

ENVIRONMENTAL PERSPECTIVES

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Coal Ash: Hazard, Waste, or Resource?

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The catastrophic failure of the ash retention pond at the Tennessee Valley Authority's Kingston power plant in December 2008 brought the issues associated with coal ash onto front pages of newspapers, and into public discussion. As that incident demonstrated, the sheer volume of material in ash retention ponds can represent a hazard if the retaining structures fail. Though EPA had previously (in 1993 and again in 2000) reviewed the classification of coal combustion products (CCP) and had not changed its hazardous waste exemption, the agency is once again reviewing the RCRA designation of coal ash. A change in the classification would affect current beneficial uses of CCP. In this article, we provide a brief review of CCP (fly ash and bottom ash) and describe its potential environmental and health hazards.



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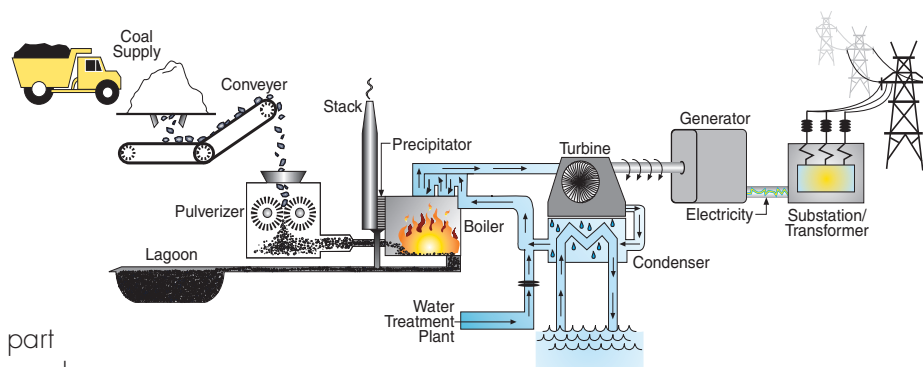
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Background on Coal Ash

Production

When coal is combusted for the production of electricity at coal-fired power plants, significant amounts of combustion residues remain and require proper disposal or reuse. The largest volume of coal combustion residue consists of fly and bottom ash, boiler slag and flue gas desulfurization (FGD) residue. Fly and bottom ash make up the majority of the coal combustion residues, or CCP.

In 2008, more than 130 million tons of CCP were produced in the United States, of which 43 percent were used beneficially and the remaining 75 million tons disposed of in landfills or slurry retention ponds¹. A part of the coal ash is also disposed in minefills. Fly ash is recycled more frequently than bottom ash, as it is used in concrete to enhance its strength and resistance to weathering. Other beneficial CCP uses include road-base materials, manufactured aggregates, flowable fills, structural fills, and embankments and soil modification, among others.



Although fly and bottom ash have a similar origin, their physical and chemical characteristics differ. Fly ash, a very small particulate with diameter typically between 10 and 100 microns, is captured and removed from flue gas by electrostatic precipitators or bag filters. Bottom ash collects at the bottom of the furnace and consists of larger (and therefore, heavier) particles. Coal ashes, in general, are mainly composed of oxides of silica, aluminum, iron, calcium, magnesium and sulfur. In addition to the macroelements, coal ashes contain several trace elements, including arsenic, selenium, boron, cadmium, and lead. The concentrations of these trace elements can be enriched between 2 and 100 times relative to the original coal.

¹ American Coal Ash Association (2010).

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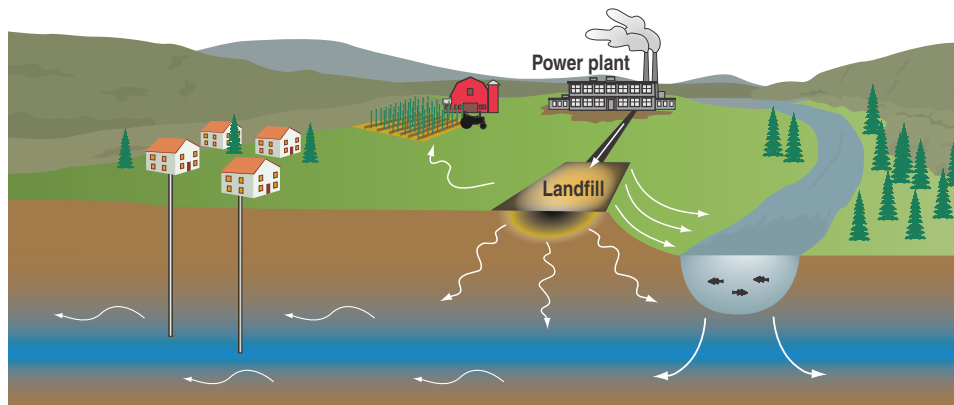
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Chemistry and Properties

The chemical composition of the two ash types varies with the coal rank, that is, with the age and maturity of the coal and its origin. For example, ashes from low-rank lignite and sub-bituminous coals contain more calcium and magnesium, which form basic solutions when mixed with water. The high-rank coals, like bituminous coal, contain more pyritic iron, resulting in acidic solutions when mixed with water. Concentrations of trace elements, such as arsenic and selenium, tend to be higher in fly ash than in bottom ash. Additionally, bituminous coal fly ash has higher amounts of arsenic than do sub-bituminous and lignite coal ashes, while the amount of selenium is similar in all ranks of coal.

Potential Hazards

Potential hazards from coal ash come from the physical properties of the ash itself, as well as from chemicals in the ash. Fine particulate coal ash material can smother terrestrial vegetation and aquatic sediments in nearby rivers or ponds. Dry ash from improperly maintained ash piles poses a health risk if inhaled because of the very small sized particles (less than 10 microns diameter). Although mercury is known to be associated with coals, a large proportion of the mercury is vaporized during the combustion process and the remaining mercury usually is tightly bound to the particles and therefore is not released to the environment. Other metals such as lead and cadmium may be present at higher amounts in ash as well. However, while cadmium is readily taken up by plants and put into the food chain, lead in ash is less available and so poses a reduced environmental and health risk. Chemical hazards in the ash come from the coal as it is combusted, and most frequently include arsenic, selenium, and boron. Because these elements can be highly mobile in soils and sediments, particularly when buried and saturated, they can readily leach out of the ash piles and move into groundwater if the impoundments are not properly lined.



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Soluble inorganic arsenic in aquatic environments is taken up by algae, aquatic plants, and fish and is converted to organic forms. Microscopic organisms in the water column or sediments also transform much of the inorganic arsenic to organic forms. The organic forms of arsenic are rapidly excreted by animals and are considered to be relatively non-toxic. Consequently, exposures for fish and other animals to arsenic in the environment and food chain are less of a concern than for people who are exposed to inorganic arsenic in drinking water (from either wells or in surface water sources). Exposure to inorganic arsenic in coal ash may also occur from incidental ingestion of soils or sediments contaminated with the ash, or by inhalation of coal ash dust.

Breathing high concentrations of airborne arsenic for many years has been associated with a risk of lung cancer², although this has not been reported in workers handling coal fly ash within power plants³, possibly because of the less toxic form of arsenic in coal fly ash or lower exposures⁴. Studies of people (non-workers) living near historical sources of arsenic emissions (such as smelters) have found no increases in diseases related to arsenic in soil or air⁵. Long-term intake of arsenic in drinking water over much of a lifetime has been associated with internal cancers (e.g., of the skin, lung, and bladder) and skin lesions (e.g., wart-like structures, pigmentation changes), as well as cardiovascular and neurological effects, primarily in the extremities. However, these effects have been observed with arsenic water levels much higher than the previous (50 µg/L) or current (10 µg/L) U.S. allowable drinking water standard. Several of these populations also have severely impoverished nutrition, which increases the toxicity of arsenic. Assessments of risk from oral exposure to arsenic are based on a conservative dose-response model and EPA's draft updated toxicity assessment raises the current cancer potency estimate for arsenic by 17 times⁶.

Arsenic, selenium and boron present more problems than other elements

Selenium is required in the diets of both people and animals as it is essential for some enzyme functions, protects against certain cancers, blocks the action of free radicals, and helps stimulate the immune system. Selenium can also be an immuno- and reproductive toxin; the difference between an effective or safe dose and a toxic dose of selenium is relatively small in most animals. Unlike arsenic, selenium in

² <http://www.epa.gov/ncea/iris/subst/0278.htm>; ATSDR (2007)

³ ATSDR (2007)

⁴ Hicks (1993)

⁵ Lyon et al. (1977); Greaves et al. (1981); Rom et al. (1982); Frost et al. (1987); Wong et al. (1992); WSDH and ATSDR (1994); CDPHE (1995); Marsh et al. (1997, 1998); Tollestrup et al. (2003)

⁶ U.S. EPA. 2010. Toxicological review of inorganic arsenic. Draft. EPA/635/R-10/001.

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fish or invertebrates remains in a form that can potentially be toxic to people, wildlife, or other fish that consume these organisms. Selenium uptake by plants generally is not a concern, as it makes the plants taste bad so wildlife or livestock typically will not eat them. Selenium in aquatic systems, particularly in lakes, reservoirs, wetlands, or the slow backwaters of rivers and streams, is converted to a chemical form that is easily taken up by algae and bacteria in sediments and passed up the foodchain to invertebrates and fish. Waterfowl or shorebirds that feed on invertebrates and osprey, herons, or other species that eat fish may be exposed to toxic levels of selenium. Several instances of selenium poisoning of fish and wildlife have occurred in the United States over the past several decades, including at Belews Lake, NC, which was used as a coal ash disposal site in the late 1970s and early 1980s. People usually do not eat enough fish to be poisoned by selenium, and human health risks from selenium in the environment are low; the few reported cases of human selenium poisoning in the U.S. are all in industrial workers, accidental poisonings, and abuse of dietary supplements.

Boron is another metalloid that is similar to arsenic and selenium, and is frequently associated with coal ash. Boron is used commercially in the manufacture of soaps, glass, steel, and as a preservative for wood or meat. It is essential for plant growth and is often used as a fertilizer. When ingested, it is rapidly taken up into the body and equally quickly eliminated. Boron is not very toxic and usually causes nausea, diarrhea, and skin rashes. Very high doses result in reduced fetal weights in rat studies (but not humans) and testicular atrophy. Toxic responses disappear rapidly once exposure is stopped. Regulatory limits in drinking water are 3 mg/L for children and 6 mg/L for adults.

Regulatory Trends and Challenges

EPA has recently proposed and is seeking public comment on two options for a possible regulatory change for managing coal ash from electric utilities and independent power producers. In the first option, residues to be disposed of in landfills or surface impoundments would be designated as a special waste that would be subject to regulation under Subtitle C of RCRA. Under Subtitle C's "cradle to grave" approach, ash would be subjected to regulatory oversight from production through disposal. Facilities that manage disposal of residues would be subjected to requirements regarding location, liners, run-on and run-off controls, groundwater monitoring, fugitive dust controls, financial assurance, corrective action, closure of units, and post-closure care. Beneficially used residues (i.e., CCP) would not be regulated. The second option would regulate the disposal of coal ash under Subtitle D of RCRA. EPA would issue national minimum criteria for disposal, but enforcement would be delegated to the states and only the disposal actions would be subjected to regulatory oversight. Both options would include safety requirements that address the structural integrity of surface impoundments.

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What to Do Next?

Companies should be evaluating the stability and risk of failure of currently operating coal ash storage impoundments, as well as assessing management options under either of the regulatory strategies being considered by EPA. Faced with increasing public concern over safety of coal ash storage impoundments, EPA inspections in 2009 found 49 with a high hazard potential following a catastrophic failure. Heightened risk of litigation resulting from increased public and regulatory scrutiny, and the possible loss of up to \$10 billion per year in revenue to utilities from the current sale/reuse of fly ash, will significantly change the existing business model. Companies should evaluate their risks and corporate liabilities, and develop specific business plans for management of coal ash.

Exponent's Role

In spite of physical and chemical hazards, current technologies allow a large part of what otherwise would be waste to be put to beneficial use. However, successful management of coal ash requires that storage ponds be properly engineered and maintained. Ash must be handled appropriately during transport. In the event of a release, plans must be in place to protect people and the environment. Exponent's scientists offer expertise in predicting and managing risks from the metals and particulates associated with coal ash, and Exponent's engineers can provide expert review of risk of failure associated with coal ash slurry ponds.

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Next Issue— Regulation of Hydraulic Fracturing Fluids

Brun Hilbert, Ph.D., P.E., Marie BenKinney, Mark Johns, Ph.D., P.G., L.G., Farrukh Mohsen, Ph.D., P.E., Paul Boehm, Ph.D.

Hydraulic fracturing of oil and gas wells has been understood and used for more than 60 years. Hydraulic fracturing is an oil and gas well stimulation operation in which fluids are pumped through a well to low permeability formations at sufficiently high pressure to create new fractures in rock or open existing natural fractures, so that greater volumes of oil or natural gas can be produced. It is well known that this operation can make otherwise non-economic wells financially viable. In fact, hydraulic fracturing operations have led to a renaissance in the natural gas drilling and production industry in shale gas and coal bed methane regions in Alabama, Colorado, Kansas, Montana, New Mexico, New York, Pennsylvania, Texas, Utah, West Virginia, and Wyoming in the United States, and in Canada. The environmental issues surrounding the technology, the uses of certain chemicals, and the disposal of fracturing fluids, have become very prominent at the state and federal levels, to the point where the development of gas resources could be significantly affected. Legislation governing disclosure of fluid composition, permitting requirements for use and disposal, and requirements for preliminary environmental assessments are under development in a number of states relating to development of the Marcellus, Barnett, Black Warrior, Powder River, and Eagle Ford Basins, among others.

On February 18, 2010, Congressmen Henry Waxman, Chairman of the House Energy and Commerce Committee, and Edward Markey, Chairman of the Subcommittee on Energy and Environment, sent letters to the CEOs and presidents of eight oil and gas industry service companies requesting that they produce documents related to the types and use of chemicals in hydraulic fracturing fluids.¹

Environmental, engineering, and regulatory aspects of these issues will be explored in the next edition of Environmental Perspectives.

¹ http://energycommerce.house.gov/Press_111/20100218/hydraulic_fracturing_memo.pdf

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Sharon Maharg

Manager—Environmental Sciences Practice
New York, New York

Ms. Sharon Maharg has joined Exponent as a Manager in the Environmental Sciences practice, based in the New York office. She specializes in managing environmental and social risks in project and structured finance transactions. She has more than 25 years of international banking experience in multiple areas of emerging markets finance (especially in Latin America), including sustainability management, project finance, structured trade, and export finance. Ms. Maharg's technical expertise includes advising project developers and lenders on how best to assess and manage environmental and social risks in order to be in compliance with international guidelines. She performs onsite due-diligence, monitors projects during construction and operation, and conducts consultations with local governmental authorities, local communities, and other key stakeholders. Ms. Maharg's recent project experience includes the 3,150-MW Santo Antonio Hydroelectric Power Project in Brazil, and a new 82-km toll road project in Azerbaijan.

Prior to joining Exponent, she served as WestLB AG's Regional Head of Sustainability Management for Latin America. Ms. Maharg assumed a leadership role among the Equator Principles Financial Institutions (the "EPFI") in early 2004, representing one of four founding EPFIs. She was a member of the EPFI Steering Committee, co-authored the Equator Principles II (2006) and acted as a stakeholder to International Finance Corporation (IFC) during the 2-year consultation period for the drafting of IFC's new Performance Standards. She led the lenders' environmental and social due-diligence and ongoing monitoring of the Oleoducto de Crudos Pesados Project (Ecuador), a US\$900 million project for the construction and operation of a 500-km heavy crude oil pipeline system, extending from the Oriente Basin in the Amazon, passing through areas of high biodiversity in the Andes, to the Pacific Coast.

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