The Electric Power Industry and Mercury Regulation:

Protective, Cost-Effective, and Market-Based Solutions

by Michael T. Rossler

INTRODUCTION
Mercury is a naturally occurring metal in the Earth’s crust that is released into the environment as a result of both natural and human activities. The same amount of mercury has existed since the Earth was formed. It occurs in numerous chemical compounds, and may change from one form to another. In its elemental form, mercury is a shiny, silver-white metal that liquefies at room temperature. Mercury can be found in both inorganic and organic forms. The most common organic mercury compound in the environment is methylmercury, which is produced by natural processes in lakes and wetlands that convert inorganic mercury into methylmercury. Methylmercury enters the aquatic food chain and bioaccumulates in fish tissue.

Mercury releases can be attributed to natural sources, such as volcanoes, oceans, and soils, as well as to anthropogenic activities, such as gold and ore mining, medical waste incineration, municipal and hazardous waste combustion, cement manufacturing, pulp and paper milling, and coal- and oil-based electric power generation. Mercury is used every day in such common items and products as thermometers, blood pressure gauges, dental fillings, fluorescent light fixtures, batteries, electrical equipment, and fungicides. The U.S. Environmental Protection Agency (EPA) and other regulatory agencies have suggested a “plausible link” between anthropogenic sources emitting mercury and the formation of methylmercury, its bioaccumulation in the food chain, and adverse health effects in humans, particularly women of childbearing age and young children.
MERCURY REGULATION
The Clean Air Act Amendments (CAA) of 1990 authorize EPA to regulate mercury emissions and other air toxics from electric utilities, if necessary, to protect against specific threats to public health caused by these emissions. On December 14, 2000, EPA issued a “regulatory determination” under the Clean Air Act (CAA) that regulation of mercury is “appropriate and necessary” for coal- and oil-based power plants, and that certain other hazardous air pollutants (HAPs) pose a “potential concern for carcinogenic effects...[and] public health.”

This decision automatically triggers a formal rulemaking. EPA is scheduled to issue a proposed rule by December 2003, a final rule by December 2004, and to require compliance by December 2007. The language of the regulatory determination limits the EPA Administrator’s policy options and immediately impacts new and reconstructed plants. Electric utilities are explicitly treated differently under the CAA than other major sources of HAPs, in that EPA’s assessment of power plants “shall” address “alternative control strategies.” EPA’s designation of a specific regulatory approach—even though the regulatory determination is not a formal rule—means that major new coal- and oil-based plants, as well as existing coal- and oil-based plants that are “reconstructed,” will be regulated immediately in accordance with a stringent, case-by-case control program. Although the regulatory determination currently applies only to mercury, EPA has suggested the possibility of regulating other HAPs emitted by power plants. The determination also limits the EPA Administrator’s ability to implement a flexible and cost-effective program. Based on this regulatory determination, EPA is working on a proposed standard for mercury that will require maximum achievable control technology (MACT). This technology requires that the emission standard be at least as stringent as the average removal efficiency of the top 12% of the best performing units in the nation.

ELECTRIC UTILITIES AND MERCURY EMISSIONS
Trace amounts of mercury are naturally present in coal. As a trace metal that is emitted during coal combustion, mercury is transformed into three major chemical species: elemental, ionic (or oxidized), and particulate. The chemical species of mercury formed during the combustion process and post-combustion conditions vary significantly from one plant to another. Of the total mercury formed, the amount of elemental mercury varies from 10% to 90%. Elemental mercury usually travels great distances from its source, and can remain in the atmosphere for months to years. Ionic mercury is water soluble, and as such, falls or washes out of the air. Deposition of ionic mercury is typically in the local vicinity (50–100 km) of its source, enabling the formation of methylmercury and possible bioaccumulation in the food chain.

The total annual global input of mercury emissions to the atmosphere from all sources, including natural, anthropogenic, and oceanic emissions is about 5500 tons. Annual anthropogenic emissions of mercury in the United States contribute about 158 tons to the global pool. Approximately 87% of U.S. emissions are from combustion sources, including waste and fossil fuel combustion. Based on this, U.S. sources contribute approximately 2–3% to total global mercury emissions. About one-third (52 tons) of U.S. anthropogenic emissions are deposited, through wet and dry deposition, within the lower 48 states. The remaining two-thirds (107 tons) are transported outside of the United States, where they diffuse into the global reservoir. In addition, approximately 35 tons of mercury from the global reservoir are deposited for a total deposition of approximately 87 tons within the continental United States.

U.S. electric utilities release about 45 tons of mercury every year, which is roughly one-third of the total anthropogenic emissions of mercury in the United States. The 45 tons of mercury emissions consist of 26 tons of elemental mercury, 18 tons of ionic mercury, and less than one ton of particulate mercury. The EPA regulatory determination noted, “there are uncertainties regarding the extent of the risks due to electric utility mercury emissions.”

Electric utilities have been taking steps to eliminate the use of mercury at power plants as a component of ongoing pollution prevention programs. Furthermore, under the agency’s Toxics Release Inventory (TRI) program, utilities are required annually to report estimates of their chemical releases, including mercury, for the public’s general knowledge. In 1998, in order to assess mercury emissions from U.S. coal-based power plants, EPA issued an information collection request (ICR) that required owner/operators to report the quantity of fuel consumed and the mercury content of that fuel for calendar year 1999. In addition, 84 plants were selected to measure flue gas mercury emissions and their chemical form.

MERCURY CONTROLS
A modern power plant is typically equipped with a high-efficiency baghouse—fabric filter (FF)—or electrostatic precipitator (ESP) for particulate removal; staged-combustion burner configurations for low-nitrogen oxides (NOx) emissions; and post-combustion flue gas treatment devices for NOx and sulfur dioxide (SO2) control—selective catalytic reduction (SCR) and selective noncatalytic reduction (SNCR) technologies for NOx control, and high-efficiency flue gas desulfurization (FGD) scrubbers for SO2 control. Not all power plants utilize all of these control devices. For example, approximately 65% of plants use only an ESP, 10% use only an FF, and 25% use a combination of an ESP and wet FGD to control particulates; approximately 25% of plants use scrubbers and the rest either use low-sulfur coal or fuel-switch to control SO2.
In addition to removing specific pollutants, such as fine particulates, SO$_2$, and NO$_x$, currently installed air pollution controls may also remove mercury. However, there is no single control technology that can effectively remove all forms of mercury. There exists no proven technology to control mercury emissions from an oil-based power plant, for example. Measurements at a variety of U.S. power plants performed under EPA’s mercury ICR indicate that existing emission control devices for particulates (fly ash) and SO$_2$ capture, on average, approximately 40% of the mercury present in the flue gas from burning coal. However, mercury removal rates varied from 0% to more than 90% among the power plants that were tested.3

Mercury control options are highly dependent on the existing power plant’s design, operating characteristics, and fuel used—in the case of coal, the type of coal used is also important. Thus, potential mercury emissions are unique to each unit. For some plants, mercury emission reductions of 70–90% may be impossible to achieve. In addition, there is still considerable uncertainty in the measurement of mercury emissions, since no reliable monitoring technology for mercury has been developed.

The characteristics of a coal-based plant that most affect emissions of mercury and the type of control technology used are the mercury content and other chemical aspects of the coal (particularly the chloride content); the boiler operating conditions; the design and operation of any particulate collection devices; the design and operation of any flue gas treatment systems; and the use of advanced NO$_x$ removal technology, such as SCR and SNCR.

**Selective Catalytic/Noncatalytic Reduction**

Some research suggests that SCR and SNCR for NO$_x$ control on plants with scrubbers may lead to increased mercury removal, as the ammonia reagent may convert mercury to a form that enhances removal by the scrubbers. EPA assumes that significant mercury reduction would result from “co-benefits” of SO$_2$ and NO$_x$ controls already installed, assuming that the installation of a scrubber along with a SCR will result in a 95% reduction in mercury emissions.7 Pilot-scale studies assessing mercury removal by an SCR device in combination with various particulate control devices have shown great variability, with results ranging from 45% to 99% removal. These results are highly dependent on the type of coal burned, operational aspects of the plant, and other installed pollution control devices. It is unclear whether these results are applicable to an actual operating power plant, as EPA assumes.
Only a small number of coal-based power plants currently have either SCRs (six plants) or SNCRs (32 plants) installed. Both the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI) have stated that more research is necessary at full-scale operating power plants to obtain more conclusive results on whether SCRs and SNCRs significantly impact mercury removal.

**Activated Carbon Injection**

A promising method under investigation as a cost-effective way to remove mercury concerns the injection of a sorbent into the flue gas that results from the combustion of coal. Sorbents being tested for mercury removal include fly ash and activated carbon. Activated carbon, in parallel with fly ashes created from coal combustion and in conjunction with enhancements for particle collection, is being studied as a mercury control for utility boiler systems that have fine particulate controls as the only installed pollution control. Activated carbon injection (ACI) is successfully used in the municipal waste combustor industry and has been shown to be capable of removing greater than 90% of the mercury for this application. Laboratory and pilot-scale testing of ACI for possible coal-based utility applications indicate that it cannot be directly applied to coal-based electric utilities for many reasons. Factors that affect the amount of mercury removed by activated carbon injection include the interaction of acid gases with activated carbon, the particle size of the activated carbon, the residence time of the carbon in the flue gas, and the temperature of the flue gas. In addition to technical issues, there is substantial uncertainty about the cost, performance, and ultimate fate of the collected mercury using ACI, since only one limited, full-scale, real-world test of the technology at these high removal rates has been performed to date. Costs could be significantly higher if the fly ash containing mercury were required to be treated as hazardous waste.

**MERCURY CONTROL RESEARCH STILL EMERGING**

Since there is no demonstrated technology that can control mercury emissions across the entire utility industry, several ways to reduce mercury are being investigated. Much of the mercury control research in the United States is being sponsored by four organizations: DOE’s National Energy Technology Laboratory (NETL), EPRI, EPA, and the U.S. Geological Survey (USGS). The research is designed to augment existing pre- and post-combustion technologies, with various combustion conditions being studied for possible mercury removal or mercury speciation modifications.

The electric power industry is involved in several areas of research, particularly mercury control technologies. Research is ongoing to improve the understanding of mercury combustion chemistry and physics, and to find ways to reduce mercury emissions in the most efficient and cost-effective manner. Other potential technologies—including advanced coal washing, systems to recycle activated carbon for reuse, and systems to control NOx, SO2, and mercury emissions together—are in various stages of research and development. A major focus of utility mercury control research involves investigating the viability of injecting materials into flue gases that can absorb or react with mercury to produce solids that can subsequently be captured by particulate control devices, or that produce compounds of mercury that can be captured by SO2 controls.

In August 2000, DOE selected two companies to test full-scale advanced mercury control technologies at several of the nation’s coal-based power plants. In May 2001, DOE selected six new projects that are looking at novel mercury control concepts that could provide utilities with a wider range of options. These projects, the first full-scale demonstrations of mercury control technologies at individual power plants, are due to be completed in two to three years. In August 2001, as part of DOE’s University Coal Research Program, four of 23 winning projects were selected to conduct research on mercury emissions from burning fossil fuels. The goal of DOE’s program is to develop a wider array of mercury control options for power plants that can reliably reduce emissions by 50–70% by 2005 and 90% by 2010 at half the current cost estimates. Many of the new technologies would tie in mercury controls with processes that reduce other air pollutants, such as SO2 and NOx.

**COST-EFFECTIVE, MARKET-BASED SOLUTIONS**

**Trading**

Emissions trading is a system of establishing a cap on emissions and allowing sources the flexibility to choose the emissions reduction plan that works best for their situation, including increasing efficiency, using lower-emitting fuels, installing pollution control equipment, and trading. Trading allows a source that can over-control its emissions to sell extra reductions to another source for which controls would be very expensive or technologically difficult (e.g., small units). Without trading, small units may have to shut down, even though their total emissions are low. Emissions trading gained prominence with the implementation of the Title IV (Acid Rain Control) trading program for SO2 in the 1990 CAAA. Some critics view emissions trading as “buying the right to pollute,” expressing concern about local “hot spots” where emissions could increase as a result of emissions trading. These groups would limit or eliminate future emissions trading for mercury. Many groups accept this logic for mercury and oppose mercury trading due to perceived “localized effects on public health.”

As noted earlier, EPA acknowledged in its regulatory determination that the agency has not yet been able to quantify the extent of the health risks due to electric utility mercury emissions. Because of the many uncertainties and still unresolved issues in this area, EPA has not quantified the health benefits associated with significant mercury reductions in its
staff “strawman” multi-emission proposal and subsequent revisions. Until this issue is clarified further, there is no health basis on which to preclude mercury trading.

Based on five years of real-world experience, studies of the SO₂ allowance trading program conducted by EPA, the Environmental Law Institute, and Resources for the Future demonstrate that trading did not significantly change where emission reductions actually occurred. The success of the acid rain SO₂ trading program provides evidence to allay fears about localized effects. Arguments that would put limits on mercury trading are not scientifically valid either. U.S. electric power generation currently accounts for approximately 20% of the mercury emitted from anthropogenic sources in the United States, northern Mexico, and southern Canada. If utility sources were to reduce their emissions by 50% from current levels, then the utility contribution would be about 10%. If trading then changed the power generation contribution in a region from 10% to 8% or from 10% to 12%, the difference would be environmentally insignificant.

As noted earlier, the application of SO₂ and NOₓ controls causes most of the remaining mercury to be elemental, which tends not to deposit locally. It is therefore probable that controls on a large number of widely dispersed power generation emissions sources would lead to a general reduction across a large region and only trivial changes in local mercury deposits due to trading. Finally, it is important to note that the emissions consequences of trading can be evaluated after the fact, and adjustments can be made if necessary. Rejecting or constraining emissions trading is contrary to the goal of flexible, market-oriented approaches to reduction; inconsistent with the clear success of the acid rain SO₂ trading program; and may result in substantial adverse consequences, such as

- Undermining future cost savings from new applications of emissions trading.
- Requiring high-cost command-and-control emissions controls where governments essentially dictate how a business runs.
- Reducing the incentive for utilities and vendors to innovate in the areas of efficiency, pollution controls, energy efficiency, and cleaner fuels, which are spurred on by different options competing against each other. Limits on trading force today’s technological fix to be cemented in place for decades without the possibility of being improved upon.

Analysis by the U.S. Energy Information Administration (EIA) shows that a cap-and-trade program would give power suppliers flexibility to reduce emissions at the lowest possible cost and that the command-and-control MACT standard supported by EPA can be significantly more expensive than cap-and-trade systems that achieve similar levels of mercury reduction. An analysis conducted for the Edison Electric Institute (EEI) on behalf of the electric utility industry indicates cost savings from mercury trading of approximately $5 billion through 2020 (comparing the same mercury cap levels, with and without trading).

**Multi-Emissions Policy**

The current regulatory approach—with its uncoordinated and inconsistent air quality regulations—is duplicative, costly, and complex, and presents significant challenges and uncertainties. Coal-based electric generators are currently subject to more than 20 major environmental regulations aimed at reducing power plant emissions. For these reasons, many policy-makers and regulators have concluded that there is a better way to achieve air quality goals, while protecting the environment and public health. A “multi-emissions” strategy, if properly designed, could streamline the current regulatory process, provide greater certainty to electric companies, accomplish the nation’s air quality goals at a fraction of the cost, and maintain a reliable supply of electricity.

The National Energy Policy report released in May 2001 noted that uncertainty about future environmental controls is of particular concern for companies that operate existing coal power plants, and that future coal electricity generation will need to meet new challenges to reduce mercury emissions. To address these concerns, the report recommended that...
EPA work with Congress to propose legislation that would establish a flexible, market-based program to reduce and cap emissions of SO\textsubscript{2}, NO\textsubscript{x}, and mercury from electric power generators. The report concluded that such a program would provide significant public health benefits even as electricity supplies increase.

As a result of the report’s recommendations, numerous proposals have surfaced to reduce utility mercury emissions. These range from co-benefits, based on mercury reductions that already are occurring as a result of other (SO\textsubscript{2} and NO\textsubscript{x}) controls, to 90%-plus removal. Legislation introduced in this Congress includes the Clean Power Act of 2001 (S.556), which would require a 90% reduction from 1999 levels by 2007 and prohibits trading; and the Omnibus Mercury Emission Reduction Act of 2001 (S.1875), which requires a minimum 90% reduction from 1999 levels and allows trading only between units within a single site. The most recent proposal put forward by EPA, in December 2001, during interagency discussions in the context of a multi-emissions bill, would require an incremental approach leading to an overall 83% reduction by 2013.11

Requiring a 90% mercury emissions reduction prior to 2010 would likely cause significant fuel switching from coal to natural gas.15 This is inconsistent with national energy policy objectives because it will limit fuel choices, impede the construction of new power plants, and increase the cost of electricity. The excessive reductions and short time frame would also lead to the installation of a large number of mercury retrofit controls and other pollution controls, whose actual mercury emission reduction potential is currently unknown. It is also unclear whether it would be possible to produce and distribute the enormous amount of activated carbon, and fabricate and install the fabric filters required to collect the activated carbon material that would be necessary to achieve such a huge reduction in mercury emissions in such a short time frame. Since mercury-specific controls are still emerging, their cost and performance are highly uncertain.15

Notwithstanding the practical problems of achieving 90% mercury reductions at all coal-based power plants, reductions in the range of 90% from current levels would be very expensive to attain. Economic analyses conducted by EIA18 and EEI16 show that the mercury component of any multi-emissions approach would be responsible for the major portion of the costs. EPA has estimated mercury control program costs of approximately $2–5 billion annually,7 while DOE and others have estimated annual costs of $6–15 billion.6 It is significant to note that these costs for mercury are in addition to the cost of other emission controls, and that the costs are based on emerging control technologies, which are relatively new and untested on a commercial scale.

EPA, DOE, and other stakeholders are in agreement that the implementation of further controls for reducing SO\textsubscript{2} and NO\textsubscript{x}, particularly as part of a multi-emissions approach, will result in significant additional reductions (e.g., at least 20 tons) in mercury emissions. Focusing on these co-benefits of reduced mercury emissions also would allow adequate time for the development and commercialization of mercury control technologies that are currently in progress.

**CONCLUSION**

Regulation of electric utility mercury emissions is proceeding on two tracks. As to the MACT rule, Section 112(n)(1)(A) of the CAA gives EPA broad regulatory authority and options. There is nothing to prevent EPA from proposing a rule that ensures scientifically justified and verifiable mercury reductions, while at the same time providing the electric utility industry maximum flexibility to achieve those reductions in a nonprescriptive and cost-effective manner. This flexibility can be achieved by subcategorization based on coal type (e.g., bituminous, subbituminous, lignite) or process/design considerations (e.g., boiler type), and by taking into account plant operational variability over time in setting the standards. As to the multi-emissions approach, integrating a mercury emissions reduction program with other existing programs will help accomplish EPA’s and industry’s objective of protecting the environment while reducing industry compliance costs. Allowing for market-based mechanisms, such as trading, to help achieve overall reductions will further increase the cost-effectiveness of any program.

The scientific data underlying policy options to reduce utility mercury emissions continue to evolve and mature. The utility industry continues to collect data on the effectiveness of various pollution control systems in reducing mercury emissions, and is funding additional health effects, fate-and-transport, and other related research. Accordingly, electric utilities are committed to working with DOE and EPA to address existing uncertainties and urge resolution of these issues as EPA moves forward with a mercury rulemaking. With respect to mercury controls, significant uncertainties include the limitations of both existing utility emission controls that also reduce mercury, and emerging mercury-specific control technologies, which are relatively new and untested on a commercial scale. The electric power industry is subject to a broad array of federal, state, and local statutes and regulations, and is one of the nation’s most regulated industries. Electric companies have exceeded many statutory and regulatory emission reduction targets, despite a growing national demand for electricity and increased electricity production.

It is essential that industry continues working with EPA as the agency determines to what extent mercury reductions may be appropriate from power plants. The industry is well represented and its representatives are pleased to participate in the Utility MACT Working Group. The group, comprised of stakeholders from industry, unions, state and local agencies, and environmental groups, is charged to provide input to EPA on the development of MACT regulations for oil- and coal-fired electric utility steam generators. The industry hopes that through this public forum involving all stakeholders, important and critical data on the effectiveness of various pollution controls will be shared.
control systems, as well as health effects, fate-and-transport, and other related research, will assist EPA in crafting a mercury reduction program and policies that are protective of public health, scientifically sound, flexible, and cost-effective.

REFERENCES

11. U.S. Environmental Protection Agency staff “strawman” multi-emission proposal for interagency review, August 2001; revised September 2001; December 2001; still in progress.

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