

Integrated Approaches to Managing Mercury

Issue Brief

Mercury, a naturally-occurring chemical element, may be released by both natural processes and industrial activities such as coal combustion. Mercury emitted to the atmosphere undergoes a complex process of cycling within the environment, and the different forms of mercury that are emitted move differently through the environment. A small portion that reaches waterways may be converted to an organic form more readily taken up by fish. This mercury at excess levels may pose risks to some humans who later eat the fish. Mercury atmospheric deposition in some locations should respond quickly as U.S. emissions are cut due to federal and state regulations. But complex mercury cycling processes in aquatic and terrestrial systems and the mercury already present in some fish will delay the overall response by years or even decades. Most importantly, the effectiveness of federal and state regulations in lowering mercury exposure in humans is limited by both the global origins of fish consumed in the U.S. and the growing amount of mercury emissions worldwide even as U.S. emissions decline.

Where Does Mercury in the U.S. Originate?

Mercury is a metallic element that, in pure bulk form, is liquid at room temperature. It is found in the earth's crust, often occurring in chemical combination with other elements in a wide variety of rocks and minerals, including coal. The various types of mercury found in the earth's crust can be divided into two primary forms: elemental mercury and inorganic mercury. Elemental mercury is the uncombined form, occurring as pure silvery metal in mineral bodies. The inorganic form is combined with other chemicals forming compounds. Inorganic mercury is often referred to as "oxidized," "ionic," or "divalent" mercury, all equivalent terms.

Global surveys of mercury emissions from industrial and energy-related activities show that U.S. emissions (about 130 tons per year) make up about 6% of the world total of roughly 2400 (U.S.) tons annually. Of this human-caused, or "anthropogenic," total, U.S. utility emissions (46 tons) comprise less than 2%. Additionally, measurements indicate that natural and other background emissions of mercury are at least twice as high as anthropogenic emissions.

Modeling and measurements indicate that about 170 tons of mercury deposit within the continental United States each year, via precipitation and by contact with the Earth's surface. These same studies show that about 3/4 of the mercury emitted nationally is carried outside the U.S. before reaching the Earth's surface. Thus, most of the mercury that deposits within the U.S. must originate elsewhere.

How Do U.S. Mercury Deposition Patterns Emerge?

Asia is responsible for roughly half of the 2400 tons of mercury emitted globally per year, and much of this appears to be depositing across the United States due to prevailing west-to-east winds. Recent aircraft and ground measurements show that between 650 and 750 tons per year of mercury that originates in China reaches U.S. airspace. Measurements show that some of this mercury appears to be in the divalent (inorganic) form, the form that is most readily deposited through precipitation.

In general, mercury deposition patterns and the influence of local sources vary greatly within the U.S. depending on a number of factors. Inorganic and elemental mercury are emitted in different amounts and proportions from most combustion sources of mercury. The former is much more soluble in precipitation and thus more easily

removed from the atmosphere. Even so, only about 20% of the inorganic mercury emitted from any source is likely to be deposited within 30 miles of its origin; the rest, and essentially all of the elemental form, stays aloft and travels much further before depositing, becoming more dilute as it travels. The result is that mercury deposition at any location is a complex mixture of nearby emissions, emissions from more distant U.S. sources, and emissions from other countries. The amount of mercury contributed by each of these source-types may vary greatly at any U.S. location. This complex and varied mixture of multiple sources over areas as large as the continental U.S. complicates approaches to mercury management.

How Does Mercury Accumulate in Fish?

Once mercury deposits in water bodies, more complex cycling may occur. Aquatic bacteria acting on inorganic mercury can convert it into the primary form of public health interest, monomethylmercury, usually referred to simply as “methylmercury.” This is the organic form most likely to occur in bodies of water, such as lakes and reservoirs, and is the form that is taken up by aquatic and marine organisms. The accumulation of mercury in, first, smaller and then larger fish that are eaten by humans, may result in health concerns for consumers.

Biochemical processes in fish, just as in humans, may over time “demethylate” this mercury, transforming it back to the inorganic form. The inorganic mercury will eventually be excreted from the organism or, as is the case with birds or mammals, including humans, be “shed” from the body via feather molting or hair loss. These mercury elimination rates, however, are typically slower than the continuing intake of mercury through feeding, so that levels of mercury in fish may increase over a lifetime. For that reason, older larger fish usually have the highest levels of mercury in any given waterway.

What Happens to Mercury Levels in Water Bodies if Emissions Are Reduced?

Measurements of mercury in the atmosphere since the 1980s have shown a steep decline in concentrations over that time – by up to 60%

globally – as a result of reductions in mercury use and the introduction of controls for some air pollutants that also capture some mercury. More recent measurements show a leveling off of this decline since the mid-1990s, apparently due to the larger increases in mercury emissions from Asian countries. If emissions from a U.S. mercury source such as coal-fired power plants are reduced, it is likely that atmospheric concentrations and deposition due to these plants will respond rather quickly, within days to weeks. However, declines in deposition may be undetectable at any distance from particular sources due to the compensating input of mercury from global sources. As a consequence, such control measures are unlikely to result in significant changes in levels of mercury in ocean fish, or in most U.S. freshwater fish.

How Would Mercury Levels in Fish Change as a Result of Lower Mercury Emissions?

Even though reducing mercury emissions might lead to changes in deposition within short periods of time, resulting changes in fish mercury will tend to take longer. Large predator fish ingest mercury present in smaller prey fish; also, large predator fish may mature over two decades or more. Consequently, these larger fish serve as “reservoirs” for the mercury that was deposited years or decades earlier. Each year’s newly spawned fish will grow in waters with lower inputs of mercury. Adult fish caught in future years will reflect lower mercury levels present in their waters resulting from earlier emission reductions. With emissions controls, young fish may show a drop in their mercury levels fairly quickly, depending on the nature of the lake in which they live. In some cases, a full response to any change in deposition will take many years.

What is the Public Health Concern Surrounding Mercury?

U.S. residents are exposed to mercury over a wide range of doses, essentially all of it through consumption of fish. The fish eaten may be either sportfish, caught by the consumer in small numbers, or store-bought. The fish may originate from either U.S. inland fresh waters or from the oceans worldwide, including nearby coastal waters. Most

marine fish in U.S. commerce are caught in the Pacific Ocean, particularly the equatorial South Pacific near Asia or the north Pacific near Alaska.

Since humans can slowly eliminate mercury once exposed to it, the health risk posed by the mercury in fish is determined by the amount present in the fish as well as the rate at which fish are eaten. Dose rates that exceed the body's elimination rate result in an increase in retained mercury, possibly exposing the individual to adverse health effects. Of greatest public health concern is the possible exposure of developing fetuses if their mothers consume fish with excess levels of mercury.

A recent federal study indicates that about 4% of U.S. women of childbearing age may have methylmercury levels above EPA's recommended highest mercury exposure level. This level is called the "Reference Dose." It is estimated that about 160,000 children are born each year to mothers with exposure above the Reference Dose.

How Can a Meaningful Mercury Management Program Be Designed?

Because of mercury's complex cycling, researchers and decision makers rely on computer models to determine how mercury emissions will end up in the human environment. Such computer models employ linked sets of environmental data; economic source models; atmospheric and aquatic simulations; and food chain models. The models can be used to examine how human exposure to mercury would change if particular sources were controlled.

Both the U.S. EPA and the Electric Power Research Institute have carried out large, integrated modeling studies. Each study used different models but the same overall approach to determine how mercury controls on coal-fired power plants would affect atmospheric mercury and mercury deposition across the U.S. Resulting mercury levels in waterways receiving mercury deposition were calculated together with the consequent changes in mercury levels in fish subject to human consumption.

The simulations were run for current emissions and then for future emissions resulting from federal and state regulation. The point-by-point results of each

simulation were compared to show how mercury controls would result in lowered exposure for U.S. women and their children.

Since particular air pollutant controls remove each type of mercury at different rates, the modeling also showed how the forms of emitted mercury will change in the future. This in turn impacts how deposition responds, since each form of emitted mercury deposits at a different rate. The studies showed, for example, how increased sulfur dioxide controls would improve the capture of inorganic mercury but would not capture significant amounts of elemental mercury.

How Would Mercury Deposition Change as a Result of Mercury Emission Regulations?

The Federal Clean Air Interstate Rule (CAIR) requires power plants to reduce SO₂ and NO_x emissions. Technologies for reducing these emissions also allow capture of variable amounts of mercury present in coal, principally inorganic mercury. Since inorganic mercury deposits closer to its source than the elemental form, higher near-source deposition rates will be reduced first. This mercury control "co-benefit" should lead to moderate declines in fish levels of mercury and consequent human exposure in some waters that are downwind of these sources.

New technologies are actively being developed and tested and will become commercially available for widespread application over the next several years. Among the most promising of these is activated (and chemically treated) carbon injection, where extremely fine powdered carbon captures both elemental and inorganic mercury. As cost and performance issues are resolved, these and other technologies will become more broadly applied and reduce even further both elemental and inorganic mercury emissions. Since elemental mercury is much less subject to nearby deposition than inorganic mercury, its removal from power plant emissions will have a much lower impact on mercury deposition than the capture of inorganic mercury. Most of the public health benefit—measured by the lower exposure of U.S. women—results from controls required under the CAIR, which capture inorganic mercury.

In June 2006, the EPA issued its final Clean Air Mercury Rule (CAMR), requiring a 70% reduction in the nation's coal-fired power plant emissions by 2018. Mercury emissions trading may delay this target by a couple of years. Several states may adopt stricter requirements, such as 90% cuts on a per-stack basis with no trading allowed. Modeling studies show that the 70% federal cut would lower overall U.S. mercury deposition by about 7%. Geographic variations in source proximity and emissions mixes result in deposition at some locations dropping by up to 65%. These isolated areas total less than 1/10th of 1% of U.S. land area.

Reductions of 90%, as being proposed in some states, would result in little further change in deposition compared to the 70% reduction under the CAMR. That is because most of the mercury that would still be emitted after the federally-mandated steps would be elemental mercury, very little of which deposits within the first 100 miles or so of the emission source.

How Would Exposure to Mercury Change as a Result of Mercury Controls?

These changes in deposition patterns, in turn, result in variable changes in fish levels of mercury. Fish inhabiting natural freshwater systems in the U.S. are generally located closer to U.S. power plants than ocean species that may end up in the U.S. fish diet. The drop in freshwater fish mercury levels from control of power plant mercury will therefore be greater than that in ocean fish, but wild freshwater fish species make up less than a tenth of the fish consumed by the U.S. population. Much of consumed fish is "farm-raised," using controlled feed that is virtually mercury-free. Mercury levels in marine fish are likely to drop only slightly, due to their vastly greater distances from U.S. power plants. All of these factors need to be considered together with data on recreational fishing to calculate how mercury exposure might change. Results of

these calculations to-date show that human exposure to mercury via fish consumption following implementation of the federal utility control measures would drop, on average, about 1.5%. In some states, such as West Virginia or Indiana, exposure might drop by 5 to 7%, based on location and the relative importance of sport fishing in these states.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

Media Information

Contact Clay Perry at 202.293.6184, clperry@epri.com or Heather Lynch at 650.855.2017, hlynch@epri.com.

Electric Power Research Institute

3420 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com