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EPA's Roadmap for Mercury

Executive Summary

July 2006

EXECUTIVE SUMMARY

OVERVIEW

Mercury is a naturally occurring element. It enters the environment as a result of natural sources (such as volcanoes) and human activities (such as industrial combustion and mining). Mercury is widespread in the U.S. and global environment. Human activities have increased the amount of mercury that is available in the atmosphere; in soils and sediments; and in lakes, streams, and oceans.

Significant progress has been made to date to reduce industrial emissions of mercury in the U.S., as well as to reduce or eliminate the amount of mercury used in various processes and products. Most of the large industrial sources of mercury emissions are sites where mercury is emitted as a byproduct of combustion processes. Other major sources of mercury include industrial processes and products that use mercury deliberately, such as certain chlor-alkali chlorine manufacturing processes, batteries, lamps, and measuring devices such as thermometers. Mercury is also released through mining practices, sewage discharge, and metal refining operations. When mercury is used in a product, most releases occur during manufacturing or disposal. In the U.S., there are over 100 manufacturing processes that use some form of mercury.[1]

While elemental mercury is toxic to humans when it is ingested or inhaled, EPA is most concerned about methylmercury, as it is a potent form of mercury and it is the form to which humans primarily are exposed. Methylmercury can be formed from other deposited mercury by microbial action in sediment and soils. Once formed, methylmercury can be taken up by aquatic organisms and bioaccumulates up the aquatic food web. While all forms of mercury can bioaccumulate, methylmercury generally accumulates to a greater extent than other forms of mercury.[2]

Mercury Sources

The primary sources of mercury releases to air, water, soils, and sediments can be grouped into four categories:

1. New releases from naturally-occurring sources (such as volcanic activity and weathering of rocks)

2. Re-releases of historic mercury previously deposited through natural and anthropogenic processes in soils, sediments, water bodies, landfills, and waste tailings/piles (also called "re-emitted sources")

3. New releases of mercury impurities from combustion of fossil fuels, and from smelting of metals such as gold and zinc

4. New releases resulting from uses of mercury in products and manufacturing processes such as chlor-alkali manufacturing

Exposure Pathways

In the United States, humans are exposed to methylmercury mainly by consuming fish that contain methylmercury. Aquatic ecosystems respond to changes in mercury deposition in a highly variable manner as a function of differences in their chemical, biological, and physical properties. Depending on the characteristics of a given ecosystem, methylating microbes convert a small but variable fraction of the inorganic mercury in the sediments and water derived from human activities and natural sources into methylmercury. Methylmercury is the only form of mercury that biomagnifies in the food web. Concentrations of methylmercury in fish are generally on the order of a million times the methylmercury concentration in water. In addition to mercury deposition, key factors affecting methylmercury production and accumulation in fish include the amount and forms of sulfur and carbon species present in a given water body. Thus, two adjoining water bodies receiving the same deposition can have significantly different fish mercury concentrations.[3]

While the primary pathway of human exposure to mercury is through eating fish containing methylmercury, individuals may also become exposed to harmful levels of elemental mercury vapor found indoors in work places and in homes. When exposed to air, elemental mercury vaporizes and can be inhaled. The number of individuals exposed in the U.S. in this way is very small.

Fish Consumption Advice

Fish and shellfish are an important part of a healthy diet, since they contain high quality protein and other essential nutrients, are low in saturated fat and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development. EPA and the U.S. Food and Drug Administration (FDA) have issued fish consumption advice to help consumers understand the connection between the risks of methylmercury and the benefits of fish.

Research shows that most people's fish consumption does not cause a health concern. Elevated methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, impairing the child's ability to learn and process information.[4] However, certain sub-populations are at higher risk than the general population because of their routinely high consumption of fish and shellfish (e.g., tribal and other subsistence fishers and their families who rely heavily on locally caught fish for the majority of their diet). Mercury concentrations in fish vary widely. While local freshwater fish also contain methylmer-

cury, the majority of fish species consumed in the U.S. are ocean species and the methylmercury concentrations in these species are primarily influenced by the global mercury pool. Fish that are higher in the food chain—such as king mackerel, swordfish, tilefish, and shark—have much higher methylmercury concentrations than fish that are lower in the food chain.

The major tool for reaching and educating affected populations has been through fish consumption "advisories" or warnings issued by states, tribes, and the FDA. In March 2004, EPA and FDA issued a joint federal fish advisory for mercury in fish and shellfish. The advisory provides advice for women who might become pregnant, women who are pregnant, nursing mothers, and young children (see Appendix for the entire FDA/EPA joint advisory).[5] Additional EPA outreach actions aimed at reducing risks from mercury are discussed in Chapter IV.

Continuing Research on Sources of Exposure

U.S. mercury deposition is from domestic man-made sources and from global sources, including natural, re-emitted, and international man-made sources. EPA has estimated that over three-quarters (83 percent) of the mercury deposited in the U.S. originates from international sources, with the remaining 17 percent coming from U.S. and Canadian sources.[6] These figures include mercury from natural and re-emitted sources. This estimate is based on an advanced, state-of-the-science modeling assessment of atmospheric fate, transport, and deposition of mercury. EPA's modeling indicates that a substantial variation in mercury deposition occurs across the U.S. with domestic sources influencing mercury deposition much more in the eastern U.S. and global sources being a more significant contributor to mercury deposition in the west, where relatively few domestic sources exist. The scientific community's understanding of mercury atmospheric chemistry is evolving and there remain uncertainties regarding the simulation of mercury in atmospheric chemistry models. EPA continues to work to advance the state of the science on mercury chemistry and fate and transport modeling.[7]

EPA has analyzed various scientific questions relating to the primary fish-to-human exposure route, including key scientific questions described in Chapter VI. EPA recognizes that there remain scientific uncertainties associated with some of these questions, and is committed to continuing to work to advance the science in these areas.

Reducing Exposure by Addressing Mercury Releases and Uses in the U.S. and Internationally

EPA's long-term goal is to reduce risks associated with mercury. EPA recognizes that to reduce the risks associated with mercury, the Agency must first understand what contributes to the risk and what the appropriate mechanisms of risk reduction might be. EPA will take action to identify exposed populations, minimize exposures through outreach efforts, and appropriately reduce anthropogenic releases. As part of its strategy, EPA will assess mercury sources of concern and will: focus on uses that would lead to risk, where cost-effective substitutes exist; promote reducing mercury in processes and products where benefits of such reductions would justify costs, even where cost-effective substitutes do not exist; and work to identify and encourage development of alternatives to essential uses of mercury that lead to risk. EPA will also work with its federal partners

to address risks associated with management and disposal of excess supplies of commodity-grade mercury in the U.S. In addition, EPA will support the efforts of other countries to take action to address risks associated with global mercury pollution by developing and implementing partnerships with international organizations, non-governmental organizations, and the private sector.

Six Areas of Focus in *EPA's Roadmap for Mercury*

EPA's *Roadmap* focuses on six key areas, with the overarching goal of reducing health risks associated with mercury exposure. EPA will reduce risk by:

1. Addressing mercury releases to the environment
2. Addressing mercury uses in products and processes
3. Managing commodity-grade mercury supplies
4. Communicating risks to the public
5. Addressing international mercury sources
6. Conducting mercury research and monitoring

Success in reducing risks associated with mercury exposure and mercury pollution in the domestic and global ecosystem will depend on pursuing all six of these actions simultaneously. The actions described in the *Roadmap* will be implemented over a number of years. EPA will periodically assess progress and make needed changes based on new information, successful efforts, and emerging needs. EPA will report on its progress, as well as on any major changes in direction from the current *Roadmap*.

ABOUT THIS REPORT

Over the past decade, addressing mercury risks to the environment and human health has been a focus for EPA. International, national, and local efforts to reduce mercury releases and uses have grown and are yielding impressive results. For example, overall U.S. mercury air emissions have been reduced by 45 percent since 1990,[8] and mercury use in products and processes decreased 83 percent between 1980 and 1997.[9] In 1997, U.S. man-made emissions contributed to approximately 3 percent of the global mercury pool.[10]

In 1998, EPA issued a draft *Mercury Action Plan* for public comment as part of its effort to address priority persistent and bioaccumulative toxic pollutants. The Agency received extensive comments on the 1998 draft and held subsequent meetings with states and tribes, municipalities, industry, and environmental groups, including a series of "listening sessions" in 2003. Stakeholders provided very useful input on those aspects of the mercury issue on which they believed the Agency should focus its efforts. EPA also created an agency-wide workgroup to develop a new action plan, now called *EPA's Roadmap for Mercury (Roadmap).*

Major offices at EPA are continuing to work to better understand the sources of mercury and how it impacts human health and the environment. The *Roadmap* describes the Agency's most important actions to reduce both mercury releases and human exposure to mercury. Creating the *Roadmap* has enabled the Agency to maximize coordination of its

many diverse efforts, with the goal of improving EPA's mercury program. In addition to providing a roadmap for EPA, this report provides important information about mercury to other federal agencies, to our partners in state, tribal, and local governments, and to the public.

SUMMARY OF THE ROADMAP

Human Health and Ecological Effects

Mercury exposure can cause a number of adverse effects on human health. These effects can vary depending on the form of mercury to which a person is exposed and the level and length of exposure. The primary way humans are exposed to methylmercury is through eating fish containing methylmercury. Research shows that most people's fish consumption does not cause a health concern. Methylmercury exposure can cause neurological impairment. The fetus and very young children are more sensitive to methylmercury than adults. Methylmercury in the mother's body passes to the fetus and may accumulate there. There is evidence in adults that the organic form of mercury, methylmercury, also affects other systems. Specifically, some studies suggest that prolonged exposure to methyl-mercury, especially at higher levels, can harm the heart, kidneys, and immune system. However, additional studies are needed to better categorize the effect of methylmercury on these health endpoints.[11]

In the United States, human populations most highly exposed to methylmercury are those that eat fish and shellfish containing methylmercury in excess of the recommendations contained in the joint U.S. FDA and EPA consumer advisory "What You Need to Know About Mercury in Fish and Shellfish." Fish and shellfish are an important part of a healthy diet because they contain protein and other essential nutrients. Although nearly all fish and shellfish contain traces of mercury, research shows that most people's fish consumption does not cause a health concern. However, elevated levels of methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, impairing the child's ability to learn and process information.[12] Fish that are higher in the food chain—such as king mackerel, swordfish, tilefish, and shark—have higher methylmercury concentrations than fish that are lower on the food chain. Mercury concentrations in commercial fish vary widely.[13] The majority of fish species consumed in the U.S. are ocean species and the methylmercury concentrations in these species are primarily influenced by the global mercury pool.[14]

While the primary pathway of human exposure to mercury is through eating fish containing methylmercury, individuals may also become exposed to harmful levels of elemental mercury vapor found indoors in workplaces and in homes. When exposed to air, elemental mercury vaporizes and can be inhaled. The number of individuals exposed in the U.S. in this way is very small.

Fish-eating birds and mammals and their predators are at risk for greater exposure to mercury than other animals. Methylmercury has been found in eagles, otters, and endangered Florida panthers.[15] Depending on the level of exposure, effects of methylmercury exposure on wildlife can include mortality, reduced fertility, slower growth, and abnormal behavior that affects survival.[16] Fish development and reproduction may also be altered by the levels of methylmercury found in water ecosystems.

I. Addressing Mercury Releases

Air

Addressing mercury releases to the air is important because mercury in the air can be deposited to water, converted to methylmercury, and taken up by fish. The U.S. has made significant progress in the reduction of industrial emissions of mercury to the air. In the last 15 years, EPA has focused most of its mercury reduction efforts on large point sources of air emissions, such as municipal waste combustors, medical waste incinerators, hazardous waste combustors, and more recently, industrial boilers and chlor-alkali facilities. With the March 2005 completion of final regulations for coal-fired power plants, the Agency now has Clean Air Act (CAA) standards in place limiting mercury air releases from most major known industrial sources in the U.S.

In addition to implementing these standards, the Agency, under the CAA Area Source program, is in the process of addressing certain smaller point sources that emit mercury.[17] Under the CAA Residual Risk program,[18] the Agency is evaluating the remaining risks, if any, from sources for which EPA has previously issued emissions standards under CAA §112(d). Mercury is one of several hazardous air pollutants that EPA will be investigating under these programs.

Water

The majority of mercury in U.S. waters, particularly in the eastern U.S., results from air deposition from a variety of sources including man-made, natural re-emitted legacy mercury, and global deposition.[19] States, tribes, and EPA's air and water programs are working together to address mercury air deposition issues that affect water quality and mercury concentrations in fish. EPA has strengthened its modeling tools to better identify sources of mercury deposition; relate changes in air deposition to mercury concentrations in fish; and ultimately determine the best mercury reduction strategies. EPA will continue to further characterize mercury discharges to water and will issue guidance on implementation of its methylmercury water quality criterion. EPA will work with its partners to develop tools and approaches for identifying mercury impairments and developing mercury total maximum daily loads (TMDLs) in water bodies.

Mercury can also be released directly to water from wastewater treatment plants, industrial facilities, and from current and historic mining activities (particularly in the western U.S.). The Association of Metropolitan Sewerage Agencies (AMSA, now known as the National Association of Clean Water Agencies) estimated that about 36 percent of mercury entering publicly owned treatment works is discharged from dental offices due to mercury in waste dental amalgam. Mercury discharges from dental offices far exceeded all other commercial and residential sources, each of which was below 10 percent.[20] EPA regions and states are working with dental offices to encourage collection of dental amalgam before it enters the waste stream. In addition, wastewater treatment plants are beginning to implement best management practices for collecting mercury from other industrial sources. EPA is providing guidance to wastewater treatment plants on how to characterize sources of mercury to the collection system and how to develop mercury minimization measures where appropriate. Mercury in the wastewater collection systems may come from the medical sector, dental offices, schools, and certain industries. EPA and the states also

are modifying surface water discharge permits to incorporate more stringent requirements in mercury discharges, where appropriate.

Land

Mining is the largest source of mercury releases directly to the land in the U.S.[21] Mining releases occur as a result of existing mining operations for gold, zinc, and silver; the smelting of zinc and other metals and runoff from waste tailings; and from abandoned gold, silver, and mercury mines. The Toxics Release Inventory (TRI) reporting indicates these types of releases to land are large in scope and appear to be increasing. Of the 5.14 million pounds of mercury released to land, 1.4 million pounds is placed in surface impoundments and 3.7 million pounds is placed directly on the land in waste piles. Less than 1,000 pounds goes to landfills.[22] Most of these releases are not generally considered as environmentally harmful as releases to air, however, because the mercury may be less mobile and less likely to reach surface waters and fish.

However, in certain areas of the western U.S., mining runoff/erosion to sediments can be the primary source of mercury in fish in local waters. The 2004 TRI data indicate increases in reported releases from mining.[23] For more details on the TRI, see Section I, Addressing Mercury Releases. As a result, EPA is placing a higher priority on efforts to understand the risk associated with mercury releases to land from mining and take appropriate action.

II. Addressing Mercury Uses in Products and Processes

Addressing uses of mercury in products and industrial processes is a component of preventing human exposure from mercury releases to air, water, and land. Historically, the largest U.S. uses of mercury were in batteries, chlor-alkali manufacturing, and paint.[24] Mercury use has now been eliminated in most batteries and in paint. Today in the U.S. the largest industrial use of mercury continues to be in chlor-alkali manufacturing, while the dominant uses in products are in electrical and measuring devices.[25]

Many states, tribes, and local governments have been leaders in reducing mercury use. States have passed legislation calling for restrictions, bans, and labeling of mercury-containing products, as well as the removal and collection of mercury containing devices from the waste stream. States and local governments continue to initiate their own use reduction and collection programs from schools, hospitals, and laboratories to encourage the proper disposal and recycling of mercury.

EPA's long-term goal is to reduce risks associated with mercury. EPA recognizes that to reduce the risk associated with mercury, the Agency must first understand what contributes to the risk and what the appropriate mechanisms of risk reduction might be. EPA will take action to identify exposed populations, minimize exposures through outreach efforts, and appropriately reduce anthropogenic releases. As part of its strategy, EPA will assess mercury sources of concern and will: focus on uses that would lead to risk, where cost-effective substitutes exist; promote reducing mercury in processes and products where benefits of such reductions would justify the costs, even where cost-effective substitutes do not exist; and work to identify and encourage development of alternatives to essential uses of mercury that lead to risk. EPA will also work with its federal partners to address risks associated with

management and disposal of excess supplies of commodity-grade mercury in the U.S.

EPA will explore both regulatory and voluntary programs looking at substitutes for mercury in products. The Agency will promote the procurement of non-mercury products by federal agencies. EPA is building a national database of information on mercury use in products. EPA will continue its successful voluntary partnerships, such as the Hospitals for a Healthy Environment program—its project with the health care industry to eliminate the use and purchase of mercury-containing medical devices and instruments.[26] The Agency also will continue to work with the U.S. Chlorine Institute to monitor mercury use in the remaining mercury-cell chlor-alkali plants in the U.S.

III. Managing Commodity-Grade Mercury Supplies

Elemental mercury is used in many products and processes, and is sold as a commodity on the global market. In recent years, approximately one-half of the current world mercury supply has come from mercury mines in Spain, Algeria, and Kyrgyzstan. (The Spanish mine has recently ceased mining operations.) The other half comes from the recycling of mercury from discarded mercury-containing products and other wastes, mercury recovered as a byproduct from mining of gold and other metals, and mercury supplies from the closure of mercury-cell chlor-alkali plants.[27]

As industry finds alternatives to uses of mercury, and as mercury-cell chlor-alkali plants phase out the use of mercury in their processes, EPA expects that there will be an excess supply of elemental commodity-grade mercury on the global market in the near future. As a result, there will be an increasing need for safe storage of excess mercury supplies.

Many states and local governments are now encouraging public and private collection programs for both bulk elemental mercury and discarded mercury-containing products. The Environmental Council of the States (ECOS) has indicated that states do not have the resources or desire to store surplus mercury, and are looking to the federal government to address this issue.[28]

The issue of whether the federal government, states, or the private sector should take responsibility for storing commodity-grade mercury supplies is an important and complex policy decision. In 2006, EPA will work with other federal agencies to initiate a process with technical experts and interested parties to discuss options for addressing the expected mercury surplus. EPA continues to evaluate options for disposal of mercury supplies, and published a report in April 2005 on the technical and economic feasibility of selected land disposal technologies in a monofill.[29]

IV. Communicating to the Public About Mercury Exposure Risks

The Agency will increase its risk communication and outreach activities to help people avoid or reduce their exposure to mercury. In the U.S., the greatest mercury exposure to the general population is from eating fish and shellfish containing high levels of methylmercury. Fetuses, nursing infants, and young children are at greatest risk because of their developing nervous systems. The primary tool for reaching and educating affected populations has been through fish consumption advisories issued by states and tribes. In addition, in 2004, EPA and

FDA issued a joint fish consumption advisory for mercury that helps consumers understand the benefits of fish consumption, the risks of consumption to certain sub-populations, and mercury levels in certain fish.[30]

Many consumers are not aware of potential indoor mercury risks in schools, homes, and the workplace. Misuse or accidental breakage of some products can create indoor air health risks and exposure to dangerous levels of mercury.

The Agency will make it a priority to provide consumers with reliable risk information about mercury exposure so that they can make informed choices about the fish they eat and the products they use. EPA's most recent effort has been the January 2005 launching of its consolidated website on mercury.[31] The Agency will develop informational materials; support and build upon existing state, tribal, and local outreach campaigns; and maintain its centralized mercury website with helpful information on all aspects of mercury. EPA will also conduct public awareness evaluations of the effectiveness of existing outreach campaigns.

V. International Mercury Sources

EPA has estimated that over three-quarters (83 percent) of the mercury deposited in the U.S. originates from international sources, with the remaining 17 percent coming from U.S. and Canadian sources. These figures include mercury from natural and re-emitted sources. This estimate is based on an advanced, state-of-the-science modeling assessment of atmospheric fate, transport, and deposition of mercury. EPA's air quality modeling indicates that a substantial variation in mercury deposition occurs across the U.S., with domestic sources influencing mercury deposition much more in the eastern U.S. and global sources being a more significant contributor to mercury deposition in the west, where relatively few domestic sources exist.[32] The scientific community's understanding of mercury atmospheric chemistry is evolving and there remain uncertainties regarding the simulation of mercury in atmospheric chemistry models. EPA continues to work to advance the state of the science on mercury chemistry and fate and transport modeling. A number of key international emission sources contribute to global cycling and deposition of mercury via air pathways, including: coal-fired combustion sources; mining and metals production, such as smelting; mercury-cell chlor-alkali manufacturing facilities; and combustion or incineration of waste products containing mercury.[33]

EPA is currently participating in a wide range of bilateral, regional, and international programs and agreements to address mercury releases and uses and the resulting exposure around the globe. At the twenty-third session of the UNEP Governing Council, which was held in Nairobi, Kenya, February 21–25, 2005, delegates agreed to further develop the UNEP Mercury Program and to support the efforts of countries to take action to address global mercury pollution. Governments agreed to develop and implement partnerships with international organizations, non-governmental organizations, and the private sector to reduce the risks that result from the release of mercury to the environment. The partnerships created will leverage resources, technical expertise, technology transfer, and information exchanges to provide immediate, effective action that will result in tangible reductions of mercury use and emissions.[34]

EPA is building on existing bilateral, multilateral, and international agreements. In addition, EPA will build collaborative partnerships under UNEP with industries and environmental groups to bring technical expertise and assistance to address the global mercury problem. EPA plans to work with its international partners to reduce risks associated with mercury emissions from large point sources such as coal-fired power plants, chlor-alkali facilities, and artisanal gold mining; to reduce mercury use in products internationally (including mercury-containing batteries) where there are cost-effective opportunities to reduce risk; to increase risk communication; to address the issue of commodity-grade mercury on the international market; and to research global fate and transport of mercury.

VI. Conducting Mercury Research and Monitoring

In 2000, EPA's Office of Research and Development (ORD) published its *Mercury Research Strategy*,[35] which outlined a strategic approach for the Agency's mercury research program. The purpose of the Agency's mercury research is to develop information that will reduce scientific uncertainties currently limiting the Agency's ability to assess and manage risks posed by mercury and methylmercury.

Research results support EPA's air, water, waste, and toxics programs in their ongoing regulatory and non-regulatory efforts to address mercury. ORD will continue to pursue its long-term goals to reduce health risks associated with mercury and to better understand the transport and fate of mercury in the environment. The major near-term emphasis of the mercury research program will continue to be focused on science and technology related to the control of coal-fired power plant mercury emissions.

To access this document electronically and to monitor the status of *Roadmap* activities visit www.epa.gov/mercury.

In addition to research, scientifically sound mercury monitoring programs are essential for assessing the effectiveness of current regulatory and voluntary programs and for tracking health and environmental trends. Much progress has been made in recent years by EPA and others to establish routine monitoring and reporting systems to collect data on mercury releases and contamination. EPA is continuing to track and report data on mercury in four areas: air emissions, ambient air, air deposition, and fish tissue. The Agency will utilize the Centers for Disease Control and Prevention (CDC) data on mercury in human blood and hair samples. EPA will also continue to work with others to monitor other mercury releases and ambient concentrations. The Agency plans to use various existing databases for tracking overall progress in reducing mercury exposure. In addition, EPA will continue to seek improvement in monitoring methods and databases for mercury.

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   Due to the evolving nature of mercury modeling science, such deposition estimates have associated uncertainties. For example, it remains difficult to distinguish between the natural emissions of mercury and the re-emission of previously deposited anthropogenic mercury and there remains uncertainty in the scientific community concerning the atmospheric processes that control the oxidation state of atmospheric mercury. Thus, further advances in the current understanding of mercury chemistry could potentially lead to changes in the modeling parameters and assumptions governing the mercury chemistry in the models and therefore, changes in the estimate of the fraction deposited in the U.S. attributable to global sources.

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