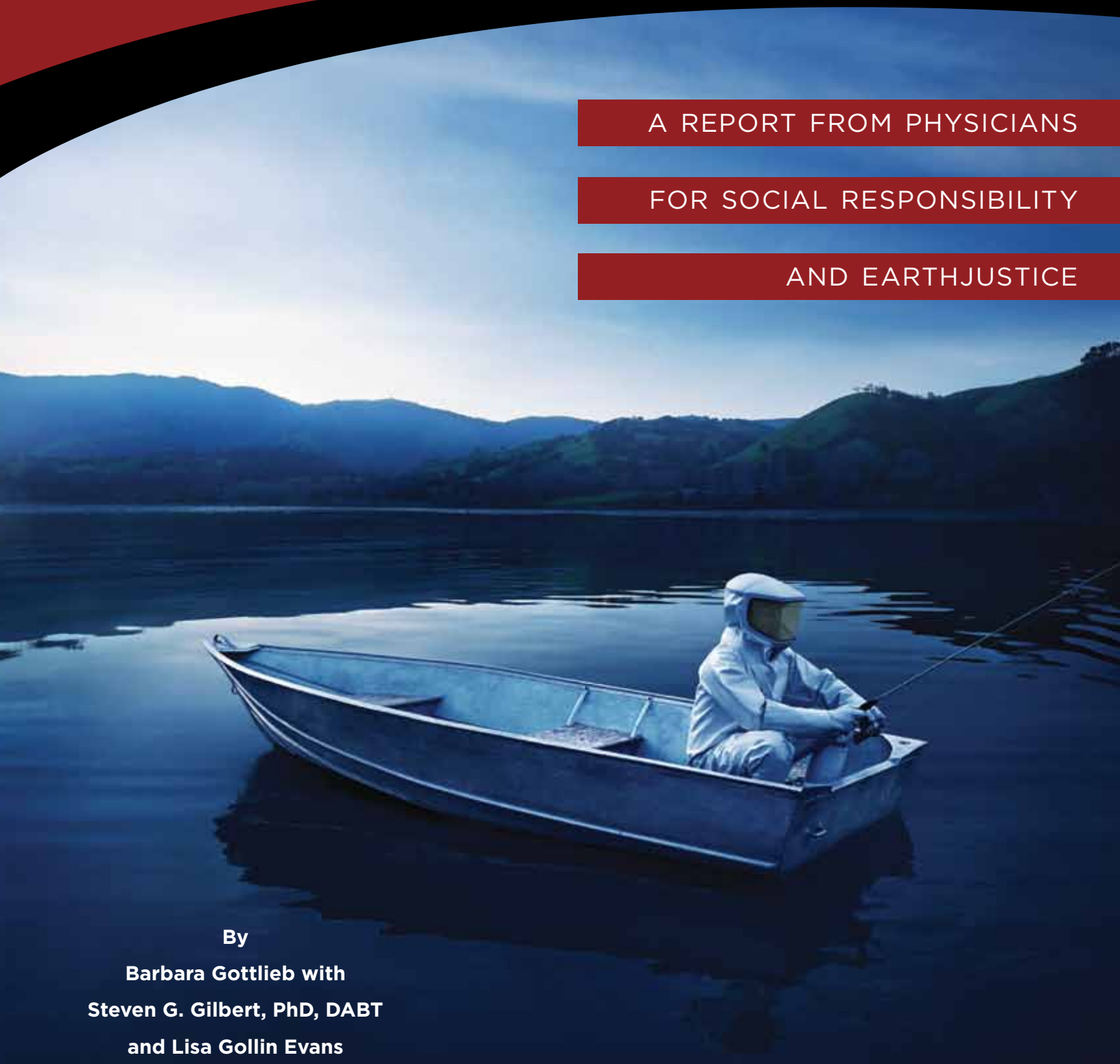
Coal Ash

The toxic threat to our health and environment

A REPORT FROM PHYSICIANS

FOR SOCIAL RESPONSIBILITY

AND EARTHJUSTICE



By

Barbara Gottlieb with

Steven G. Gilbert, PhD, DABT

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Contents

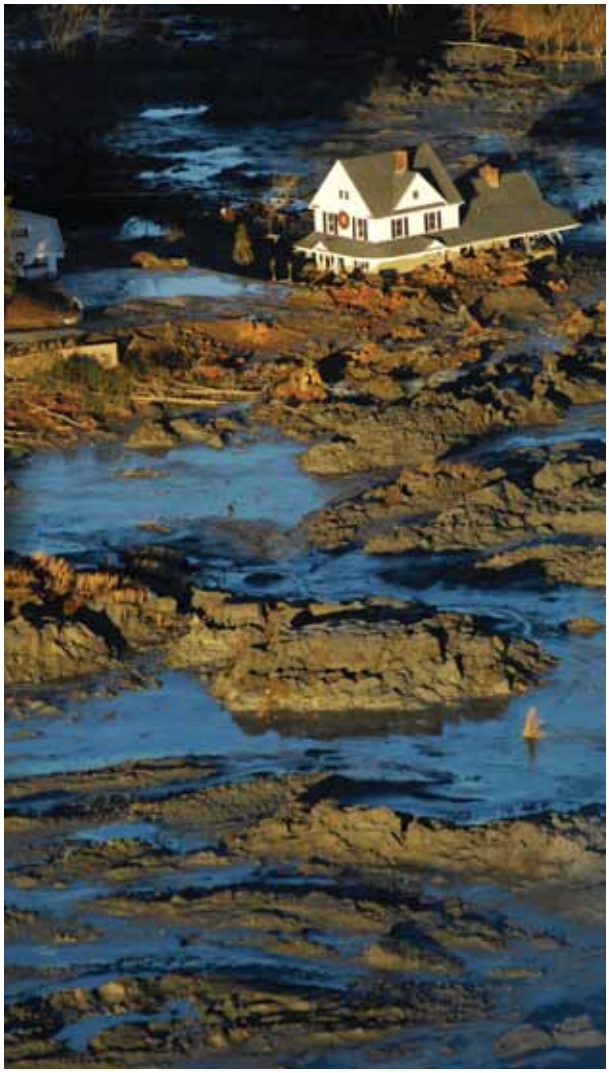
Executive Summary

Coal ash, one of the dirtiest secrets in American energy production, burst into the U.S. consciousness three days before Christmas, 2008 when an earthen wall holding back a huge coal ash disposal pond failed at the coal-fired power plant in Kingston, Tennessee. The 40-acre pond spilled more than 1 billion gallons of coal ash slurry into the adjacent river valley, covering some 300 acres with thick, toxic sludge, destroying three homes, damaging many others and contaminating the Emory and Clinch Rivers.[1]

When the U.S. Environmental Protection Agency tested water samples after the spill, they found toxic heavy metals including arsenic, which they measured at 149 times the allowable standard for drinking water.[2] Water samples also contained elevated levels of other toxic metals: lead, thallium, barium, cadmium, chromium, mercury, and nickel.

Despite that catastrophic spill in Tennessee, the full dimensions of the health threats from coal ash are just beginning to register with the American public. Coal ash is the waste product left over after coal is combusted, or burned. Many people are still not aware of how toxic coal ash is, much less how much coal ash is generated each year and how grossly mismanaged its disposal is:

- While the toxic contents of coal ash may vary depending on where the coal is mined, coal ash commonly contains some of the world's



Appalachian Voices

Two dozen homes were destroyed or damaged by the 2008 coal ash spill in Kingston, Tennessee.

deadliest toxic metals: arsenic, lead, mercury, cadmium, chromium and selenium.[3]

- These and other toxicants in coal ash can cause cancer and neurological damage in humans. They can also harm and kill wildlife, especially fish and other water-dwelling species.

- Coal ash is the second-largest industrial waste stream in the U.S., after mining wastes.[4]

- Coal ash is disposed in approximately 2,000 dump sites across the nation: at least 629 wet ash ponds [5] and 311 dry landfills at power stations, at least 100 offsite dry landfills,[6] and 750 inactive dumps,[7] and hundreds of abandoned and active mines (as fill).[8]

- Coal ash dumps likely exist in every state in the U.S. due to the widespread use of coal to generate electricity in the nation's 495 coal-fired power plants and hundreds of industrial boilers.[9,10]

After the Tennessee spill, public attention focused at first on the possibility of more sudden catastrophes. But the most common threat that coal ash poses to public health comes from a less dramatic scenario: the slow leakage of toxic pollution from disposal sites such as ponds and landfills.

Toxic pollution, some of it cancer-causing, can and does escape from some of those sites, according to the EPA.[11] This occurs in a variety of ways, most frequently when coal ash comes into contact with water, allowing toxics to "leach" or dissolve out of the ash and percolate through water. Coal ash toxics have leached from disposal sites in well over 100 communities, carrying toxic substances into above-ground and underground waterways including streams, rivers, aquifers, and drinking water wells, forcing some families to find new drinking water supplies. Several coal ash-contaminated sites are federal Superfund sites, including one entire community that has been designated a Superfund toxic site due to the contamination of its water supply by coal ash.[12]

Large quantities of coal ash are "recycled," presenting another potential route of exposure to coal ash toxics. Some states allow coal ash to be used as structural fill, agricultural soil additive, top layer on unpaved roads, fill for abandoned mines, spread on snowy roads, and even as cinders on school running tracks. These uses may expose coal ash to water, increasing the risk of leaching. Coal ash is also dangerous if inhaled, so some of these forms of recycling may endanger human health from airborne particles, even where no water is involved.

The EPA has documented that coal ash contains toxic materials, and that these toxicants can and do escape from disposal sites. It has confirmed and measured toxic leaching into water supplies. And it has identified specific sites at which humans have been exposed to coal ash toxics, whether from drinking contaminated water, eating

contaminated fish, or breathing "fugitive dust."[13] Yet as of late 2010, **no federal standards exist to regulate how coal ash is disposed or where and how it can be recycled.** Instead, a patchwork of insufficient state regulations allows widely disparate uses of and disposal methods for coal ash. This report examines the risks to public health that result from that inadequate regulation and highlights the damage that has occurred in the absence of strong, federally enforceable safeguards. The report concludes with recommendations for effective policy reforms that could significantly protect human health.

Given the high toxicity of coal ash's constituents, the growing number of proven and potential damage cases, and the prospect of more damage cases emerging as toxicants reach peak concentration in the coming years, the magnitude of coal ash as a threat to human health is likely only beginning to emerge.

WHAT IS COAL ASH AND HOW TOXIC IS IT?

Coal ash has different physical and chemical properties depending on the geochemical properties of the coal being used and how that coal is burned.

- "Fly ash" consists of the fine powdery particles of minerals, plus a small amount of carbon, that are carried up the smokestack by the exhaust gases.
- "Bottom ash" is a coarser material that falls to the bottom of the furnace.
- "Boiler slag" is created from the molten bottom ash that, when cooled in contact with water in wet-bottom boilers, forms pellets of a hard, glassy material.
- Flue gas desulfurization (FGD) waste is the by-product of air pollution control systems used to reduce the sulfur dioxide emissions from coal-fired power plants. "Scrubbers" spray lime or limestone slurry into the flue gas, where it reacts with the sulfur to form calcium sulfite that is processed to make FGD or synthetic gypsum.
- Fluidized bed combustion (FBC) wastes are generated by a specialized combustion technology in which a heated bed of sand-like material is suspended (fluidized) in a rising jet of air. FBC waste may include fly ash and bottom ash and tends to be more alkaline because of the limestone used in the process.

The EPA has found that living next to a coal ash disposal site can increase your risk of cancer or other diseases, especially if you live near an unlined wet ash pond that contains coal ash comingled with other coal wastes and you get your drinking water from a well. According to the EPA's peer-reviewed "Human and Ecological Risk Assessment for Coal Combustion Wastes," people in those circumstances have as much as a 1 in 50 chance of getting cancer from drinking water contaminated by arsenic, one of the most common and dangerous pollutants in coal ash.[14] This risk is 2,000 times greater than the EPA's goal for reducing cancer risk to 1 in 100,000. That same risk assessment says that living near ash ponds increases the risk of health problems from exposure to toxic metals like cadmium, lead, and other pollutants.

Typically, coal ash contains arsenic, lead, mercury, cadmium, chromium and selenium, as well as aluminum, antimony, barium, beryllium, boron, chlorine, cobalt, manganese, molybdenum, nickel, thallium, vanadium, and zinc.[15] All can be toxic.[16] Especially where there is prolonged exposure, these toxic metals can cause several types of cancer, heart damage, lung disease, respiratory distress, kidney disease, reproductive problems, gastrointestinal illness, birth defects, impaired bone growth in children, nervous system impacts, cognitive deficits, developmental delays and behavioral problems. **In short, coal ash toxics have the potential to injure all of the major organ systems, damage physical health and development, and even contribute to mortality.**

Adding to the toxicity of coal ash is that some power plants mix coal with other fuels and wastes, such as used tires and even hazardous wastes. In addition, when coal ash is disposed with coal refuse, a highly acidic waste, the resulting mixture is

significantly more toxic and prone to release metals into the environment.[17] Utilities that manage coal ash in ponds often mix coal refuse with coal ash, a practice that greatly increases the cancer risk to nearby residents who get their water from drinking wells.[18]

Not only is coal ash toxic, it is likely to grow increasingly dangerous. Air pollution control technologies—scrubbers, selective catalytic reduction, and activated carbon injection technologies to capture mercury and other hazardous air pollutants —capture an increasing proportion of the coal pollutants that would otherwise go up the smokestacks. When those pollutants are captured, they are shifted from the air to the coal ash.[19] Mercury and other pollutants that previously contributed to air pollution are now becoming solid wastes—and when they leach into water, their toxicity is carried into the water. The EPA speaks of "ensuring that emissions being controlled in the flue gas at power plants are not later being released to other environmental media."[20] Unfortunately, that's exactly what is happening: **One toxic environmental problem is being traded for another.**

1. *Health Impacts of Coal Toxicants*

Coal ash contains a range of toxic constituents that are known to leach, leak, or spill out of coal ash disposal sites and adversely affect human and environmental health. We summarize here the effects on the human body that can be caused by exposure to nine of the most common toxic contaminants in coal ash.[21]

ARSENIC

Arsenic is an ancient and well-known poison and a dangerous environmental contaminant. In recent years it has been widely used as a wood preservative in treated lumber to construct decks, playground equipment, fences, utility poles and piers. Because of its excessive toxicity, arsenic has now been banned in wood for most residential settings, including decks and play sets. Arsenic is present in coal ash and has been shown in numerous cases to leach from ash and contaminate drinking water.

Arsenic produces a variety of adverse health effects. Ingesting very high levels can result in death. Chronic exposure to arsenic in drinking water can cause several types of cancer, including skin cancer, bladder cancer, lung cancer and kidney cancer. Recent studies have linked arsenic ingestion to cardiovascular disease and diabetes mellitus.[22] Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, and cardiovascular effects including abnormal heart rhythm, damage to blood vessels, and damage to the peripheral nervous system. According to the Agency for Toxic Substances and Disease Registry (ATSDR), there is some evidence that in childhood, long-term exposure to arsenic may result in lower IQ scores and exposure to arsenic in the womb and early childhood may increase mortality in young adults.[23] Many of arsenic's effects are dose- and time-dependent. Repeated low levels of exposure over an extended period of time can produce effects similar to a one-time high level of exposure.

Contaminated drinking water is a primary route of arsenic exposure. Scientific studies have shown that exposure to arsenic in drinking water results in an elevated risk of urinary tract cancers (cancer of the bladder, kidney, ureters, etc.). Both the level of exposure and the duration of exposure are significant factors, according to a 2010 article in the journal of the American Association for Cancer Research. Reporting on a study in Taiwan of residents whose well water was contaminated with naturally occurring arsenic, the article found a "significant" trend of increased cases of urinary tract cancer as exposure levels increased.[24]

The duration of exposure was also significant, especially at high levels of exposure. Those who had been drinking arsenic-contaminated well water since birth — that is, those with the longest-term exposure — exhibited a four- to five-fold increased risk of urinary cancers. The study also found that exposure from birth may increase urinary cancer risk much later in life. This find-

ing of a long latency period (the time that elapses from exposure until the time of illness) suggests that people whose drinking water is contaminated by arsenic from coal ash should be monitored long-term for urinary tract cancer, even if they stop drinking the contaminated water.[25]

In addition to drinking water, arsenic can enter the body via other pathways. Inhaling sawdust from construction with arsenic-treated lumber can greatly increase the danger of lung cancer, as it can be absorbed through the lungs. Inhaling arsenic from coal ash fugitive dust can likewise pose a danger to human health. Arsenic can also be absorbed through the skin, which is why its use in decks and play equipment was outlawed. Children who play near spilled coal ash or where there is fugitive dust may be at risk of arsenic exposure.

Because arsenic occurs naturally as an element distributed widely in the earth's crust, we are exposed to constant low levels of arsenic from air and water. Normally, air contains a background concentration of less than 0.1 micrograms per cubic meter, and drinking water less than 5 micrograms per liter, but water levels can be significantly higher, as can exposure from other sources. **Thus, health concerns involving arsenic exposure from coal ash must take into account the cumulative effect of acute exposure from ash combined with background exposure and exposure from other sources.**

BORON

Boron occurs in nature as an essential plant nutrient. It is used in a variety of products and processes ranging from detergents and cleaning products to the production of glass, fiberglass and ceramics. Breathing moderate levels of airborne boron causes non-persistent irritation of the nose, throat, and eyes. Airborne exposure most commonly occurs in the workplace, for example, where borates are mined or processed. However, ingestion (eating or drinking) of large amounts of boron can result in damage to the testes, intestines, liver, kidney, and brain. Exposure to large amounts of boron over short periods of time can eventually lead to death. Children living near waste sites containing boron and boron compounds are likely to be exposed to higher-than-normal levels through inhaling boron-containing dust, touching soil, and swallowing contaminated soil.

Boron is an essential micronutrient for plants, where it plays a role in cell division, metabolism, and membrane structure. However, while it is needed as a nutrient, there is a small range between deficiency and excess uptake or toxicity. Dangerous levels of boron may occur in soils that have been contaminated by pollutant sources such as coal ash from coal-fired power plants.[26]

CADMIUM

Cadmium is a metal widely used in manufacturing. Dietary exposure to cadmium is possible from shellfish and plants grown on cadmium-contaminated soils. Fortunately, oral ingestion of cadmium results in low levels of absorption. The lungs, however, readily absorb cadmium, so inhalation exposure results in much higher levels of absorption. This makes cadmium a potential hazard from coal ash dust, which may be released into the environment when dry coal ash is stored, loaded, transported, or kept in uncovered landfills. Chronic exposure can result in kidney disease and obstructive lung diseases such as emphysema. Cadmium may also be related to increased blood pressure (hypertension) and is a possible lung carcinogen. Cadmium affects calcium metabolism and can result in bone mineral loss and associated bone pain, osteoporosis and bone fractures.

CHROMIUM

While chromium (III) is an essential nutrient in the body, the other common form of chromium, chromium (VI), is highly toxic and is frequently found in coal ash. When ingested via contaminated water, chromium (VI) can cause stomach and small intestine ulcers. Frequent ingestion can cause anemia and stomach cancer. Contact with the skin by some compounds of chromium (VI) can result in skin ulcers. When inhaled in large

amounts, chromium (VI) can cause lung cancer, breathing problems such as asthma and wheezing, and nose ulcers.

LEAD

Lead is a very potent neurotoxicant that is highly damaging to the nervous system. Its dangers have been acknowledged, if not fully understood, for thousands of years. Health effects associated with exposure to lead include, but are not limited to, neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment.[27] Importantly, many of lead's health effects may occur without overt signs of toxicity. Scientists have long recognized that children are particularly sensitive, with high levels of lead resulting in swelling of the brain, kidney disease, effects on hemoglobin and possible death. Adverse effects in children can also occur well before the usual term of chronic exposure can take place. Children under 6 years old have a high risk of exposure because of their more frequent hand-to-mouth behavior. It is now well accepted that there is no safe level of lead exposure, particularly for children.[28] Harmful levels of lead exposure can result from drinking water contaminated by coal ash and from exposure to coal ash contaminated soils.

MERCURY

Another well-known neurotoxicant, mercury has the dangerous capacity to bioaccumulate, or build up in animal tissue. When mercury leaches from coal ash into the soil or water, it is converted by bacteria into methylmercury, an organic form that can be absorbed by small organisms and the larger organisms that eat them. As it moves up the food chain, the concentration of methylmercury increases. When it has accumulated to high concentrations in fish, this becomes a major pathway for human exposure.

Mercury is particulary toxic to the developing nervous system. Exposure during gestation, infancy, or childhood can cause developmental delays and abnormalities, reduced IQ and mental retardation, and behavioral problems. State agencies regularly issue fish consumption advisories to caution women of child-bearing age and children against eating mercury-contaminated fish. The FDA has set a limit for safe consumption of 1 part per million of methylmercury in fish.[29]

MOLYBDENUM

Molybdenum is a metal with an extremely high melting point that is often used to strengthen steel. It is found in the human body in small quantities, and some foods naturally contain molybdenum such as liver, eggs, and some grains.

As a contaminant, molybdenum exposure is of concern from inhalation of dust or ingestion. This may occur from exposure to dust on food or on the hands, or if molybdenum in the air is inhaled and then coughed up and swallowed. Exposure can occur in mining, and the Occupational Safety and Health Administration has set an occupational exposure maximum permissible limit at 5 mg per cubic meter of air in an 8-hour day. Chronic exposure to molybdenum can result in excess fatigue, headaches and joint pains.

Some molybdenum compounds have been shown to be toxic to rats. Although human toxicity data are unavailable, animal studies have shown that chronic ingestion of more than 10 mg/day of molybdenum can cause diarrhea, slowed growth, low birth weight and infertility, and can affect the lungs, kidneys, and liver.

THALLIUM

Thallium, a metal found in trace amounts in the earth's crust, enters the environment primarily from coal-burning and smelting. Once in the environment, it is highly persistent and enters the food chain by being absorbed by plants and building up in fish and shellfish. Eating food contaminated with thallium may be a major source of exposure for most people; however, the ATSDR lists "[l]iving near hazardous waste sites containing thallium" as a path to exposure; in fact, it is the

only path which the ATSDR notes "may result in higher than normal exposures."[30] Other paths include touching thallium, breathing in low levels of thallium in air and ingesting low levels in water, or, for children, eating soil contaminated with thallium.

Exposure to high levels of thallium can result in harmful health effects. Workers who inhale thallium over several years report nervous system effects such as numbness of fingers and toes. Ingesting large amounts of thallium over a short time has been shown to lead to vomiting, diarrhea, and temporary hair loss, along with adverse effects on the nervous system, lungs, heart, liver, and kidneys. Ingesting thallium can even lead to death. It is not known what the effects are of ingesting low levels of thallium over a long time. Studies in rats have shown adverse developmental effects from exposure to high levels of thallium, and some adverse effects on the reproductive system after ingesting thallium for several weeks. It is not known if breathing or ingesting thallium affects human reproduction.[31]

SELENIUM

Selenium is a common element, an essential nutrient, and readily available in a variety of foods including shrimp, fish, meat, dairy products, and grains. It is readily absorbed by the intestine and is widely distributed throughout the tissues of the body, with the highest levels in the liver and kidney. While selenium is used by the body in a variety of cellular functions, too much can be harmful, as can too little. The recommended daily intake is 55 to 70 micrograms. Excess selenium intake can occur in both animals and humans living in areas with elevated selenium in the soil. Most grasses and grains do not accumulate selenium, but when an animal consumes plants that do accumulate selenium (some up to 10,000 mg/kg), they can develop a condition called the "blind staggers." Symptoms include depressed appetite, impaired vision, and staggering in circles. High exposures can ultimately lead to paralysis and death. Humans are susceptible to similar effects as well as additional neurological impacts.

Selenium exposure also affects fish, which absorb the metal through their gills or by eating contaminated food sources such as worms. Extremely high levels of selenium have been found to accumulate in fish and amphibians living in coal ash-contaminated waters and wetlands, if they survive exposure to the toxin. As confirmed by laboratory studies, selenium accumulation can cause developmental abnormalities in fish and amphibians and has led to the death of entire local fish populations. Selenium is bioaccumulative, meaning it is passed up the food chain in increasing concentrations, and excessive amounts have been found in water snakes, small mammals, birds and humans.

■ ■ ■

Concern also exists about the risks to health from coal ash toxicants in combination. While the properties of coal ash toxicants are understood as they function individually, little is known about what happens when these toxic substances are mixed—as routinely happens in coal ash. **Concurrent exposure to multiple contaminants may intensify existing effects of individual contaminants, or may give rise to interactions and synergies that create new effects.** For example, aluminum, manganese and lead all have adverse effects on the central nervous system; barium, cadmium and mercury all have adverse effects on the kidney. Where several coal ash contaminants share a common mechanism of toxicity or affect the same body organ or system, exposure to several contaminants concurrently produces a greater chance of increased risk to health.[32] Yet the EPA has not taken into account in its risk assessments the possibility of synergistic interactions, despite the common occurrence of multiple contaminants in combination in coal ash.[33] Figure 1 summarizes the effects of some of the most harmful coal ash contaminants on the body.

Figure 1. Health Impacts of Coal Toxicants

Mercury*
Mercury poses particular risk to children, infants and fetuses. Impacts include nervous system damage and developmental defects like reduced IQ and mental retardation.

Lead*
Exposure to lead can result in brain swelling, kidney disease, cardiovascular problems, nervous system damage, and even death. It is accepted that there is no safe level of lead exposure, particularly for children.

Chromium
Ingestion of chromium can cause stomach and intestinal ulcers, anemia, and stomach cancer. Frequent inhalation can cause asthma, wheezing, and lung cancer.

Arsenic*
Ingestion of arsenic can lead to nervous system damage, cardiovascular issues, and urinary tract cancers. Inhalation and absorption through the skin can result in lung cancer and skin cancer, respectively.

Selenium
Selenium is used in many bodily functions, but deficiencies or excesses can be bad for one's health. Excess intake of selenium can result in a host of neurological effects, including impaired vision and paralysis, and even death.

Boron
Inhalation of boron can lead over the short-term to eye, nose, and throat irritation. Ingestion of large amounts, however, can result in damage to the testes, intestines, liver, kidneys, and brain, and eventually lead to death.

Other Toxicants

Antimony
Eye, skin irritation
Stomach pain, ulcers
Lung disease

Cadmium
Emphysema
Kidney disease
Hypertension
Lung cancer

Molybdenum
In animals:
Slowed growth
Low birth weight
Infertility

Thallium
Nervous system damage
Lung, heart, liver, kidney problems

*Children are particularly at risk

2. *From Containment to Contamination: The Risk of Exposure*

COAL ASH DISPOSAL: HOW, WHERE, AND HOW SAFE?

Utility companies have three basic options for disposing of their ash. If the ash is dry, it can be disposed in landfills. According to the EPA, an estimated 36 percent of the coal combustion waste generated by utilities in 2007 was disposed of in dry landfills, frequently on-site at the power plant where the coal was burned. Coal ash may also be mixed with water and stored in so-called "ponds"—some more than 1,000 acres—and some constructed only with earthen walls. These wet disposal areas are called "surface impoundments" and in 2007 accounted for 21 percent of coal ash disposal.[34] The remaining 43 percent of coal ash was reused in a variety of industrial and other applications, discussed at the end of this section.

The EPA has found that two factors dramatically increase the risk that coal ash disposal units pose, both to human health and to ecosystems: (1) the use of wet surface impoundments rather than dry landfills, and (2) the absence of composite liners to prevent leaking and leaching. Surface impoundments (wet ash ponds) consistently pose higher risks than do landfills.[35] Some surface impoundments are little more than pits in the earth, totally lacking protective liners, with native soils as the bottom and sides. These unlined wet disposal areas constitute a disproportionate number of the "damage cases" where coal ash toxics are documented to have escaped from disposal facilities and damaged human health or the community.[36] (See section 3 for details.) Ponds lined with clay are also subject to leaching dangerous amounts of toxics to underlying groundwater. The greatest level of protection is afforded by composite liners, constructed from various layers including human-made materials, such as a plastic membrane like high-density polyethylene, placed over clay or geosynthetic clay. However, these liners have a finite lifespan, so truly permanent safe storage of coal ash toxicants will require ongoing diligence well into the future.

Despite the obvious danger to human health associated with coal ash disposal, **it is hard to determine precisely how many coal ash disposal areas there are in the U.S.** In 2009, the EPA requested information from electric utilities operating wet ash ponds. The EPA received information on 629 coal ash ponds in 33 states.[37] Because this count included groups of ponds at some sites, the number of power plants with ash ponds was 228. The EPA's 2010 Regulatory Impact Analysis estimated that the number of active landfills was more than the 311 known dumps utilized at power plants. An estimated 149 power plants utilize an unspecified number of landfills located outside the plants' boundaries, adding to the total number of landfills.[38] Although the number of states and sites is hard to specify with precision, there appears to be disposal of coal ash in at least 46 states.[39]

Susceptible populations

With coal ash disposal sites located in most of the 50 states, the threat to public health affects many

communities. However, that threat is not shared equally. Many coal ash disposal sites are located in rural areas, where land availability and lower land prices make it cheap to purchase the multi-acre sites necessary for ash ponds and landfills—and where the power plants that generate the ash are also frequently located. In fact, the majority of coal ash disposal sites are on the power plant site, thus avoiding costly transportation of the ash, but concentrating the pollution. Low-income communities live near a disproportionate share of coal ash disposal facilities.[40]

Children are another susceptible population. This is due in part to their size: any exposure they suffer is more significant for their small bodies than it would be for an adult. In addition, children's organ systems, particularly the nervous system, are still undergoing development and are thus more susceptible to the effects of toxics exposure. This is particularly the case during gestation (*in utero*) and infancy, and it remains true throughout childhood. Children also breathe more rapidly than adults and their lungs are proportionately larger, thus increasing their susceptibility to airborne toxics. Finally, young children are prone to hand-to-mouth behaviors that expose them to higher levels of ambient contaminants, such as the "fugitive dust" that can blow off of exposed coal ash.

HOW MUCH COAL ASH IS THERE?

Coal ash constitutes one of the largest waste streams in the United States. The American Coal Ash Association, an industry group, estimates that coal combustion generated approximately 131 million tons of coal ash in 2007.[41] The Environmental Protection Agency, noting that this figure excludes smaller coal-fired power plants (those generating between 1 and 100 megawatts per year), has suggested that a more accurate figure is 140 million tons of coal waste annually.[42] The EPA estimates that the storage capacity for all existing coal ash ponds and landfills is approximately 864,000 acre feet. This is enough coal ash to flow continuously over Niagara Falls for four days straight. Coal ash is the second largest industrial waste stream in the United States, second only to mine wastes.

Enough coal ash is stored in waste ponds and landfills to flow over Niagara Falls for four consecutive days.

PATHWAYS TO EXPOSURE

The toxic contaminants in coal ash follow various routes, or pathways, to make their way into what we eat, drink or breathe. Some escape from coal ash by leaching or dissolving into water, subsequently contaminating underground aquifers (groundwater) or surface waters like rivers and streams. Some are consumed when people eat fish that have been contaminated by coal ash-exposed water or sediments. Coal ash toxicants also travel through the air as fine particles or dust or over the ground and other surfaces, due to erosion, runoff, or settling dust.

The surface water path

Coal ash contamination of surface waters such as streams, rivers, ponds, lakes, and wetlands poses a serious threat to the life forms that live in and eat from those waters. The most dramatic acts of contamination occur when impoundment retaining walls give way, spilling enormous quantities of coal ash slurry directly into surface waters. The rupture of the retaining dam at the Kingston, Tennessee, coal ash waste pond spilled more than 1 billion gallons of coal ash slurry into the Emory River. Although it is the best known example of a coal ash pond failure, it is not the only case. For example, a rupture occurred in August 2005 when

a dam failed at the Martin's Creek Power Plant in eastern Pennsylvania, allowing more than 100 million gallons of coal ash-contaminated water to flow into the Delaware River. Arsenic levels in the river jumped to levels that exceeded water quality standards, and a public water supply was temporarily closed downstream. The response action cost $37 million.[43]

Some coal ash impoundments are rated for the degree of danger they pose to the communities and environments downstream. According to the EPA rating system, a "high" hazard rating indicates that a dam failure is likely to cause loss of human life. A "significant" hazard rating means that failure of the impoundment would cause significant economic loss, environmental damage, or damage to infrastructure. In 2009, the EPA found that of the 629 ash ponds it identified, only 431 were rated. Of those, 50—more than one in ten—had a "high" hazard rating and 71 had a "significant" rating.[44] The number of coal ash dams with high and significant hazard ratings is likely to rise much higher because almost 200 coal ash dams are not yet rated. Currently no federal regulations exist to require hazard safety ratings.

Dramatic failures aren't the only source of surface spills; smaller spills occur when impoundment dikes and dams leak less significant amounts, or impoundments overflow in heavy rains or floods.

In addition, both coal ash ponds and landfills often discharge coal ash-contaminated waters directly into surface water. In one documented case, at the U.S. Department of Energy's Savannah River Project in South Carolina, a coal-fired power plant transported fly ash mixed with water to a series of open settling ponds. A continuous flow of that water exited the settling ponds and entered a swamp that in turn discharged into a creek. Toxicants from the coal ash poisoned several types of aquatic animals inhabiting the wetlands: bullfrog tadpoles exhibited oral deformities and impaired swimming and predator avoidance abilities, and water snakes showed metabolic impacts. According to the EPA, the impacts were "caused by releases from the ash settling ponds."[45] A more common occurrence is the permitted discharge of ash-laden water—often containing very high levels of arsenic, selenium, and boron—directly into streams, rivers and lakes. At the majority of power plants, the permits allowing these discharges contain no limits on the levels of heavy metals and other toxics that can be released into surface water.

Leaching into groundwater

Far more common than a dam break is leaching of contaminants from ponds and landfills: the process by which toxic materials in coal ash dissolve in water and percolate through the earth. The dissolved toxics, called "leachate," can endanger public health and the environment by contaminating surface water or groundwater used for drinking supplies. Leaching may be less spectacular than a rupture, but it happens with much greater frequency[46] and may continue to release toxic substances into the environment for decades.

Leaching can expose people to dangerous toxicants at levels above safe drinking water standards. The amount of leaching that takes place at coal ash storage facilities varies greatly from place to place, reflecting the type of coal ash that is stored, its concentration and acidity, and the nature of the disposal site. As a result, leachate concentrations are different in different sites and vary for different elements.[47] The rate of leaching may be affected by a number of factors: the size of the disposal pond, pond depth, and the amount of pressure the waste creates; the underlying geology (the types of soil and rock that lie underneath); the gradient or slope of the land; and how far beneath the pond or bottom of the landfill an aquifer or underground stream might lie. What most determines the amount of leaching is not the coal, however, but the robustness of the storage site. The single most important factor is whether the disposal site is lined, with composite liners being the most effective in keeping the ash from contact with water. Another essential safeguard is a leachate collection system that collects the leachate that develops and pumps the dangerous chemicals back into the lined unit.

Verified damage from leaching has occurred at dozens of dump sites throughout the U.S., contami-

nating drinking water, streams, and ponds and killing wildlife. For example, in Gambrills, Maryland, residential drinking wells were contaminated after fly ash and bottom ash from two Maryland power plants were dumped into excavated portions of two unlined quarries. Groundwater samples collected in 2006 and 2007 from residential drinking water wells near the site indicated contamination with arsenic, beryllium, cadmium and lead, among other suspected "constituents of concern." Testing of private wells in 83 homes and businesses in areas around the disposal site revealed exceedances in 34 wells of Maximum Contaminant Levels, the highest level of a contaminant that is allowed in drinking water.[48] In November 2007, power plant owner Constellation Energy settled with residents of Gambrills for $54 million for poisoning water supplies with dangerous pollutants.

Other documented cases of harm from leaching are presented in section 3.

How toxic is coal ash leachate?

As the discussion of pathways indicates, dangerous substances in coal ash can leach out of disposal facilities and expose humans to serious health risks. A report released by the EPA in 2009 documented that many of those toxicants leach at concentrations high enough to seriously endanger human health. The findings reflected the EPA's adoption of new and improved analytical procedures that, according to the EPA, are better able to determine how much toxic material would leach out of coal ash and scrubber sludge.[49] The EPA's conclusions greatly altered our understanding of the toxicity of coal ash leachate.

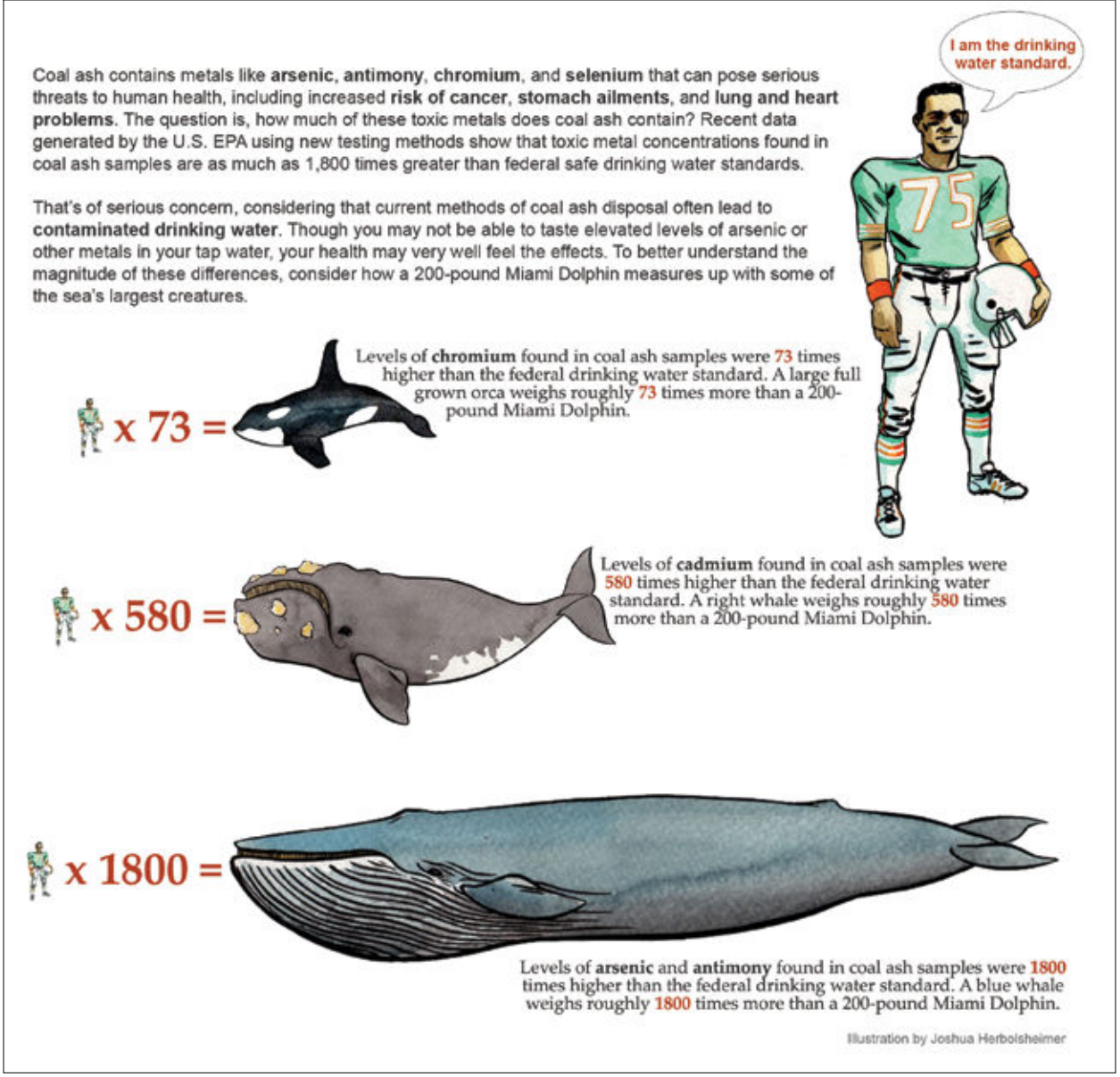
The report analyzed 73 samples of coal ash waste of different types and analyzed the physical properties, the content of elements, and the leaching characteristics. What the report found was that for some coal ashes and under some circumstances, the levels of toxic constituents leaching out of coal ash can be **hundreds to thousands of times greater than federal drinking water standards.** Several toxic pollutants, including arsenic and selenium, leached in some circumstances at levels exceeding those which the federal government defines as a hazardous waste. Here are some of the most elevated readings the EPA observed:

- The highest leaching level for arsenic was 18,000 parts per billion (ppb). This amount is 1,800 times the federal drinking water standard and over three times the level that defines a hazardous waste.
- The concentration of antimony in coal ash leachate reached 11,000 ppb, also 1,800 times the federal drinking water standard for this pollutant.
- For selenium, the highest leaching level found by the EPA was 29,000 ppb, a level that is 580 times the drinking water standard, 29 times the hazardous waste threshold, and 5,800 times the water quality standard.
- The EPA found that barium could leach to the level of 670,000 ppb, which is 335 times the drinking water standard and almost seven times the hazardous waste threshold.
- For chromium, the highest leaching level found by the EPA was 73 times the federal drinking water standard and more than 1.5 times the threshold for hazardous waste.[50]

Not only are these levels high enough to harm human health, they are also many times higher than the leaching levels that the EPA previously reported: for arsenic, more than 76 times higher than the highest levels reported and for antimony, more than 916 times the earlier levels.[51] In short, the new and more sensitive test shows far higher levels of leaching of known toxic substances.

The report notes that the leach test results represent a theoretical range of the potential concentrations of toxics that might occur in leachates rather than an estimate of the amount of a toxic that would actually reach any given aquifer or drinking water well. It cautions that "comparisons with regulatory health values, particularly drinking water values, must be done with caution."[52]

Figure 2. Coal Ash is EVEN MORE TOXIC than Previously Thought



However, the new leach tests consider a number of factors that earlier tests didn't take into account. These include the pH (acidity) of the ash itself, the acidity of the environment, and the variety of other conditions that coal ash encounters in the field when it is disposed or recycled. The EPA noted that an evaluation using a single set of assumptions is insufficient to reflect real-life conditions and "will, in many cases, lead to inaccurate conclusions about expected leaching in the field." With the wider range of conditions and values that the new tests take into account, the EPA itself found that the prediction of leaching was done "with much greater reliability."[53] For these reasons, we accept the new data as the basis for addressing the potential impacts coal ash has on human health.

Consumption of fish

Even if people are not drinking contaminated water, their health may be threatened if they eat fish from

water sources contaminated by coal ash toxicants. There are several pathways by which the water (and the fish) can become contaminated: runoff and erosion; airborne ash particles that settle on the water; contaminated groundwater that migrates into surface water; direct discharge of coal ash runoff due to heavy precipitation or flooding; and direct discharge of ash pond water and landfill leachate through pipes from waste units. Once the toxics are in the water or sediment, fish can absorb them through their gills or by eating contaminated food sources (algae, worms, and other fish food sources have all been shown to absorb coal ash toxicants), passing these pollutants up the food chain to humans.[54]

A well documented case of toxic fish contamination is that of Belews Lake. Belews Lake, near Winston-Salem, North Carolina, served as a cooling reservoir for a large coal-fired power plant. Fly ash produced by the power plant was disposed in a settling basin, which released selenium-laden water back to the lake. Due to the selenium contamination:

- 19 of the 20 fish species originally present in the reservoir were entirely eliminated, including all the primary sport fish.
- Selenium fish impacts persisted for 11 years.
- Eight years after the flow of selenium-laden water to the lake was ended, the state issued a fish advisory for selenium, urging people to reduce their consumption of fish from Belews Lake. The advisory remained in effect for seven more years.[55]
- Adverse impacts to birds feeding on contaminated fish persist, decades after the coal ash was released into the cooling pond.

Over land and by air

Coal ash also follows land and air pathways to result in human exposure. Coal ash disposal operations can generate dangerous quantities of airborne ash, due to mismanagement of both ponds and landfills. Ash ponds in arid environments may

be allowed to dry, resulting in wind dispersion of dried ash. Landfills may not be covered daily or capped, also resulting in unsafe levels of ash blowing from the disposal site. Where coal ash is used for fill in construction sites and engineering projects, or on agricultural fields as a "soil amendment," it can blow or erode and travel over land as well as through surface waters. Windblown particulates from dry disposal—so-called "fugitive dust"—can also arise when coal wastes are loaded and unloaded, transported, or when vehicles travel through ash disposal sites and nearby communities and coal ash is spread or compacted.

Coal ash is dangerous if inhaled, making fugitive dust a serious health concern. The health threat arises from minute particles of dust known as particulate matter, which may be composed of various substances. Airborne particles of fly ash, if breathed in, can affect the lungs and bronchii. Of particular concern are the extremely small particles known as "fine particulate matter" (PM2.5). These can lodge deep within the lung, where they can affect the lung lining, causing inflammation, altering immunological mechanisms, and increasing the risk of cardiopulmonary disease.[56] They can or even pass through the lungs into the blood, causing serious adverse health effects ranging from triggered asthma attacks to increased mortality rates. People with pre-existing chronic obstructive pulmonary disease, lung infection or asthma

are particularly susceptible to coal ash effects, as are people with type II diabetes mellitus.[57]

When coal ash blows from dry storage sites, particulate matter can readily exceed the national ambient air quality standards (NAAQS) that exist for levels of particulate matter in the air. In the EPA's own words, "there is not only a possibility, but a strong likelihood that dry-handling [of coal ash] would lead to the NAAQS being exceeded absent fugitive dust controls."[58] To compound the problem, high background levels of particulate matter may add to the potential for fugitive dust from coal ash to lead to significant human health risks.

Protective practices to control dust, such as moistening dry coal ash or covering it, can minimize the dangers to health from this source. Yet at some coal ash dump sites, dust controls are applied only monthly or even yearly. The EPA found such infrequent practices to "have the potential to lead to significant risks," adding that "Even at the median risk, yearly management leads to a PM10 concentration almost an order of magnitude above the NAAQS.… [It is even] "uncertain whether weekly controls would have the potential to cause NAAQS exceedences … only daily controls can definitively be said not to cause excess levels of particulates in isolation."[59] Yet, as the EPA itself notes, many states do not require daily cover to control fugitive dust at coal ash landfills and most states do not require caps on coal ash ponds to control dust.[60]

Workers and nearby residents run the risk of being exposed to significant amounts of fugitive dust. Residents living near power plants, as well as workers at the plants, may be subject to exposure to dust when coal ash is loaded. Residents living along transport routes may be exposed to emissions during transportation. Residents living near dry landfills and eroding ash ponds may be exposed both during ash unloading and

Reuse of coal ash as fill in rural Illinois encroaches on private property and threatens drinking water wells at the Rocky Acres fill site in Oakville, Illinois. The Illinois EPA advised residents to stop drinking their well water.

subsequently due to windblown emissions. Due to multiple routes of exposure, residents who live near landfills are likely to be exposed to more dust for longer periods of time.

EXPOSURE AND PEAK CONCENTRATIONS

In addition to being geographically widespread, coal ash is also persistent over time, raising long-term concerns and challenges in regard to health. Chemicals move at different rates through groundwater, so when contaminants leach out of coal ash disposal sites, some take longer than others to reach places where they may expose humans to risk. The EPA has conducted sophisticated modeling to estimate how long leaching substances would take to reach their maximum concentrations in well water. For unlined surface impoundments, the median average years until peak well-water concentrations would occur is estimated to be 74 years for selenium, 78 years for arsenic, and 97 years for cobalt. In comparison, if the surface impoundment were clay-lined, the median average years until peak concentration rises to 90 years for boron and selenium, 110 years for arsenic, and 270 years for cobalt. The comparable time periods for these materials escaping from composite-lined units are in the thousands of years.[61]

The implication of these projections is that coal ash toxicants are going to be with us—and with our descendants—for a very long time. Because many coal ash contaminants are persistent in the environment, they do not disintegrate or lose their toxicity. They may be contained or may disperse into the environment but they never really "go away." They remain in the environment and continue to pose exposure risks for years, even generations. Unless coal ash disposal is required to comply with modern engineering safeguards, we can expect to see increased levels of human exposure to coal ash toxics in the future. Taking a longer view, the persistence of coal ash toxics is a health-based argument for reducing our reliance on coal as a means of generating electricity.

COAL ASH REUSE: ADDITIONAL PATHWAYS TO EXPOSURE

Approximately 40 percent of coal ash is "recycled" in engineering, manufacturing, agricultural and other applications rather than being disposed.[62] Fly ash, which hardens when mixed with water and limestone, can be used in making concrete. Bottom ash is sometimes used as an aggregate in road construction and concrete, and FGD gypsum sometimes substitutes for mined gypsum in agricultural soil amendments and in making wallboard. Ash is also used in structural fills and road construction projects, spread as an anti-skid substance on snowy roads, and is even used as cinders on school running tracks. And perhaps as much as 20 percent of the total coal ash generated in the U.S. is dumped in mines as fill.

This recycling offers a significant economic benefit to the utilities and industries that generate coal ash: they generate income from its sale and avoid costs of its disposal. However, some forms of coal ash recycling raise health concerns, especially where the ash is not "encapsulated," that is, not bound to other materials and in a loose particulate or sludge form. Unencapsulated coal ash when exposed to water is subject to leaching. This poses a potential problem in several forms of coal ash recycling, such as when coal ash is sprinkled on snowy roads or used to fill mines, or when used as fill in construction projects. Other forms of recycling appear to minimize the potential threats to health. Applications where the ash is encapsulated (bonded with other substances) such as in concrete and wallboard seem to be the most stable and least likely to leach. However these uses may still pose a hazard to the construction workers who must cut, drill or perform other dust-generating activities. In general, further testing is needed on many forms of coal ash recycling, especially the unencapsulated ones, in order to establish with greater certainty their potential impacts on human health.

3. *Evidence of Harm: The Damage Cases*

The potential risk of coal ash to our health and environment is clear. But is the risk only theoretical? Or has coal ash actually caused harm to real people in real communities?

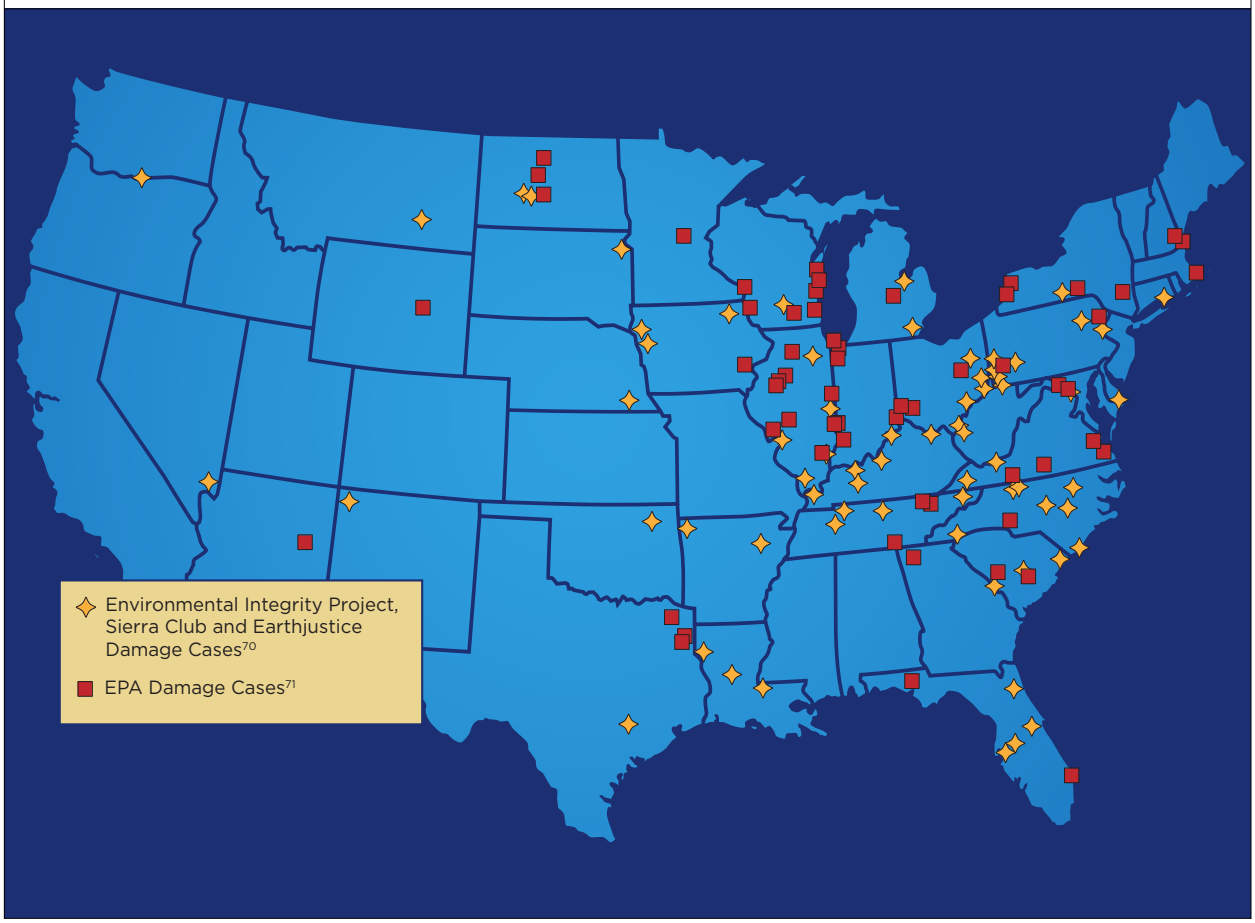
The law requires the EPA to examine documented cases of the disposal of coal combustion wastes "in which danger to human health or the environment has been proved."[63] Where proven damage is found, the EPA can require corrective measures such as closure of the unit, capping the unit, installation of new liners, groundwater treatment, groundwater monitoring, or combinations of these measures. The EPA has formally identified 63 "proven and potential" damage cases where coal ash poison has contaminated drinking water, wetlands, creeks, or rivers.[64] In addition, two nonprofit organizations, Earthjustice and the Environmental Integrity Project, using monitoring data and other information in the files of state agencies, have documented an additional 70 cases shown to have caused contamination.[65] This brings the total number of damage cases to almost 140, with more still to be investigated. In 38 of these cases, toxics are known to have migrated beyond the property belonging to the utility company and into a nearby community.[66]

The EPA does not make damage case determinations lightly. For "proven damage" to be found, evidence must show one or more of the following:

- Toxics have been found and measured in ground water, at levels above health-based standards known as Maximum Contaminant Levels (MCL's). MCLs are the highest level of a contaminant that is allowed in drinking water and are enforceable standards;[67]
- These toxics must be found at a distance from the waste storage unit "sufficient…to indicate that hazardous constituents have migrated to the extent that they could cause human health concerns;"
- A scientific study has provided documented evidence of another type of damage to human health or the environment; or
- An administrative ruling or court decision presents an explicit finding of specific damage to human health or the environment.[68]

In addition to cases of "proven damage," the EPA also recognizes cases of "potential damage." The EPA defines potential damage cases as "those cases with documented MCL exceedances"—toxics levels exceeding the allowable standard—"that were measured in ground water beneath or close to the waste source."[69] In these potential damage cases, the association with coal combustion wastes is established, but the hazardous substances have not migrated to the extent that they could cause human health concerns—yet. As the earlier discussion of peak concentrations indicates, leaching from coal ash often continues for

Figure 3. Coal Ash Groundwater and/or Surface Water Contamination Sites



years and may endanger local residents years or even generations later.

Taken together, these requirements create a high bar for the designation of a damage case—making it all the more disturbing that so many damage cases have been identified.

Two-thirds of the proven damage cases show damage to ground water—a serious concern, since ground water feeds drinking water wells. The leaching occurred at different types of storage facilities: four unlined landfills, five unlined surface impoundments, six unlined sand and gravel pits, and one due to a liner failure at a surface impoundment.[72] This demonstrates that unlined storage was far and away the leading cause of ground water contamination. But even a lined storage pond resulted in contamination, in the case of an unanticipated failure. This is a small reminder that where toxic substances are concerned, accidents do happen, and may lead to ecological and health-threatening consequences.

PROFILES OF SELECTED DAMAGE CASES

When a damage case occurs, what does it look like? What impacts does it have on local communities? The majority of damage cases result not from breakages, but from leaching. This process is invisible and gradual, often occurring over a number of years. It is detected by monitoring and testing of ground and/or surface waters, procedures that are not routinely conducted at most coal ash disposal sites. The damage cases profiled here begin to tell the story of how coal ash impacts our health and our environment.

LEACHING FROM DISPOSAL SITES

Virginia: Residential wells contaminated with vanadium and selenium

From the mid-1950s to the mid-1970s, Virginia Power operated a disposal site for the Yorktown Power Station, storing fly ash from coal and petroleum coke in abandoned sand and gravel pits. Six years after the last load of coal ash was disposed of, area residents reported that the water in their drinking wells had turned green. Studies found their wells were contaminated with nickel, vanadium, arsenic, beryllium, chromium, copper, molybdenum, and selenium. Fifty-five homes had to be placed on public water, as their well water was too dangerous to drink. In addition, heavy metal contamination existed in ground water around the fly ash disposal areas, in onsite ponds, and in the sediments of a nearby creek. Six hundred feet of the creek had to be relocated to minimize contact with the fly ash disposal areas, even though years had passed. This site became the Chisman Creek Superfund Site, which was listed on the nation's list of most polluted Superfund sites, the National Priorities List (NPL).[73]

Montana: Leaking unlined coal ash pond contaminates drinking wells, ranches

At the PPL Montana Power Plant in Colstrip, Montana, leaking unlined coal ash ponds contaminated drinking water wells with high levels of metals, boron, and sulfate. The community located near the power plant had to be supplied with safe drinking water. The plume of contamination stretches at least a mile from the power plant, affecting ranchers far from the waste ponds.

Wisconsin: Contamination migrates offsite into private drinking-water wells

At the WEPCO Highway 59 Landfill, fly ash and bottom ash were dumped into an old sand and gravel pit. The facility was unlined and the underlying soil consisted of sands and gravel with minor amounts of silt and clay, believed to be relatively permeable. Contamination from the facility appears to have migrated to off-site private wells: Ground water monitoring of those wells found them to be contaminated with sulfate, boron, manganese, chloride, and iron at levels above the state's Enforcement Standards and arsenic above the state's Preventive Action Level. State environmental officials considered this one of the most seriously affected coal ash sites in Wisconsin.

New York: Landfill contaminates wells with lead, a potent neurotoxicant

A leaking dump containing fly ash, bottom ash, and other material generated by the Dunkirk Steam Station on Lake Erie contaminated drinking water wells with lead, a very potent neurotoxicant that can harm the developing nervous system at even low levels of exposure.

The landfill owner was required to cease receiving coal ash wastes, to conduct extensive remediation, and to close the facility. Post-closure ground water and surface water monitoring and maintenance were expected to continue for 30 years after final closure of the entire facility.[74]

COAL ASH USED AS FILL MATERIAL IN CONSTRUCTION

Indiana: Town is declared a Superfund site due to coal ash

The Northern Indiana Public Service Corporation (NIPSCO) deposited an estimated 1 million tons of fly ash in Town of Pines, Indiana. The ash was buried in a leaking landfill and used as construction fill in the town, where it contaminated drinking water wells throughout the town with toxic chemicals, including arsenic, cadmium, boron and molybdenum. Hundreds of residents were put on municipal water, and Town of Pines was declared a Superfund site.

Virginia: Use of coal ash in constructing a golf course leads to groundwater contamination with heavy metals

A 216-acre golf course in Chesapeake, Virginia, was built using 1.5 million cubic yards of fly ash. When groundwater at the golf course was tested, arsenic, boron, chromium, copper, lead, and vanadium were detected, indicating a potential threat to nearby residential drinking water wells. As the contaminants had not yet been detected off of the site, this was classified as a potential damage case.[75]

COAL ASH IMPACTING LIVES: PORTRAIT OF R.G. HUNT

R. G. Hunt lives in Waterflow, New Mexico, on land his family has owned for four generations. As the town's name suggests, they drank from a fresh-water well on the property, and for years his sheep grazed nearby and drank from natural springs and an arroyo (a dry creek bed that runs during the rainy season)—until the mid-1970's.

In 1972 a utility company built the San Juan Power Plant next to Hunt's land and began using the dry arroyo to discharge their wastewater. The company also buried coal ash in nearby dry streambeds, rather than building surface impoundments with protective liners. Lacking effective containment, the ash leached into underground aquifers, contaminating Hunt's water with high levels of arsenic, selenium, potassium, chromium, lead, sulfate, and other toxicants.

"By 1975 after the dumping of the coal ash began, my family started to get sick," Hunt told the U.S. House of Representatives Subcommittee on Energy and Environment in formal testimony in December 2009. "I was diagnosed with heavy metal poisoning with extremely high arsenic, iron, lead, and selenium levels. I lost nearly 100 pounds in less than a year. I was so weak I couldn't stand or work, and wasn't expected to live."

Hunt did survive, although he and his wife suffered from indigestion, diarrhea, nausea, and vomiting and had problems with mental focus and comprehension. Their children also had constant indigestion and diarrhea, their hair began to fall out, and their eyesight worsened. The children's teachers reported that the kids also had difficulty with simple tasks of concentration and comprehension.

For two years, the family bought drinking water and carried it into their home until they could afford the connection fees for the public water system. "Once we stopped using the well," Hunt recounts, "we began, slowly, to improve." He, his wife, and their kids had been sick for more than ten years.

Hunt's animals suffered as well. "I watched 1,400 sheep slowly suffer and die from the lack of safe drinking water," he told Congress. "Within two years I lost my entire sheep herd and took outside jobs, rather than risk selling contaminated meat to my customers."

In 1984 the EPA fined the utility company and required it to line the ponds. However, the utility arranged to bury their fly ash in unlined pits in the neighboring San Juan Coal Mine. As a result, fly ash and scrubber sludge continue to contaminate the Hunts' arroyo and groundwater.

Hunt's closing words to Congress indicate his deep disillusionment: "My experience is that the energy industry cannot be entrusted with innocent lives or to regulate themselves, for the good of the community, in lieu of a profit for their stockholders. I urge you to take every measure available to you to prevent this from happening to anyone, anywhere in our nation, ever again."[76]

UNPREDICTABLE FAILURES

North Dakota: Lined coal ash ponds leak arsenic and selenium

At the United Power Coal Creek Station, a power plant in North Dakota, surface impoundments were built with protective linings. However, the linings of several impoundments developed severe leaks within a few years of construction. Ground water monitoring at the site showed arsenic and selenium in excess of health-based levels. The state eventually required that the ponds be relined with a composite liner.[77]

Georgia: Millions of gallons spill into creek from a huge sinkhole

This sinkhole highlights the many ways in which toxic substances can escape from storage areas and contaminate the environment. An unlined coal ash pond in Cartersville, Georgia, developed a sinkhole that ultimately reached four acres and a depth of 30 feet. An estimated 2.25 million gallons of coal ash and water were released into the tributary of a local creek, causing a temporary arsenic spike in a public drinking water source. Remedial action followed, involving dredging coal ash from the creek.[78]

CONTAMINATION OF WATER AND FISH

Texas: Selenium contamination leads to fish kills and fish consumption advisories

Discharges from coal ash ponds poisoned fish with high levels of selenium at three reservoirs in Texas—and, through the fish, the selenium potentially reached human beings. The reservoirs—the

COAL ASH IMPACTING LIVES: PORTRAIT OF GAYLE QUEEN

During the ten years that Gayle Queen lived in Gambrills, Maryland, a small community south of Baltimore, a power company dumped 4.1 million tons of coal ash near her home. Trucked in from another community, the coal ash was deposited into an unlined sand and gravel pit with excavations as deep as 80 feet.

The dumping created two problems. Ash dust went airborne, meaning "we all breathed the dust in," according to Mrs. Queen. And while there was supposed to be no contact between the coal ash and surface or ground water, dangerous chemicals did leach out of the unlined pit. From 1999 through 2007, tests showed that arsenic, iron, manganese, and sulfate were leaching at dangerous levels, eventually entering an aquifer that supplies the community's drinking water and contaminating residents' private wells.

Mrs. Queen, who has a well at her home, noted, "I rely on my well water to provide cooking, drinking and bathing water."

Because of the coal ash contamination, Mrs. Queen fears that she has lost both her financial security and her health. "My biggest monetary asset, my home, is worthless," she stated. "I may have to file for bankruptcy." In addition, according to the 56-year-old Mrs. Queen, "My doctor has told me I have the lungs of an 80-year-old woman because of breathing in the coal ash. I am terrified about my future health."

She also worries about the health of her children and grandchildren. "They drank the water, bathed in it, brushed their teeth and breathed in this dust. Will they get a disease, too? No one can tell me for sure. But I do know they never should have been exposed to this stuff."

Mrs. Queen, testifying before the U.S. Congress, called on the government to prevent coal ash contamination from happening again, adding, "If the Environmental Protection Agency had the authority to require liners and force power companies not to dump close to drinking water systems, what happened to me and my community would not happen to anyone else."[79]

Brandy Branch Reservoir in northeastern Texas along the Louisiana border, the Welsh Reservoir northeast of Dallas, and the Martin Lake Reservoir southeast of Dallas—all received contaminated run-off from power plants. In response to elevated levels of selenium in fish in the reservoirs, the Texas Department of Health issued fish consumption advisories, in one case warning people to eat no more than eight ounces of fish from the reservoir per week. Another advisory urged children under six and women who were pregnant or might become pregnant not to consume any fish from the reservoir whatsoever. That advisory remained in effect for 12 years.[80]

Tennessee: Toxics damage fish, plants, and small mammals

At the Department of Energy's Chestnut Ridge Operable Unit 2 in Oak Ridge, Tennessee, coal ash slurry was stored in a pond created by building an earthen dam across a creek. Constructed to hold 20 years' worth of ash, after only 12 years it was filled

SCIENTIFIC STUDIES OF ECOLOGICAL DAMAGE FROM COAL ASH

Besides being documented in damage cases, the effects of coal ash residues on wildlife have been the focus of published scientific studies. These studies show that coal ash presents significant risks, especially to aquatic and semi-aquatic organisms. Its effects range from producing physical deformities in fish and amphibians, to wiping out entire populations.[81]

Bill Wadell, USFWS

Duck embryos damaged by selenium contamination (Utah).

Plants and animals that inhabit coal ash-contaminated sites accumulate toxic elements, including arsenic, cadmium, copper, and lead, sometimes in very high concentrations. Among plants, high levels of accumulation have been noted in algae (for copper); arrowhead (copper and lead); cattails (copper), and sago pondweed (for arsenic and chromium). Among invertebrates, plankton accumulate high levels of selenium; caddisflies of cadmium, chromium and copper; Asiatic clams of cadmium and copper; crayfish of copper and selenium; crickets of chromium; and earthworms of arsenic, chromium, and selenium. Moving up the food chain, bullhead minnows, sunfish, largemouth bass, and bluegill have all been documented to accumulate high levels of selenium, as have banded water snakes, slider turtles, barn swallows and muskrats. Bullfrogs accumulate both selenium and arsenic.[82]

Exposure to coal ash contaminants may lead to death or cause other, lesser effects. Coal ash toxicants often build up in animals' organs, including the reproductive organs, where they can negatively influence reproductive rates. Sublethal effects also include physical abnormalities that can influence critical behaviors, such as feeding, swimming speed and predator-avoidance reflexes. In one study,[83] scientists raised Southern Leopard Frog tadpoles on either sand or coal ash-contaminated sediment. Ninety percent of the tadpoles exposed to the contaminated sediment displayed abnormalities of the mouth, while none of the control individuals did. Contaminated tadpoles also had decreased developmental rates and weighed significantly less. These and other abnormalities can have a negative impact on population survival rates. Coal ash contaminants can also affect the abundance, diversity and quality of food resources, thus creating substantial indirect effects that ripple up through food chains to impact higher life forms.

SELENIUM

Scientific studies have shown that selenium can have devastating impacts on fish populations. Selenium can bioaccumulate in fish until it is up to 5,000 times as concentrated in their bodies as in the surrounding water, causing anemia; heart, liver, and breathing problems; and deformities.[84]

Because selenium concentrates in the yolk of developing embryos, stunting their development and causing organ abnormalities in the larval fish, it can contribute to death in the affected fish and reproductive failure of the local species population.[85]

These effects reflect the extremely high levels of selenium found in coal ash. While 10 micrograms of selenium per liter of water—a concentration of 10 ppb—can cause total population collapse in a reservoir, coal ash can produce leachate with selenium concentrations of 29,000 parts per billion, a level that is 580 times the drinking water standard, 29 times the hazardous waste threshold, and 5,800 times the water quality standard.[86]

In the coal ash-contaminated Belews Lake in North Carolina, 19 of 20 fish species were eliminated due to selenium contamination. Surviving fish exhibited deformities and serious pathological problems.[87]

The photograph shows a spinal deformity in fish, attributed to selenium from coal ash.

to within four feet of the top of the dam. Once the pond was full, slurry was released over the dam directly into the creek, resulting in contamination of the creek, spring water and groundwater with toxics. The local creek was found to be under severe stress, with no fish populations in some areas and downstream sunfish populations having high percentages of deformed heads and eroded fins. Elevated concentrations of selenium, arsenic, and possibly thallium were found in largemouth bass. Selenium was also absorbed by plants, creating a possible pathway to exposure for soil invertebrates and small mammals. Elevated readings of arsenic, selenium and lead were found in small mammals.[88]

4. *Policy Implications*

Because of its array of severe effects on human health and the environment, coal—across all of its life cycle, including coal ash—must be addressed in a public health context. Use of coal is also an ethical issue. Corporations that burn coal and generate coal ash must not be free of responsibility for the consequences they unleash on human and environmental health. Rather, coal's contaminants must be handled in ways that minimize their impacts on human health and the planet. The responsibility for that handling must fall first on those who produce, utilize, dispose, and reuse coal and its waste products.

Because coal ash contains such high levels of dangerous toxics, its disposal and reuse call for high levels of prudence and care. From a health and medical perspective, the situation calls for application of the "precautionary principle." The precautionary principle states that where an action risks causing harm to the public or to the environment, the burden of proof that it is *not* harmful falls on those who would take the action. In other words, rather than waiting until harm has occurred, we should require those who want to use coal ash to demonstrate that the proposed use is safe. It is the same principle applied by the Food and Drug Administration to keep our food supply safe, and it is a wise one to apply when dealing with leaking, leaching, toxic substances.

In contrast to a classical risk assessment approach, which asks, "How much harm can we tolerate?" the precautionary principle asks, "What actions can we take to prevent harm?" When we distribute arsenic, lead, mercury, or selenium into the environment, we expose ourselves and our children to compounds that

rob us all of our potential for full development, while also harming the much broader biotic community. Yet our duty as health professionals and environmental stewards includes the responsibility to protect people from harm, especially those who cannot protect themselves, such as children. The precautionary principle supports an approach to policy-making that emphasizes our responsibility to actively promote human and environmental health, for ourselves as well as for future generations.[89]

We have the knowledge and resources to make appropriate decisions to protect public health and the environment, and therefore, the responsibility to do so. Prudent, precautionary options available that should guide the handling of coal ash include:

- Incorporating the best available elements of preventative hazard design in storage and disposal facilities. These include engineered composite liner systems, leachate collection systems, long-term ground water monitoring, and corrective action (cleanup standards), if these systems fail.

- Phase out the wet storage of coal ash, the disposal of coal ash in mines and unprotected landfills, and the disposal or reuse of unencapsulated ash where it is exposed to surface or ground water.

- Pursuing further independent research and assessment of coal ash recycling. Reuse of coal ash should only be permitted when research indicates that the toxic chemicals in coal ash will not migrate from the ash in quantities that pose a threat to human health or the environment during the entire lifecycle of the reuse application.

- Particular care must be taken to assess the health and environmental impact of the unencapsulated use of coal ash before such uses are allowed to continue.[90] This includes the reuse of coal combustion waste in agriculture and as anti-skid material on roads. Large unencapsulated uses, such as unlined and unmonitored fills, must be prohibited or treated as disposal sites and be required to maintain all the necessary safeguards.

- Research is needed to determine the possible health effects from coal combustion waste on workers who are exposed to ash and sludge at disposal facilities, construction projects and manufacturing plants.

- In view of the immense amount of coal ash generated in the U.S. and its disposal and reuse in nearly every state and territory of the nation, it is essential that the EPA enact federally enforceable safeguards that protect the health and environment of every citizen equally and effectively.

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