clinch rivers, and springs near the spill area in Kingston and Harriman, Tenn., (Figure 1) were collected on two field trips on January 9-10 and February 6-7, 2009. Water sampling strictly followed the U.S. Geological Survey sampling protocol; trace metal and cation samples were filtered directly into new, high-purity acid-washed polyethylene bottles containing high-purity HNO_3 in the field for preservation using syringe-tip 0.45 μm filters. Trace metals in water were measured by inductively coupled plasma mass spectrometry (ICP-MS), mercury in sediments and coal ash by thermal decomposition, amalgamation, atomic absorption spectroscopy (Milestone DMA-80), and radium isotopes by gamma spectrometry at the Laboratory for Environmental Analysis of RadioNuclides (LEARN) at Duke University (http://www.nicholas.duke.edu/learn/).

3. Water contamination

The chemical data show that surface water in the tributary that was dammed by the coal ash spill and turned into a standing pond ("the Cove" in the area of Swan Pond Circle Road; Fig. 1) has relatively high levels of arsenic, calcium, magnesium, aluminum, strontium, manganese, lithium and boron. The concentration of arsenic was up to 86 μg/L in the Cove area (for reference, the EPA Maximum Contaminant Level in drinking water is 10 μg/L). The concentrations of these elements in springs that emerge into the Cove area are low, thus indicating that the shallow groundwater was not contaminated. We suggest that the non-contaminated groundwater discharges into the dammed tributary and causes leaching of metals from the sludge ash that was released from the TVA coal ash spill. Under restricted water exchange, the formation of standing water in the Cove resulted in contaminated surface water with high concentrations of arsenic, boron, strontium and other elements (Table 1).

Sample ID	Li	B	Al	Mn	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Cr
The Cove													
TN1	13.24	431.89	-	846.9	2.11	3.98	1.54	16.54	69.59	2.44	15.57	578.4	1.88
TN1U	-	425.93	344.0	974.1	3.08	-	5.03	42.40	95.25	0.42	17.13	632.6	-
RC5	19.60	470.80	22	3014	6.96	8.97	1.57	47.16	85.56	3.75	23.76	1245	1.92
TN9	3.07	84.92	43.0	296.5	0.29	4.26	0.79	12.18	9.27	0.52	5.02	108.3	6.56
TN9U	-	112.89	197.0	331.8	1.15	-	3.48	24.86	12.60	-	6.25	120.1	-
RC8	7.39	229.63	40	556	1.89	1.67	2.77	36.64	20.70	1.83	6.35	456	0.47

U=unfiltered water

Table 1. Concentrations of trace metals (μg/L) in surface water from the Cove area (see location in Figure 1).

In contrast, surface waters from the Emory River and Emory-Clinch River downstream from the breached dam show low concentrations of these metals, and all river inorganic dissolved constituents concentrations are below the EPA-Maximum Contaminant Levels. In spite of the absolute low concentrations, the metal contents in the downstream river samples are higher relative to the upstream river samples. For example, the arsenic levels in the downstream river samples are up to 3 μg/L relative to <0.4 μg/L in upstream rivers (Figures 2 and 3). We are able to detect these small changes due to the high sensitivity of our analytical instrument (inductively coupled plasma mass spectrometry; ICP-MS). This indicates that leaching of these metals from the coal ash in the river sediment is taking place in the rivers, yet the massive dilution of the rivers reduces the content of these metals to below the MCL level. A report by TVA indicates that during storm events, remobilization of the coal ash resulted in short-term spikes of arsenic in the river (TVA, 2009). Remobilization of the river sediment by dredging could enhance metal leaching and contamination of the river water. Since dredging of the coal ash from the river bottom is an essential part of TVA restoration plan (TVA, 2009), it is essential to continue monitoring the water quality in order to evaluate the impact of dredging on the river water quality.

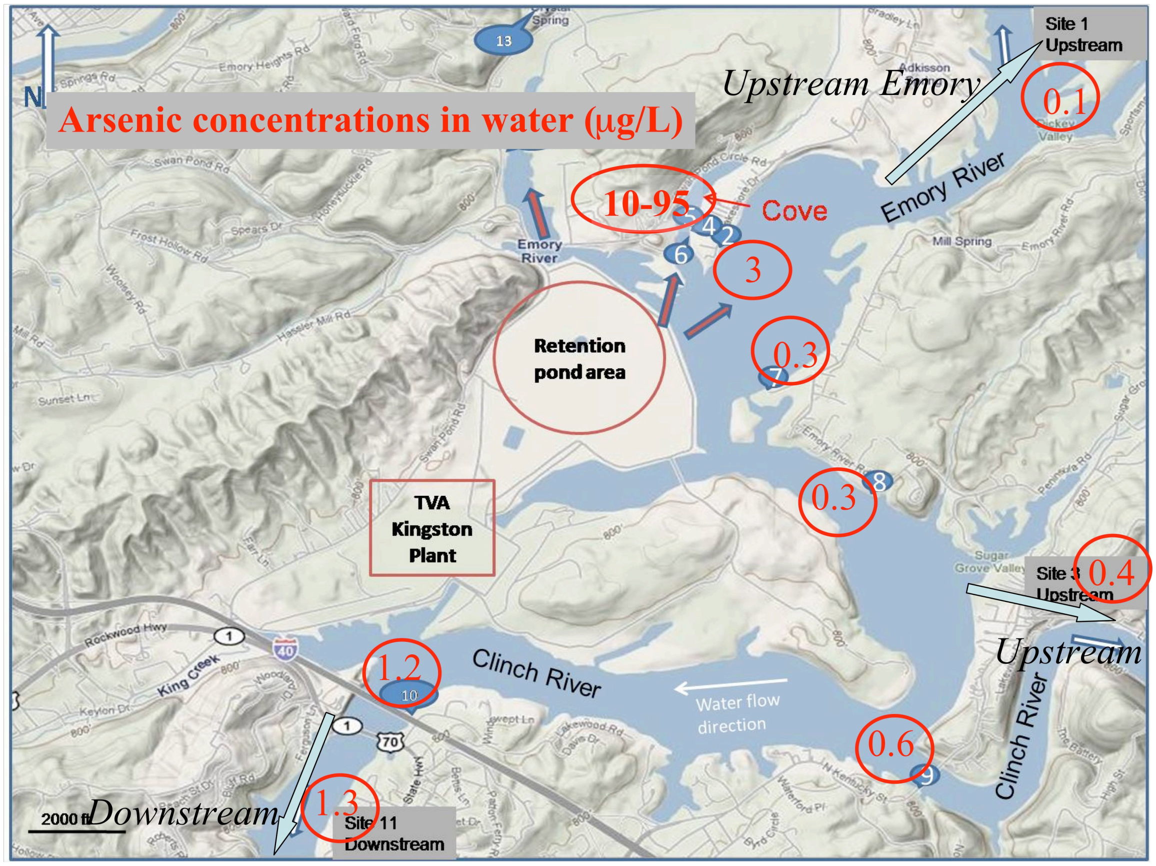

Figure 2: Map of the sampling sites of the TVA coal ash spill in Kingston, Tenn., with concentrations of arsenic (µg/L) in surface waters associated with the TVA coal ash spill.

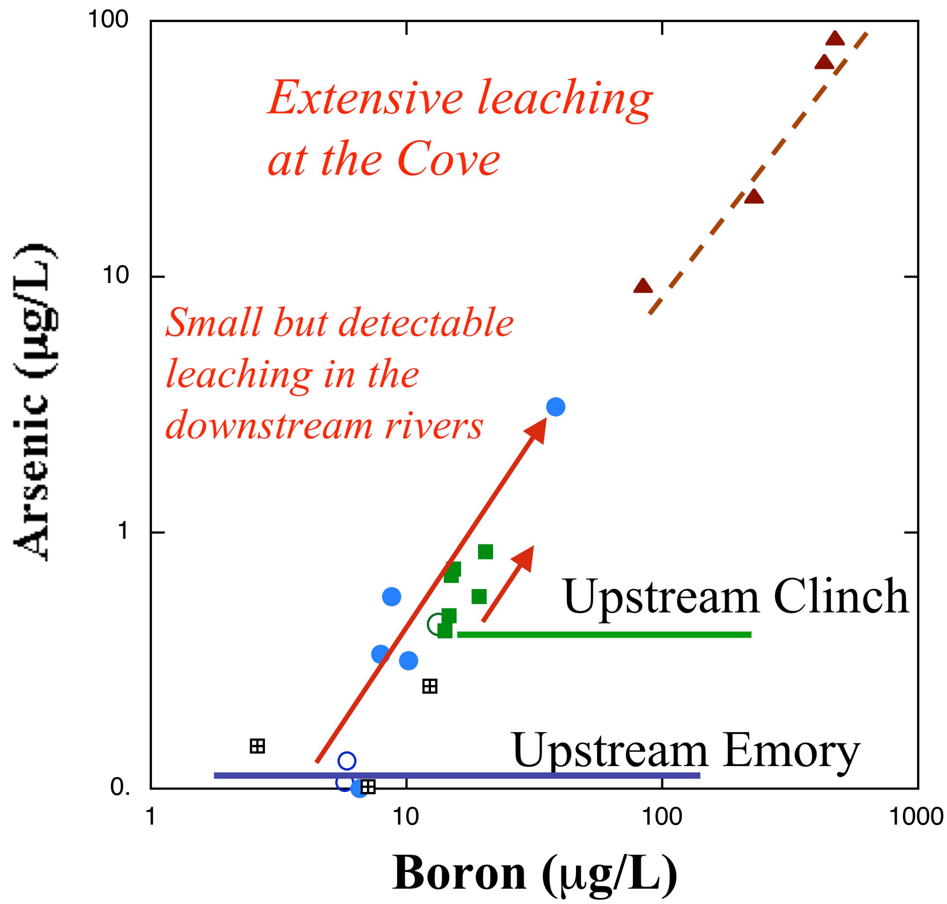

Figure 3: Concentrations of arsenic versus boron in Emory (blue) and Clinch (green) rivers and in groundwater (squares) in logarithmic scale. Note the relative enrichment of the downstream Emory and Clinch river samples relative to the respective upstream river samples.

4. River sediment contamination

The mercury concentration in the TVA coal ash sludge (an average of 151.3±15.9 µg/kg) is higher than background soil in Tennessee (45-50 µg/kg) (USGS survey data, 2004). These concentrations are consistent with mercury concentrations previously reported in fly ash (100 to 1500 µg/kg) (Sanchez et al., 2006). In the sediments of the Emory and Clinch rivers, the mercury concentration increases from 29.7-43.3 µg/kg in upstream sediments, to 115-130 μg/kg in downstream sediments from the spill site (Figure 4). The mercury concentrations of the upstream sediments are consistent with previously reported Hg data for the lower Clinch River and for the overall Tennessee River (USGS survey data, 2004). However, the relatively high mercury concentrations in the downstream river sediments could indicate a significant transport of the coal ash in the river and deposition in the river sediments. We measured relatively high mercury in sediments at Site 10, downstream from the underwater bar that was built to prevent migration of the ash (Fig. 1). A simple mass balance between the mercury content of coal ash (150 μg/kg) and background soil (50 μg/kg) suggests that the downstream river sediment at Site 10 was composed of about 66 percent ash. The assumption that mercury in the river sediments is derived from only redistribution of coal ash needs to be confirmed by further research.

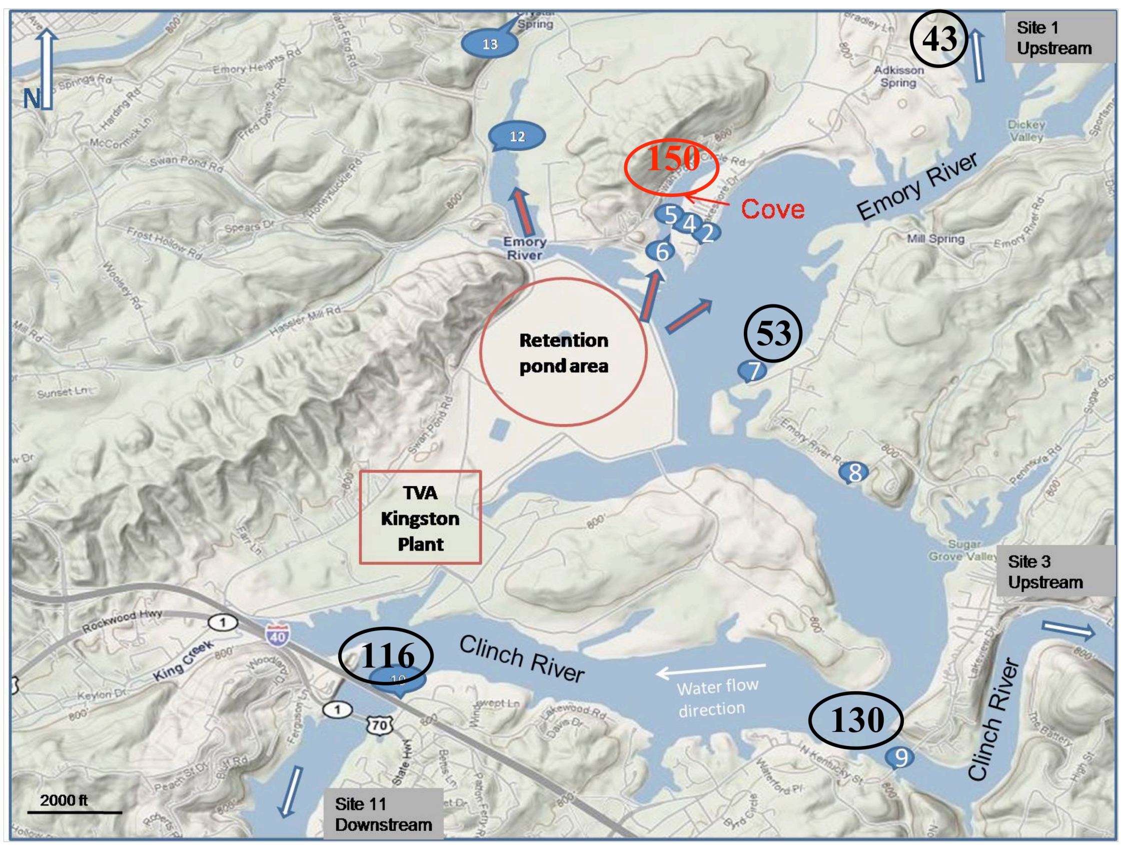

Figure 4: Map of the sampling sites of the TVA coal ash spill in Kingston, Tenn., with concentrations of mercury (μg/kg) in sediments (black) and coal ash (red) Data from Ruhl et al. (in revision).

The ecological impact of high mercury (and arsenic) in the river sediments has not been determined as yet. We hypothesize that accumulation of coal ash in the river sediments might generate transformation of elemental mercury to methylmercury by anaerobic bacteria in river sediments. Forming of methylmercury in river sediments is a concern because of bioaccumulation of methylmercury in food webs. In addition, accumulation of As-rich fly ash in bottom sediment and leaching of arsenic to pore water might cause fish poisoning via both food chains and decrease of benthic fauna that is a vital food source. These potential hazards should be monitored.

5. Conclusions

- Leaching of the coal ash sludge in the aquatic environments resulted in severe water contamination (e.g. high arsenic content) in areas of restricted water exchange - the Cove area.
- Further downstream in the Emory and Clinch rivers, much lower levels of these metals were found due to river dilution, but with metal concentrations above the background upstream levels.
- Remobilization of the river sediment by dredging could enhance metal leaching thus it is essential to continue monitoring the water quality in order to evaluate the impact of dredging on river water quality.
- High concentrations of mercury in downstream sediments of the Emory and Clinch rivers suggest physical transport of coal ash in the rivers.
- The high concentration of mercury in the downstream river sediments could impact the aquatic ecosystems by formation of methylmercury in anaerobic river sediments. Forming of methylmercury in river sediments is a concern because of bioaccumulation of methylmercury in food webs.
- Accumulation of As-rich ash in bottom sediment and leaching of arsenic to pore water might cause fish poisoning via both food chains and decrease of benthic fauna that is a vital food source.

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