COAL COMBUSTION WASTE IS A *DEADLY* POISON TO FISH

prepared by

A. Dennis Lemly
Research Professor of Biology
Wake Forest University
Winston-Salem, NC 27109

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What makes coal combustion waste so hazardous to fish?

Coal wastes contain the trace element selenium, which causes severe reproductive impacts on fish. The basis for this toxicity is quite simple. Selenium is leached out of coal waste by rain or ash disposal water, dissolves into solution, and is carried into nearby lakes, rivers, and wetlands. From there it moves into the food chain and bioaccumulates in the organisms eaten by fish, birds, and other animals that utilize aquatic habitats (Figure 1). By consuming a contaminated diet, fish can further concentrate selenium in their tissues until it reaches over 5,000 times the original water concentration. However, even though they have an elevated level of selenium in their body, and some direct toxicity may result, the primary hazard of selenium is to developing embryos. Selenium consumed by parent fish is passed to their offspring in eggs, where it is highly concentrated in the yolk. When eggs hatch, larval fish absorb and metabolize selenium-laden yolk as a source of nutrition while they are developing. Selenium exerts its toxicity by preventing normal development of proteins and tissues. Visible symptoms of selenium poisoning include such things as skeletal deformities (teratogenic effects) and missing body parts (Figures 2-5, Lemly 1993b). Inside, a variety of tissue abnormalities occur in major organs (Sorensen 1986). Collectively, these symptoms will quickly kill a larval fish. The end result is reproductive failure which, over time, will cause fish populations to collapse. This mechanism of toxicity, in which adult fish can live relatively unaffected yet experience total reproductive failure, constitutes a particularly deceptive threat to fish health. The ease with which selenium moves from coal waste into aquatic systems, its propensity to bioaccumulate, and its insidious mode of toxicity combine to make coal waste a highly hazardous material (Lemly 2002b).

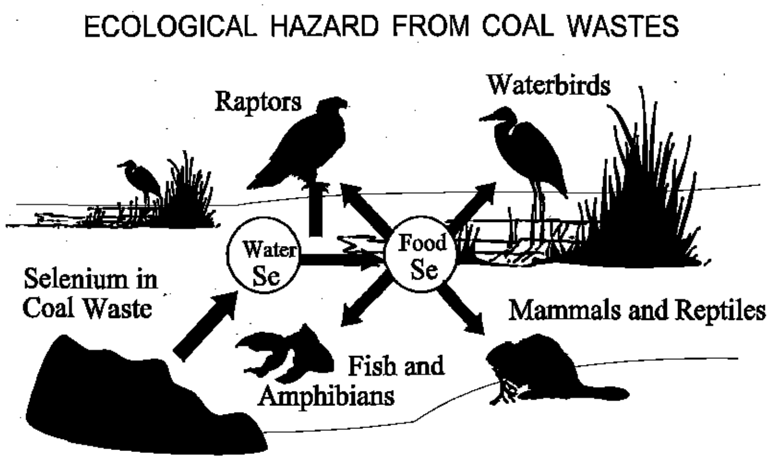

Figure 1. Pathways for selenium movement from coal wastes, bioaccumulation in food chains, and dietary exposure of fish and wildlife populations.

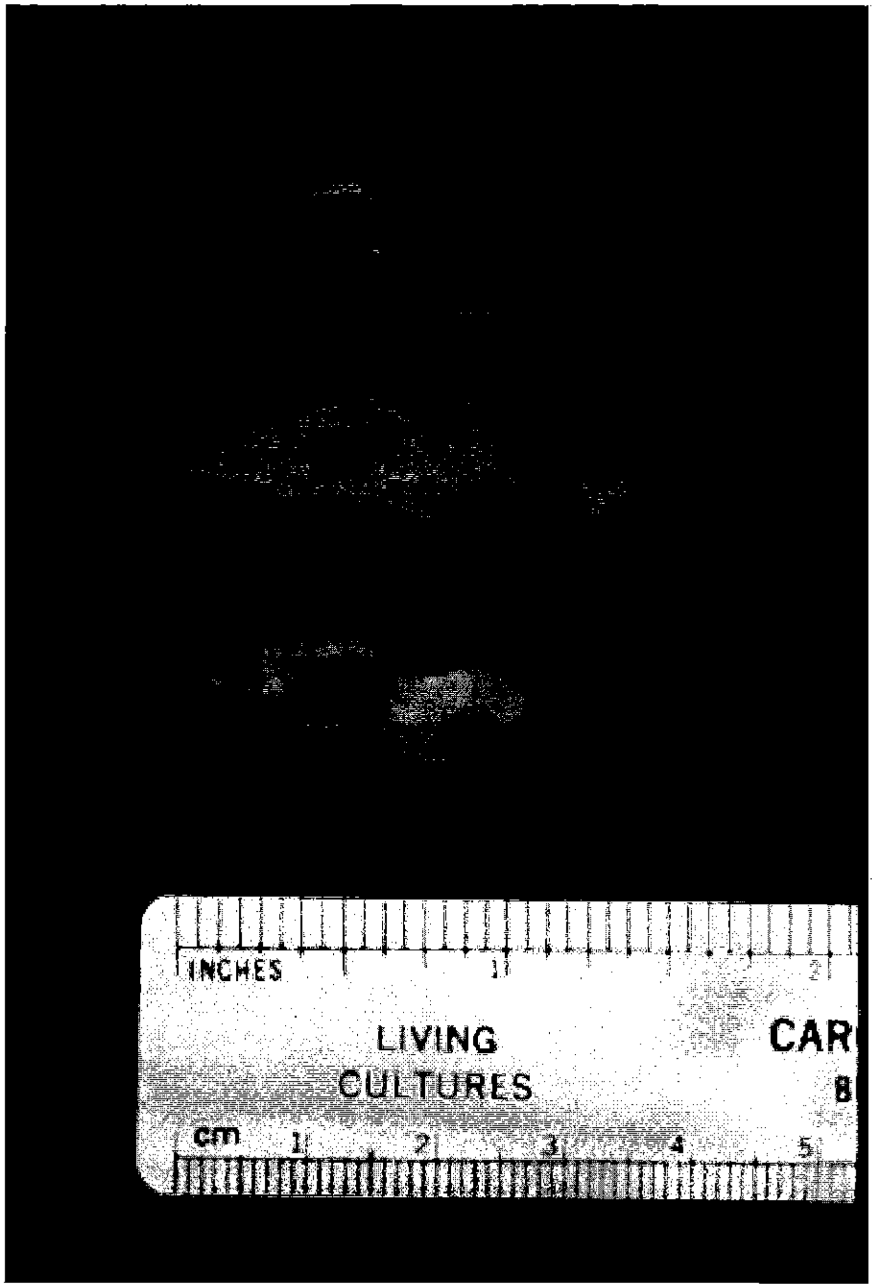

Figure 2. One of the most common and outwardly visible teratogenic effects of selenium in fish is deformity of the spine. Shown here are examples of dorso-ventral abnormalities (kyphosis and lordosis) caused by exposure to selenium in coal ash leachate water.

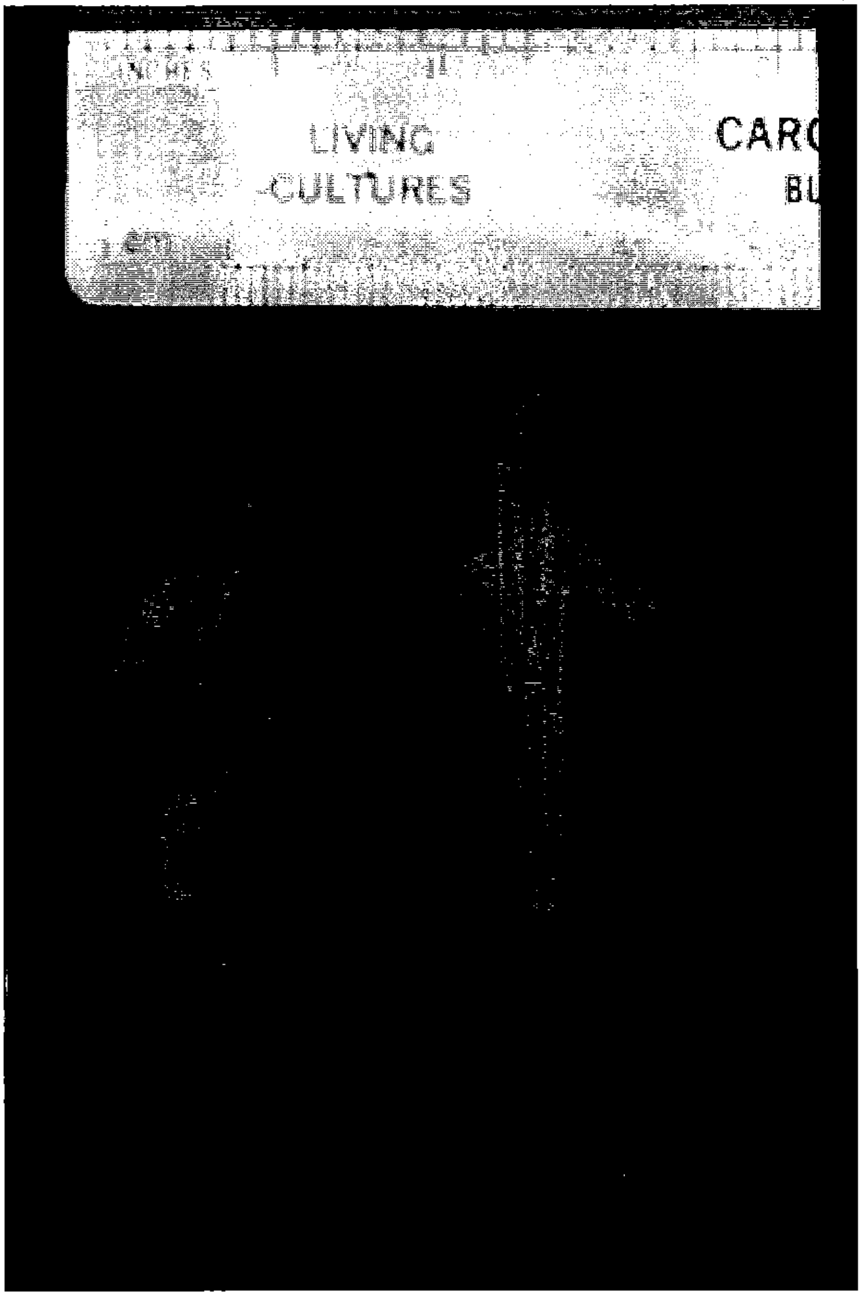

Figure 3. Lateral curvature of the spine (scoliosis) caused by exposure to selenium in coal ash leachate water. Individual on right is normal.

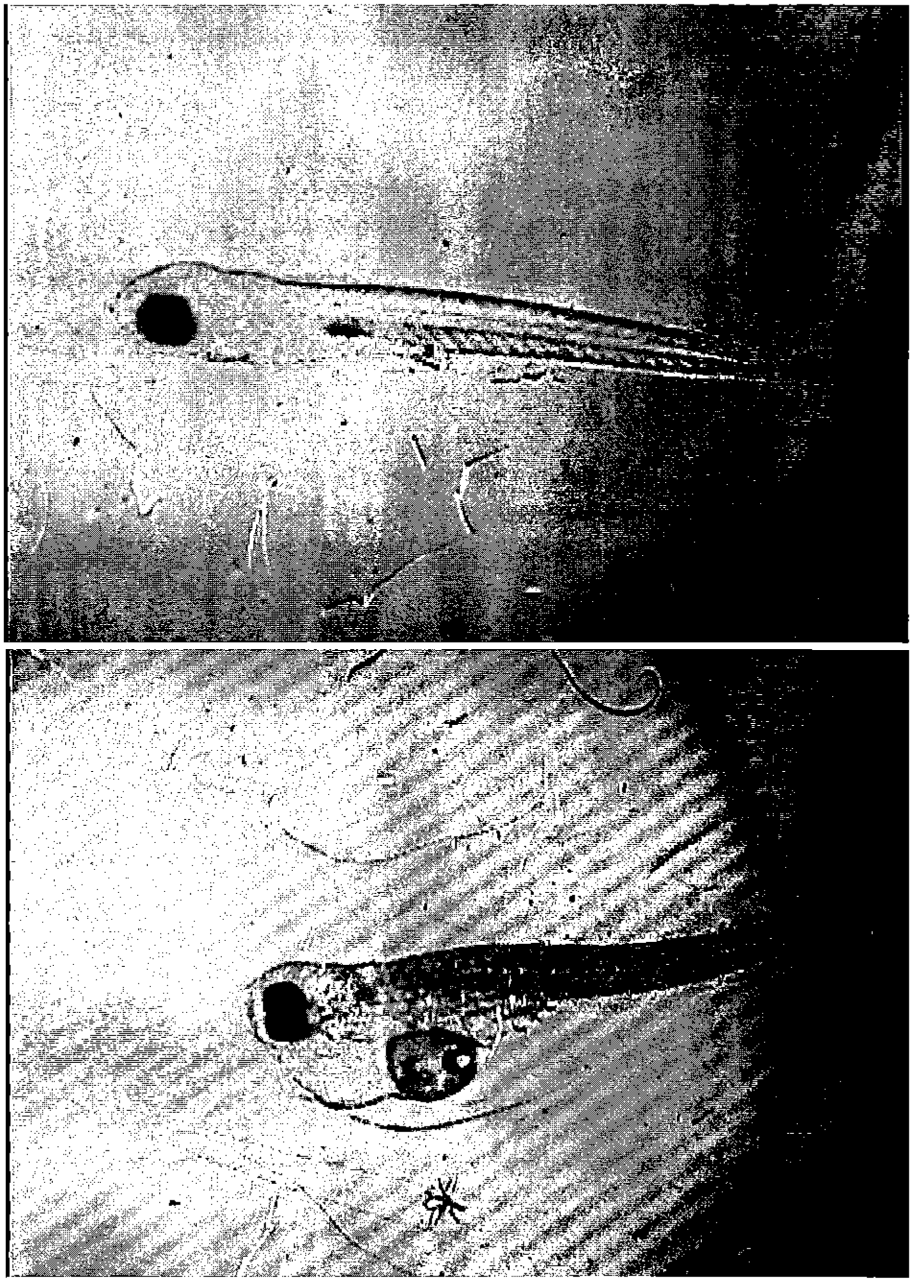

Figure 4. TOP: Typical fish larva showing normal eye development, straight spine, and complete yolk absorption with no evidence of edema or a swollen, deformed yolk sac. BOTTOM: Abnormal fish larva from parents exposed to selenium in coal waste. Note the distended, fluid-filled yolk sac (edema) and delayed yolk absorption. This individual also has dorso-ventral curvature of the spine (kyphosis) and deformed pectoral fins and eyes (both eyes are on the same side of the head). All of these abnormalities are characteristic biomarkers of selenium poisoning and will kill this fish.

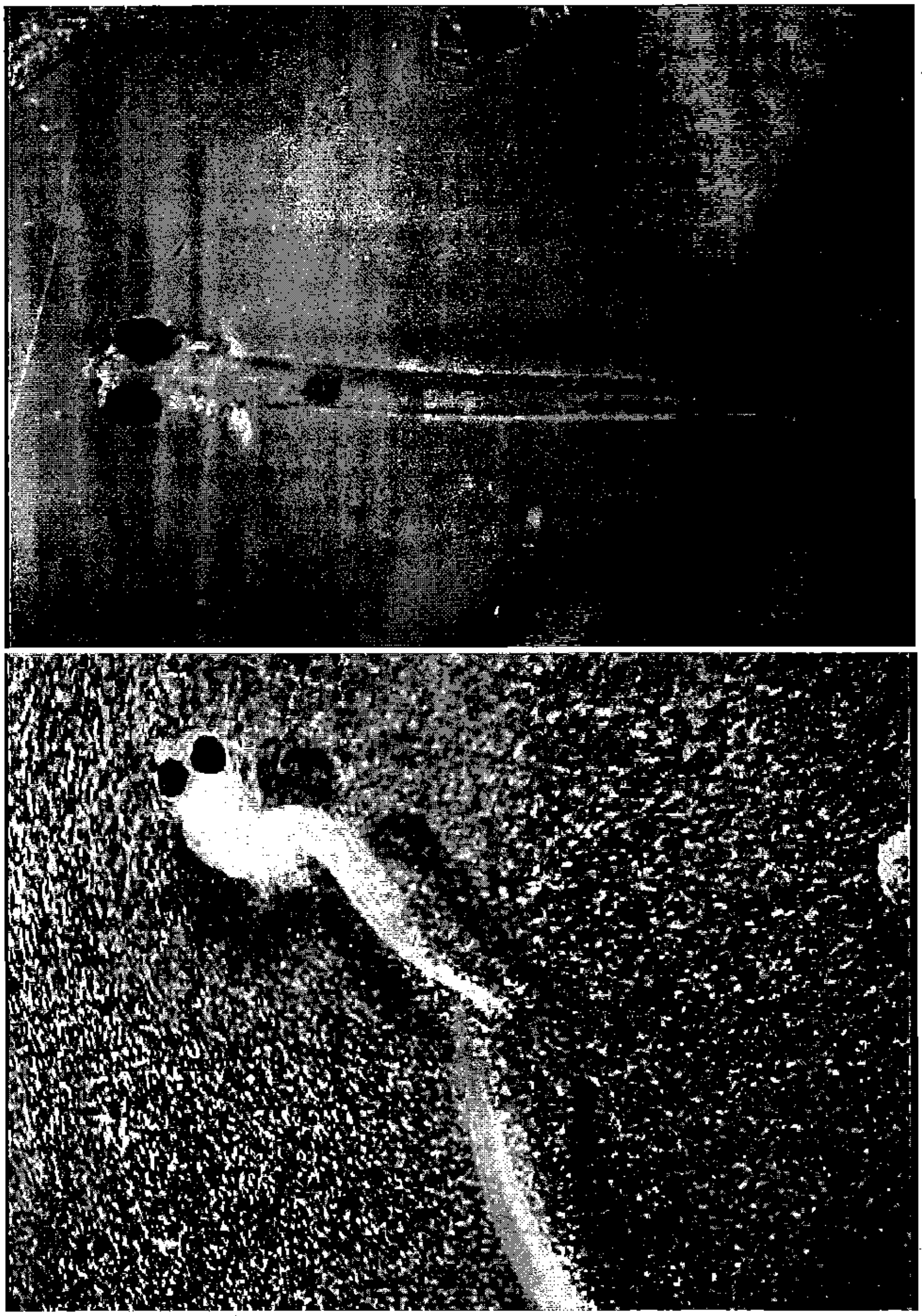

Figure 5. TOP: Dorsal view of normal fish larva showing well developed pectoral fins and straight spine. BOTTOM: Dorsal view of abnormal fish larva from parents exposed to selenium in coal waste. Note deformed spine in "S" shape, typical of scoliosis due to selenium poisoning. This fish will die because it cannot swim or feed normally.

What are the toxic concentrations of selenium to fish and what are the levels of selenium in coal combustion waste?

Detailed field and laboratory investigations have determined that waterborne concentrations of selenium in the 1-5 ug/L (micrograms per liter or parts-per-billion) range can bioaccumulate and begin to cause reproductive failure in fish. The exact number is site-specific, and depends on the kind of aquatic system (stream, reservoir, wetland), its biological productivity, and the chemical form of selenium present in the water. Field case studies show that if waterborne selenium reaches 10 ug/L, complete reproductive failure and population collapse can occur in reservoirs, and reproduction may be reduced by 40% in streams (Cumbie and Van Horn 1978, Lemly 1985b, Gillespie and Baumann 1986, Hermanutz et al. 1993). In one particular case, 19 species of fish were totally eliminated over a period of 4 years due to reproductive failure (Lemly 2002b).

Concentrations of selenium in coal wastes are far greater than the toxic levels for fish (Figure 6). For example, the largest component of coal waste (fly ash) produces leachate and disposal water with up to 2,700 ug/L selenium (Lemly 1985a), a concentration that is several orders of magnitude greater than the range for toxic bioaccumulation in aquatic habitats.

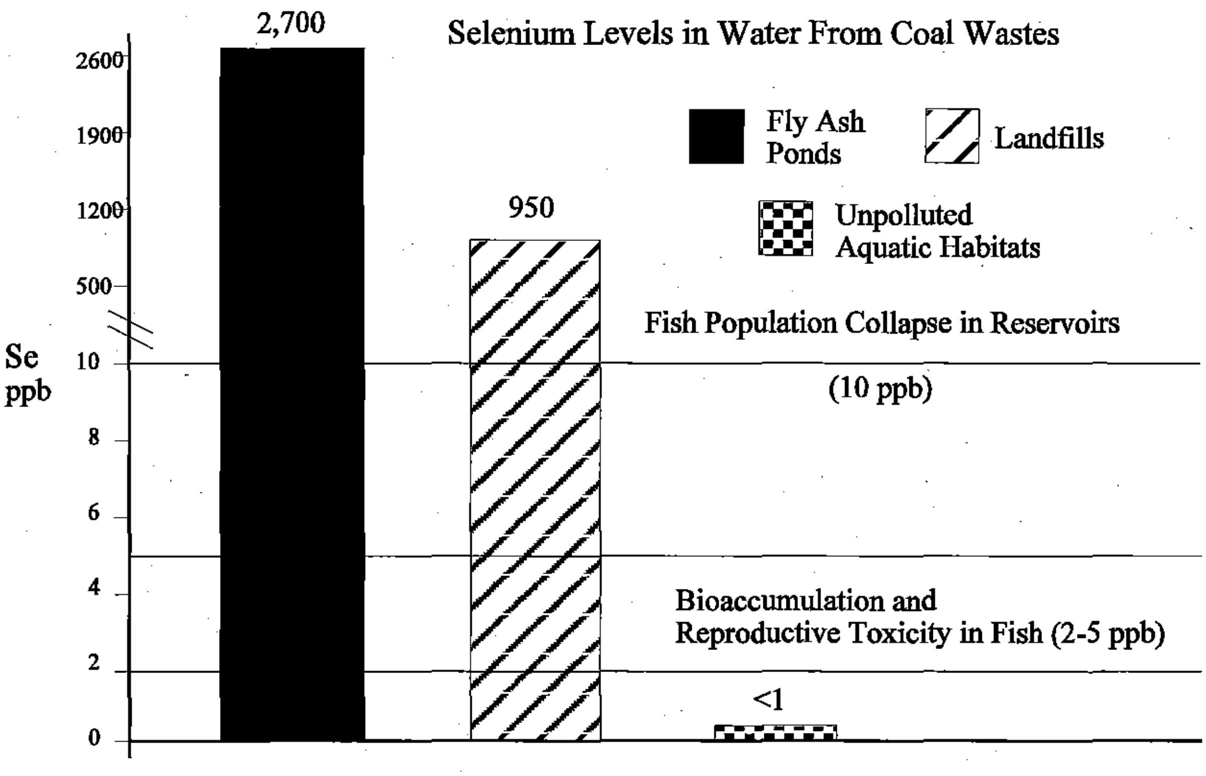

Figure 6. Levels of selenium emanating from coal waste relative to toxic levels for fish.

How widespread is selenium poisoning associated with coal combustion waste?

Because adult fish may be unaffected by selenium concentrations that impair their ability to reproduce, reductions in spawning success or impacts to fish population must be determined by something more than routine monitoring surveys, that is, simply finding fish does not indicate the absence of selenium poisoning. Moreover, the residency status of fish must be known because movement patterns may bring uncontaminated individuals from other locations into the study area. These individuals would not exhibit the same selenium concentrations in tissues and associated reproductive failure as resident fish. Thus, proper assessment techniques must be applied in order to definitively evaluate selenium poisoning. In most locations where coal waste could be an issue, there has been either no fish health assessment at all, or the investigation did not look closely enough, using the proper evaluation techniques, to determine actual impacts. At sites where proper techniques were applied, numerous cases of impacts have been identified and documented (Figures 7-8). Moreover, the number of documented cases is growing rapidly. For example, the USEPA found that substantiated coal waste environmental damage cases more than doubled during the period 2000-2005 (USEPA 2005). These cases are spread across the nation and involve surface impoundments as well as landfills (Table 1), so the hazard and impact from coal waste is not limited to one disposal method. Since 2005 new cases have been steadily added to this unfortunate, but preventable, coal waste pollution legacy. The most remarkable of these is the massive December 2008 spill at the TVA Kingston Coal Plant in Tennessee (Figures 9-10), which released over 5 million cubic yards of coal ash (the largest US industrial spill on record) and contaminated an entire river ecosystem for many miles downstream. Fish have already accumulated selenium to toxic levels at this site (Babyak et al. 2009).

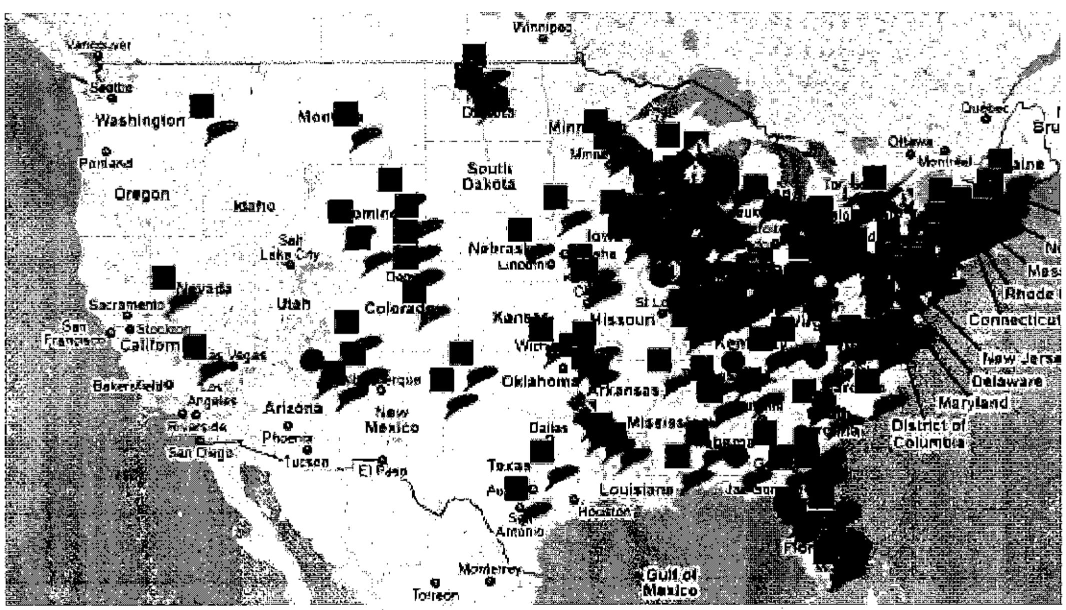

Figure 7. Coal combustion waste sites where toxicity to fish is suspected (blue), has been confirmed (red). and is also implicated in human health effects (yellow).

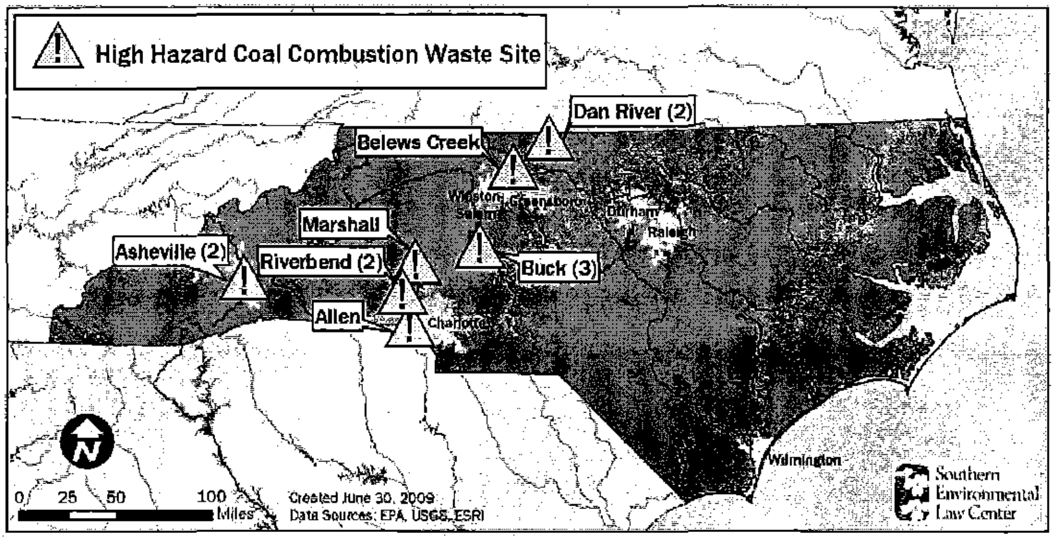

Figure 8. Multiple hazardous coal waste sites have been identified in some states. For example, North Carolina has 12 high hazard sites.

Table 1. Environmental Protection Agency proven environmental damage cases due to coal combustion wastes as of 2005.

Facility	Type	State
Vitale Fly Ash Pit	Landfill	MA
Salem Acres	Landfill	MA
Don Frame Trucking	Landfill	NY
PEPCO Faulkner Off-site Disposal Facility	Landfill	MD
VEPCO/Virginia Power Possum Plant	Surface Impoundment	VA
VEPCO/Vvirginia Power Chisman Creek	Landfill	VA
Chestnut Ridge Y-12 Steam Plant Operable Unit 2	Surface Impoundment	TN
Georgia Power Bowen	Surface Impoundment	GA
South Carolina E&G Canadys Plant	Landfill	SC
Savannah River Project	Surface Impoundment	SC
Belews Lake	Surface Impoundment	NC
Hyco Lake (CP&L Roxboro)	Surface Impoundment	NC
Lansing Board P&L North Lansing Landfill	Landfill	MI
Daryland Power Ash Pond - Cassville Site	Surface Impoundment	WI
WEPCO Highway 59 Landfill	Landfill	WI
Alliant Nelson Dewey	Landfill	WI
WEPCO Cedar Sauk Landfill	Landfill	WI
WEPCO Port Washington	Landfill	WI
Yard 520, Pines	Landfill	IN
Martin Creek Reservoir	Surface Impoundment	TX
Brady Branch Reservoir	Surface Impoundment	TX
Welsh Reservoir	Surface Impoundment	TX
Basin Electric W.J. Neal Station	Surface Impoundment	ND
Cooperative Power Association-United Power Coal Creek	Landfill	ND

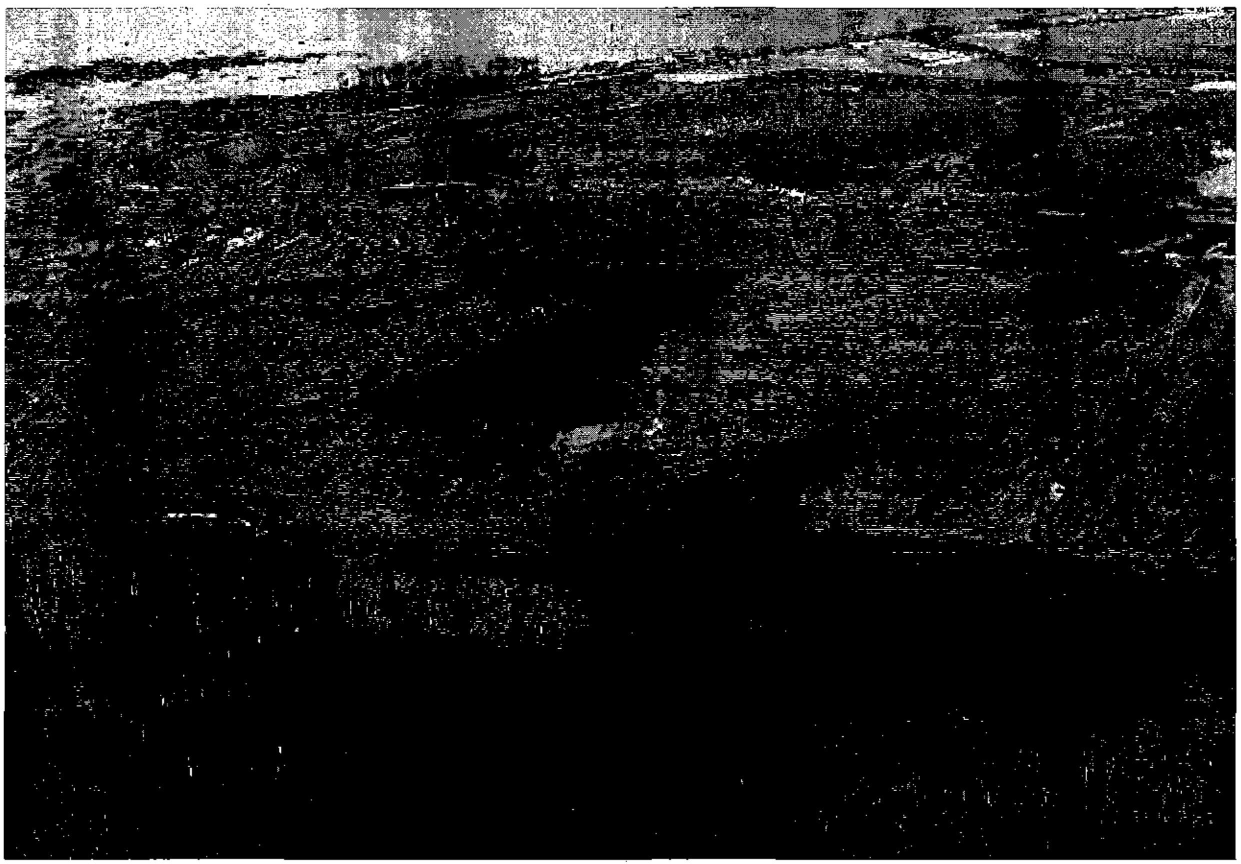

Figure 9. Aerial view of the TVA Kingston Coal Plant Ash Disposal Basin shortly after the retaining dyke failed in December 2008, releasing over 5 million cubic yards of ash onto adjacent lands and into the Emory River. Prior to the spill, the intact ash pile was approximately one mile long and 50-100 feet deep.

Figure 10. View looking downstream into the Emory River shortly after the TVA Kingston Coal Plant ash spill in December 2008. The river is almost entirely plugged by coal ash. The Kingston Plant can be seen in the background.

What is the outlook for the future?

Coal use continues to increase, as does the amount of waste that must be disposed. The track record we as a society have established tells us what the future will look like unless some fundamental and far reaching changes are made......more pollution, more fish poisoning, more tabulating cases of management and disposal failures appended by scientist "I told you so's" and "should have done's". I, for one, do not want to continue investigating cases of selenium poisoning in fish from coal waste.....as I have repeatedly done for the past 30 years. There is no need for this. The information presented above, along with the scientific reports listed in Supplemental Information, provide clear, irrefutable evidence that coal combustion residues are a hazardous waste. They should be treated as such with respect to regulatory policy. Safeguarding the nation's water supply is of utmost importance. This can be done only if environmentally sound regulations governing the disposal and management of coal waste are established and enforced. Ironically, as we strive to make coal "cleaner" by removing particulates and airborne emissions, we simply add to the amount of ash and other residual wastes that must be disposed. With respect to fish health, there is no such thing as clean coal. The only long-term solution is to replace coal with alternative energy sources. Until we achieve this transition it is imperative that adequate regulatory controls are in place. EPA and the Office of Management and Budget can, and should, take the steps necessary to provide this control. The US needs to assert a leadership role in coal waste regulation, not only for the benefit of our nation, but also to set an example for other countries to follow with respect to their own coal waste management policies.

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SUPPLEMENTAL INFORMATION:

This is a sampling of the many studies on environmental damage and risks to human health from power plant ash and other coal combustion wastes.

The scientific reports listed below provide clear evidence that coal combustion residues are a hazardous waste. That fact has been know for many years as indicated by the early publication dates (pre-1990) for much of this research.

Ecological Damage:

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QUALIFICATIONS STATEMENT
Dr. A. Dennis Lemly

I have spent over 30 years investigating the effects of selenium pollution in aquatic ecosystems. I have extensive experience conducting field and laboratory research on selenium toxicology, primarily involving aquatic cycling, bioaccumulation, and effects on fish. These studies include intensive investigations of the two most substantial cases of selenium pollution that have taken place in the USA; (1) Belews Lake, North Carolina, where 19 species of fish were eliminated, and (2) Kesterson Marsh, California, where thousands of aquatic birds were poisoned. My career began in the late 1970's with studies of the landmark pollution event at Belews Lake, which established the fundamental principles of selenium bioaccumulation and reproductive toxicity in fish. In the 1980's, I was a research project manager for the U.S. Fish and Wildlife Service, directing studies that determined impacts of selenium from agricultural irrigation on aquatic life at Kesterson and in 14 other western states. In the 1990's, the emphasis of my research shifted to the development of methods and guidelines for hazard assessment and water quality criteria for selenium, which led to the publication of a reference book (see item 42 below). This handbook contains the first comprehensive assessment tools for evaluating selenium pollution on an ecosystem scale. I have consulted on selenium contamination issues around the world, including such problems as power plant discharges in Australia, gold mining effluents in Russia, agricultural irrigation drainage in Egypt, and landfill leachate in Hong Kong. I provide the methods and technical guidance necessary to identify, evaluate, and correct aquatic selenium problems before they become significant toxic threats to fish and wildlife populations. I have devised and applied techniques for protecting aquatic life in habitats from the Arctic to the tropics, and from high mountain streams to coastal lagoons. My selenium evaluation guidelines and water quality criteria recommendations have been adopted by the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, 23 states and over 60 nations and provinces around the world. I have Masters and Doctorate degrees in biology from Wake Forest University.

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