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EPA's Roadmap for Mercury

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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.

ENDNOTES

1. EPA, 1999a. 1999 National Emissions Inventory Documentation and Data—Final Version 3.0. Accessible at: www.epa.gov/ttn/chief/net/1999inventory.html.

2. EPA, 2005c. U.S. Environmental Protection Agency. National Listing of Fish Advisories. Fact Sheet, Sep. 2005. EPA-823-F-05-004. Accessible at: http://epa.gov/waterscience/fish/advisories/fs2004.pdf.

3. RIA, Regulatory Impact Analysis, Clean Air Mercury Rule. EPA, 2005. Accessible at: http://epa.gov/ttn/atw/utility/TSC-112final.pdf.

4. NRC, 2000. National Research Council. Toxicological Effects of Methylmercury. Committee on The Toxicological Effects of Methyl-mercury, Board on Environmental Studies and Toxicology. Accessible at: http://books.nap.edu/books/0309071402/html/1.html.

5. EPA and FDA, 2004. What You Need to Know About Mercury in Fish and Shellfish. EPA-823-F-04-009. Accessible at: www.epa.gov/waterscience/fishadvice/advice.html.

6. EPA, 2005a. Technical Support Document, Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants From Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the §112(c) List: Reconsideration, Oct. 21, 2005. Accessible at: www.epa.gov/ttn/atw/utility/TSC-112finaL.pdf.

7. A Community Multiscale Air Quality (CMAQ) modeling run was performed to estimate the impact of global sources on U.S. deposition estimates. For this analysis, all non-U.S. mercury input species to the model were set to zero. By comparing the results of this analysis with the 2001 Clean Air Mercury Rule (CAMR) base case run, which included all U.S. and global mercury species, the percent of total mercury deposition attributable to global sources can be estimated. The model estimated that over 80 percent of total mercury deposition in the U.S. is attributable to global sources.

   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.

8. EPA, 1999a. U.S. Environmental Protection Agency. 1999 National Emissions Inventory Documentation and Data—Final Version 3.0. Accessible at: www.epa.gov/ttn/chief/net/1999inventory.html.

9. Jasinski, S.M. 1994. The Materials Flow of Mercury in the United States. U.S. Bureau of Mines, Information Circular 9412. Accessible at: http://pubs.usgs.gov/usbmic/ic-9412/.

10. EPA, 1999a, and UNEP 2002. United Nations Environment Programme. Global Mercury Assessment. Accessible at: www.chem.unep.ch/mercury/report/GMA-report-TOC.htm.

11. CDC, 2005. Centers for Disease Control. Mercury, pp. 45-51 in Third National Report on Human Exposure to Environmental Chemicals. Accessible at: www.cdc.gov/exposurereport/3rd/downloads.htm.

12. NRC, 2000. National Research Council. Toxicological Effects of Methylmercury. Committee on The Toxicological Effects of Methyl-mercury, Board on Environmental Studies and Toxicology. Accessible at: http://books.nap.edu/books/0309071402/html/1.html.

    EPA, 2001a. Reference Dose for Chronic Oral Exposure (RfD)—Methylmercury, last revised 7/21/01. Integrated Risk Information System (IRIS). Accessible at: www.epa.gov/iris/subst/0073.htm#reforal.

13. FDA. U.S. Food and Drug Administration. Mercury in Fish: FDA Monitoring Program. For information, see: www.cfsan.fda.gov/~frf/seamehg2.html.

14. EPA, 2005a. Technical Support Document, Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants From Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the §112(c) List: Reconsideration, Oct. 21, 2005. Accessible at: www.epa.gov/ttn/atw/utility/TSC-112final.pdf.

15. EPA, 1997. Mercury Study Report to Congress. EPA-452/R-97-003, December 1997. Accessible at: www.epa.gov/ttn/oarpg/t3/reports/volume1/pdf.

16. EPA, 1998. Study of hazardous air pollutant emissions from electric utility steam generating units—Final Report to Congress. EPA-453/R-98-004a&b, February 1998.

17. EPA. Area Source Standards. For information, see: www.epa.gov/ttn/atw/urban/arearules.html.

18. EPA. Residual Risk Program. For information, see: www.epa.gov/ttn/atw/rrisk/residriskpg.html.

19. EPA, 1997.

20. LWA, 2002. Larry Walker Associates. Mercury Source Control and Pollution Prevention Evaluation, Final Report, March 2002, amended July 2002. Prepared for: Association of Metropolitan Sewerage Agencies. Accessible at: www.amsa-cleanwater.org/advocacy/mercgrant/finalreport.pdf.

21. EPA, 2005b. 2003 Toxics Release Inventory (TRI) Public Data Release eReport, May 2005. Accessible at: www.epa.gov/tri/tridata/tri03/2003eReport.pdf.

22. EPA, 2005b.

23. EPA, 2005b.

24. Jasinski, S.M., 1994. The Materials Flow of Mercury in the United States. U.S. Bureau of Mines, Information Circular 9412. Accessible at: http://pubs.usgs.gov/usbmic/ic-9412/.

25. Lawrence, Bruce, 2001. Bethlehem Apparatus Company, Inc. Personal communication, June 22, 2001.

26. H2E. Hospitals for a Healthy Environment. For information, see: www.h2e-online.org/.

27. Maxson, P.A., 2004. Mercury Flows Report: Mercury Flows in Europe and the World, The Impact of Decommissioned Chlor-alkali Plants. European Commission. Accessible at: http://europa.eu.int/comm/environment/chemicals/mercury/pdf/report.pdf.

28. Quicksilver Caucus, 2003. Mercury Stewardship Storage of Mercury, Review Draft, February, 2003. Accessible at: www.sso.org/ecos/Quick%20silver%20documents/RD%20QSC-STOR%20Mar-03.pdf.

29. EPA, 2005f. Economic and Environmental Analysis of Technologies to Treat Mercury and Dispose in a Waste Containment Facility. See: www.epa.gov/ORD/NRMRL/pubs/600r05157/600r05157.pdf.

30. EPA and FDA, 2004. What You Need to Know About Mercury in Fish and Shellfish. EPA-823-F-04-009. Accessible at: www.epa.gov/waterscience/fishadvice/advice.html.

31. EPA. Mercury Web site. For information, see: www.epa.gov/mercury/.

32. EPA, 2005a.

33. UNEP, 2002. United Nations Environment Programme. Global Mercury Assessment. Accessible at: www.chem.unep.ch/mercury/Report/GMA-report-TOC.htm.

34. UNEP, 2005. Results of the Governing Council's discussions on chemicals management, including mercury programme, at its 23rd session in February, 2005. Accessible at: www.chem.unep.ch/mercury/GC23-results.htm.

35. EPA, 2000. Mercury Research Strategy. EPA-600-R-00-073. Accessible at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20853.

EPA'S ROADMAP FOR MERCURY: Introduction

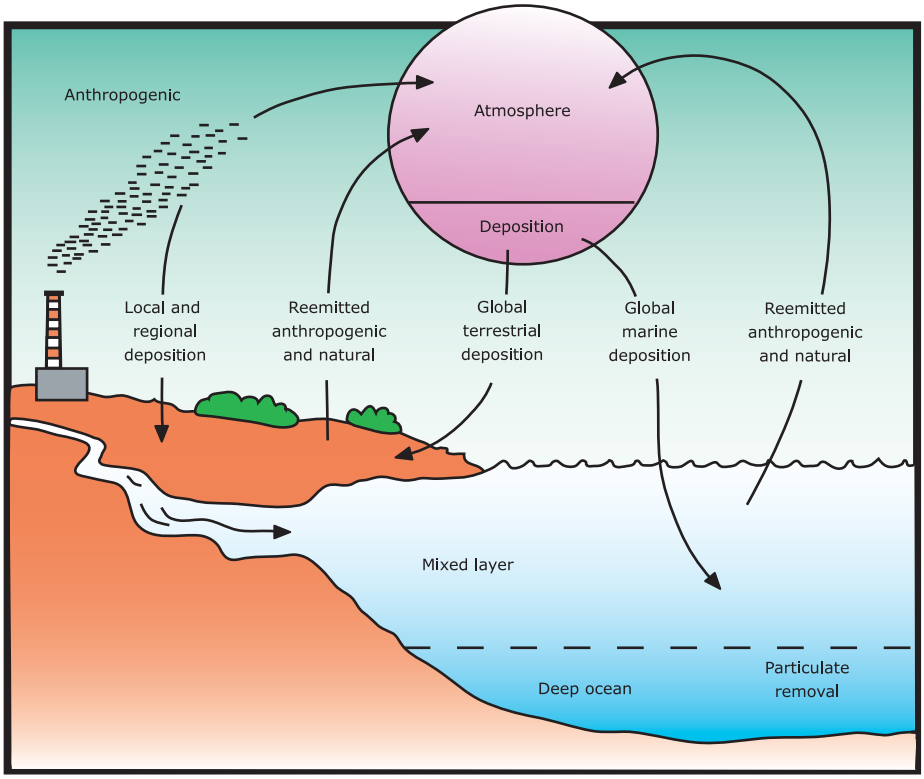
Mercury is a naturally occurring element. It enters the environment as a result of natural sources (such as volcanoes) and human activities (such as industrial combustion and mining). Mercury is widespread in the U.S. and global environment. Human activities have increased the amount of mercury that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

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.

Methylmercury accumulates in fish tissue, which may then be consumed by people and wildlife. Mercury concentrations in fish vary widely. 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 on the food chain. 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.

Local freshwater fish also contain methylmercury. States monitor their waters by sampling fish tissue for persistent pollutants that bioaccumulate. States issue their advisories and guidelines voluntarily and have flexibility in what criteria they use and how the data are collected. As a result, there are significant variations in the number of waters tested, the pollutants tested for, and the threshold for issuing advisories.Based on self-reporting, the national trend is for states to monitor different waters each year, generally without retesting waters monitored in

FIGURE 1. The Mercury Cycle[4]



previous years.[1] Forty-four states, one territory, and two Indian tribes have issued fish consumption advisories recommending that some people limit their consumption of fish from certain water bodies as a result of methylmercury found in fish.[2] Human-caused mercury emissions have dropped 45 percent in this country since 1990.[3] EPA has not monitored natural mercury emissions in this country, which may also have changed over the same period.

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

Human Health Effects

Mercury exposure 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. However, 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. There is some evidence that exposures to methylmercury may result in genotoxic or immunotoxic effects. Other research suggests that reproductive, renal, cardiovascular, and hematologic impacts may be of concern. However, additional studies are needed to better characterize the effect of methylmercury on these endpoints.[5]

While the primary way humans are exposed to methylmercury is through eating fish containing methylmercury, individuals may also become exposed to harmful levels of elemental mercury vapor in homes and workplaces. When exposed to air, elemental mercury vaporizes and can be inhaled. Exposures from improper handling of mercury in schools, laboratories, and manufacturing plants; from accidental mercury spills; or in cultural and ritualistic uses can result in severe effects. Very small amounts of elemental mercury (even a few drops) can raise indoor air concentrations of mercury to harmful levels. The longer people breathe the contaminated air, the greater the risk to their health. At high exposures elemental mercury vapors can produce severe lung, gastrointestinal, and nervous system damage. The number of individuals exposed in this way in the U.S. is very small.

Ecological Effects

Birds and mammals that eat fish and their predators are at risk for greater exposure to methylmercury than other animals. Methylmercury has been found in eagles, otters, and endangered Florida panthers. The 1997 *Mercury Study Report to Congress* provides some data that suggest some highly-exposed wildlife species are affected by methylmercury.[6] Depending on the level of exposure, effects of methylmercury exposure on wildlife can include mortality, reduced fertility, slower growth and development, and abnormal behavior that affects survival.[7]

Reducing mercury releases to the air is important because airborne mercury can travel short and long distances; be deposited on land and water resources locally, nationally, regionally, and globally; and lead to elevated methylmercury levels in fish. EPA estimates that since the beginning of the industrialized period, total global atmospheric mercury burden has increased by a factor of between two and five.[8] Figure 1 illustrates the physical cycle of airborne mercury from natural and anthropogenic sources as it is deposited to land and water and re-released.

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.[9] These figures include mercury from natural and re-emitted sources. This estimate is based on an advanced, state-of-the-science modeling assessment of atmos-pheric fate, transport, and deposition of mercury. Air emissions of mercury from combustion and industrial processes are the largest contributor to U.S. emissions. 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. 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.[10]

Reducing Mercury Exposure

To further reduce risks associated with mercury, EPA's priority activities focus on six key areas:

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

EPA will continue to pursue regulatory and voluntary actions that will reduce risks associated with mercury. 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 the cost, 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. As we work on these short and long-term plans, EPA will continue to work with federal partners to continue to educate the public about the risks of exposure from dietary and non-dietary sources.

State, Tribal, Local, and International Government Collaboration with EPA

In order to achieve reductions risks from mercury exposure, EPA will continue to collaborate with its state, tribal, and local government partners. As co-regulators with EPA, states have been actively engaged in a range of programs and partnerships to reduce mercury uses, releases, and exposure and to conduct mercury monitoring activities. In many cases, states and local governments have been leaders in mercury reduction efforts. EPA will build on these efforts and, where appropriate,

help state and local governments replicate successful efforts.

In May of 2001, a coalition of state government environmental association leaders formed the Quick-silver Caucus (QSC) in order to provide a forum for states to work together, and with EPA, to develop collaborative holistic approaches for reducing mercury in the environment. In addition, the Environmental Council of the States (ECOS), an association of state environmental agency leaders, has passed a number of resolutions over the past several years that address mercury issues, many of which are also addressed in the *Roadmap*. EPA and states are continuing to work together on mercury issues under a cooperative agreement with ECOS.

EPA is also working with tribes to develop new activities that will help the Agency make progress toward attainment of EPA's long-term goals of "fishable waters" and "edible fish." Tribal community members who follow traditional diets and lifestyles may face greater risk from locally-caught fish than do members of the general population due to the prevalence of locally-caught fish and shellfish in their diets. EPA will work with tribes to improve the quality of water and sediments in order to improve fish tissue concentrations in tribal waters.

EPA will also continue to collaborate with other federal agencies involved in domestic and international mercury issues, including the U.S. Food and Drug Administration; the Centers for Disease Control and Prevention; and the Departments of Energy, Defense, and State.

In addition, partnering with the international community is of great importance to furthering global mercury reductions. The majority of fish species consumed in the U.S. are ocean species and the methylmercury concentrations in these species are primarily influenced by global mercury contributions.[11] Also, even domestic freshwater and estuarine fish in many parts of the U.S. may contain methylmercury as a result of contributions from international sources in addition to domestic sources.

I. ADDRESSING MERCURY RELEASES

OVERVIEW

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]

In the last 15 years, EPA 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 EPA final regulations for coal-fired power plants, the Agency now has standards in place limiting mercury air releases from most major known industrial sources in the U.S.

In the next 10 years, in addition to implementing the regulatory standards in place, the Agency's efforts to reduce mercury pollution will focus on three areas in particular: smaller sources and industrial uses that collectively contributed over 20 percent of the nation's mercury air releases in 1999;[2] understanding and addressing mining releases that in some areas of the western U.S. are the major sources of mercury pollution to water and land; and international emissions which continue to

contribute to the mercury deposited in the U.S. EPA's strategy for addressing these three areas will include, where applicable, a combination of regulatory and voluntary approaches to reduce mercury releases to air, land, and water, coupled with efforts to address the use of mercury in products and processes. As the U.S. continues to address domestic mercury use and releases, it will also promote international efforts to address mercury use and emissions abroad as discussed further in Section V on international mercury efforts. (Note: The *Roadmap* generally uses metric tons when discussing global mercury use and emissions. However, U.S. air emissions are reported in English tons. One English ton is equivalent to 0.9070 metric tons.)

TABLE 1. National Air Emissions Estimates for Mercury[3]

Source Category	1990 (tons)	1999 (tons)[f]	% reduction
Utility Coal Boilers[b]	51.1	47.9[a]	6%
Industrial Boilers[b]	12.0	12.0	0%
Medical Waste Incinerators	49.7	1.6	97%
Municipal Waste Combustion	56.7	4.9	91%
Hazardous Waste Incinerators[b]	6.6	6.6	0%
Chlorine Production	10.0	6.5	30%
Electric Arc Furnaces[c]	6.9	NA	NA
Gold Mining	3.4[d]	11.5	NA
Other[e]	23.5	21.6	6%
Total	219.9	112.6	45%

[a] *1990 estimate derived using a different methodology.*
[b] *Regulations for these categories finalized after 1999.*
[c] *Electric Arc Furnaces data not available for 1999. The 2002 estimate is 10 tons per year.*
[d] *The 1990 emissions estimate is a preliminary estimate and is based on back calculations and assumptions using data from 1999 along with information about types of processes, production rates, and ores used in 1990 compared to 1999.*
[e] *Other includes, but is not limited to such items as, Portland cement production –2.36 tons per year (tpy), pulp and paper production–1.69 tpy, and over 219 miscellaneous industrial processes.*
[f] *1 ton equals 0.9070 metric ton.*

Releases to Air

Sources. When the 1990 Clean Air Act Amendments passed, more than half of U.S. mercury air emissions came from just three source categories: coal-fired power plants, municipal solid waste combustors, and medical waste incinerators. The major air emissions source categories are shown in Table 1.

Progress to date. EPA's Clean Air Rules. Medical waste incinerators and municipal solid waste combustors are now subject to stringent control standards that require facilities to reduce mercury emissions by over 90 percent from 1990 levels. These efforts have contributed to reducing overall mercury emissions to the air by about 45 percent (from 220 tons in 1990 to 113 tons in 1999—see Figure 2).

EPA's recently promulgated Clean Air Mercury Rule (CAMR) is part of a suite of regulatory actions that will dramatically improve America's air quality. CAMR directly regulates mercury emissions from coal-fired

power plants. Among other things, CAMR requires compliance with a two-phase nationwide cap on mercury emissions. The first phase cap (effective in 2010) is 38 tons per year ("tpy"), and the second phase cap (effective in 2018) is 15 tpy. Once fully implemented, CAMR will result in about a 70 percent reduction in mercury emissions from domestic coal-fired power plants, which is a reduction from a 1999 baseline of 48 tons.[4]

In addition to CAMR, the Agency recently issued another rule called the Clean Air Interstate Rule (CAIR) that addresses the transport of pollution across state borders in the eastern U.S. CAIR will result in the deepest cuts in sulfur dioxide and nitrogen oxide emissions in more than a decade. Although affected States retain flexibility to decide how to achieve the sulfur dioxide and nitrogen oxide emissions reductions required by CAIR, EPA has concluded that obtaining the reductions from power plants is highly cost-effective. EPA therefore anticipates that affected States will meet their emission reduction obligations by controlling power plant emissions through the two-phase cap-and-trade approach provided in the final CAIR, the first phase of which occurs in 2010 and the second in 2015. EPA also concluded that the technologies that most cost-effectively achieve sulfur dioxide and nitrogen oxide emission reductions for power plants are scrubbers for sulfur dioxide and selective catalytic reduction for nitrogen oxide. These technologies, once implemented, not only reduce sulfur dioxide and nitrogen oxide, they provide important reductions of mercury emissions from coal-fired power plants. Thus, CAIR and CAMR work together and provide a flexible multi-pollutant approach for reducing sulfur dioxide, nitrogen oxide, and mercury emissions from power plants. From a legislative perspective, the President's proposed Clear Skies legislation, if enacted, would require a mandatory 70 percent annual cut in power plant pollution (NOx, SOx and mercury) when fully implemented.[5]

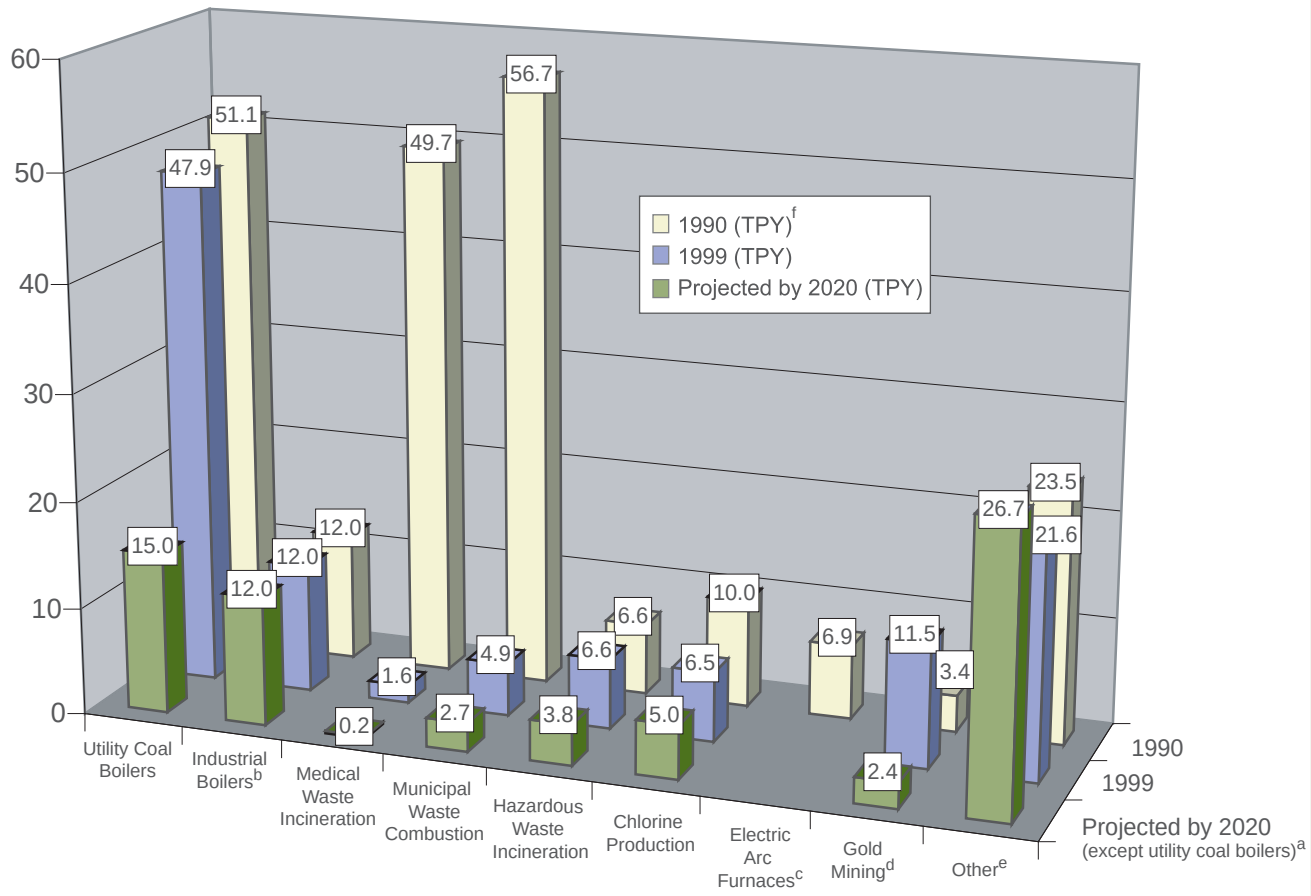
What is EPA's National Emissions Inventory (NEI)?

Section 112 of the 1990 amendments to the Clean Air Act (CAA) presents a list of Hazardous Air Pollutants (HAPs), also called air toxics, which includes mercury and mercury compounds. In 1993, EPA began developing the National Toxics Inventory (NTI). This database has been expanded and is now called the National Emissions Inventory (NEI). The NEI is a national repository of emissions inventory data for HAPs. The emissions data and estimates cover major, area, and mobile sources, and include estimates of emissions at the national, regional, county, and facility-specific levels.

The 1999 NEI generally serves as the national baseline inventory for this Roadmap because it includes HAP emission data supplied by 36 states in addition to data gathered while developing Maximum Achievable Control Technology (MACT) standards and Toxics Release Inventory (TRI) data. More information on the NEI, including summary data and documentation, can be obtained at http://www.epa.gov/ttn/chief/index.html.

In addition, §112 (f) of the Clean Air Act (CAA) required EPA to complete a Report to Congress that includes a discussion of methods EPA would use to evaluate the risk remaining after the application of Maximum Achievable Control Technology (MACT) standards. These are known as residual risks. EPA published the Residual Risk Report to Congress in March 1999.[6] The Agency continues to evaluate the remaining residual risks, if any, for a

FIGURE 2. Air Emissions Data for Mercury



[a]*Fifteen tons per year will be acheived when full implementation of the Clean Air Mercury Rule is achieved, which may exceed 2020.*
[b]*Growth in this sector is being offset by regulation.*
[c]*Electric Arc Furnaces data not available for 1999. The 2002 estimate is 10 tons per year.*
[d]*The 1990 emissions estimate is a preliminary estimate and is based on back calculations and assumptions using data from 1999 along with information about types of processes, production rates, and ores used in 1990 compared to 1999.*
[e]*These projected emissions do not account for reductions from non-regulatory actions described elsewhere in the Roadmap.*
[f]*1 ton equals 0.9070 metric ton*

number of source categories for which EPA has issued MACT standards. In the context of that review, EPA will evaluate the hazardous air pollutants (HAPs) emitted by each source category, including mercury.

Regional initiatives have also resulted in substantial reductions in air emissions of mercury. For example, EPA's Region 9 office and the State of Nevada entered into an innovative collaboration with four of the largest gold mining companies in Nevada to reduce mercury emissions associated with gold mining.[7] The Voluntary Mercury Emission Reduction Program set a goal to reduce mercury emissions by 50 percent by 2005, and has already surpassed this goal. In 2004, the program participants reported a 75

percent reduction from the baseline year. This is a reduction of 15,702 pounds of mercury from the baseline emissions of 21,098 pounds.[8]

Future focus. The Integrated Urban Air Toxics Strategy, which was published in the Federal Register in 1999[9], is an important element in EPA's national air toxics program. The strategy outlines actions to reduce emissions of air toxics, as well as assessment activities to improve EPA's understanding of the health and environmental risks posed by air toxics in urban areas. One major component of the Urban Air Toxics Strategy is the Area Source Program.[10] Area sources are smaller sources that can cumulatively emit significant amounts of hazardous air pollutants.

The 1999 Strategy identifies 33 hazardous air pollutants, including mercury, that EPA determined posed the greatest threat to public health in the largest number of urban areas. The Strategy further identifies 30 of those 33 HAP as being emitted by area sources. Finally, the Strategy identifies the 70 categories of industry sectors (i.e., source categories) that represent 90 percent of the aggregate emissions of the 30 identified HAP emitted by area sources. To date, EPA has issued standards for 16 of the 70 source categories and is currently collecting data and information for many other source categories.

Electric Arc Furnaces (EAFs)—one of the area source categories that the Agency is currently evaluating—emitted about 10 tons of mercury in 2002.[11] In EAFs, mercury is emitted through the stack when ferrous scrap containing mercury switches and other materials contaminated with mercury are melted. Many of these mercury-containing switches are found in scrap automobiles—over 200 million of these switches were installed in vehicles from 1974 to 2002. Although mercury switches were eliminated from new vehicles at the end of 2002, mercury switches will remain in the steel scrap supply for the next 10 to 15 years. The steel industry recycles about 12 to 14 million end-of-life vehicles each year, and vehicles retired in 2003 had 8.5 million mercury-containing switches.[12] The EPA air toxics program has identified EAFs as a priority sector and currently intends to propose emissions standards for that source category in 2006.

Releases to Water

Sources. The majority of mercury in surface waters from human activity in the U.S. is the result of air deposition, both from international and domestic sources. Mercury in surface waters can also occur naturally. Mercury can be released directly to surface waters from municipal sewage treatment plants, also called Publicly-Owned Treatment Works (POTWs), and non-municipal facilities (e.g., industrial and federal facilities). Point source discharges of pollutants to surface waters are required to have National Pollutant Discharge Elimination System (NPDES) permits.[13] On a national basis, these mercury discharges to surface waters are significantly smaller than nationwide inputs to water from air deposition. In some areas, particularly in the western states, mercury resulting from past mining practices (specifically mercury, silver, and gold mining) are significant sources of contamination to water bodies.[14]

EPA's Toxics Release Inventory (TRI) provides information on mercury releases to land, air, and water. (See box on page 27). Based on the EPA TRI data, total quantities of mercury discharged to surface waters have declined steadily from 2000 to

2004.[15] From 2000 to 2001 the decline was over 25 percent; from 2001 to 2002 nearly 32 percent; from 2002 to 2003 4 percent; from 2003 to 2004 nearly 59 percent and from 2000 to 2004 nearly 38 percent. TRI data for 2004 indicate that surface water releases of mercury totaled approximately 694 pounds (0.31 metric tons). An additional 219 pounds (0.10 metric tons) per year of mercury effluent is estimated from POTWs.[16]

Clean Water Act requirements. Under the Clean Water Act, states and authorized tribes must have water quality standards in place that define the designated uses and acceptable levels of pollutants for each water body under their jurisdiction. For mercury, EPA has published a national methylmercury ambient water quality criterion for protection of human health. This is a fish tissue concentration of 0.3 parts per million of methylmercury, based on EPA's 2001 Reference Dose (RfD) for methylmercury and consumption rates.[17] EPA's RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily oral exposure to the human population (including sensitive groups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.[18]

When pollutant levels exceed water quality standards, state water quality program managers must take action to reduce pollutant loadings. An initial step in this process is the development of a TMDL for a water body. The TMDL is the maximum daily amount of a pollutant that can enter a water body and still ensure that the water meets applicable water quality standards. TMDLs also allocate the allowable pollutant loads between the point and non-point sources of a pollutant.[19] Over 8,000 individual water bodies are identified as impaired (not meeting water quality standards) due to mercury contamination and will require mercury TMDLs,[20] and 44 states, 1 territory, and 2 tribes have fish consumption advisories due to mercury contamination.[21] States and EPA have been discussing how to best address mercury in their water bodies, since mercury can travel from sources out-of-state and from international sources and be deposited on local waters. Developing TMDLs that identify reductions from local sources alone is unlikely to result in attainment of water quality standards in many water bodies.

Progress to date. Because past analytical methods could not detect mercury at the level of current water quality standards in many effluents, there are limited data on low-level mercury discharges to water from point sources. To address the critical data gap, EPA recently developed a new more sensitive analytical method for use in water discharge permits.[22] As NPDES permits are reissued, they should require use of this more sensitive method where appropriate. Requiring use of this analytical method will improve EPA's understanding of the significance of point source mercury contributions to surface waters, and will provide necessary data for EPA and states to determine whether surface water discharge permits need to include mercury effluent limits.

As noted earlier, the states, tribes, and EPA's air and water programs are working together on how to address mercury pollution in TMDLs and water permitting programs, particularly mercury from air sources. To date, mercury TMDLs have been developed for over 250 water bodies in 19 states.[23] Many of these TMDLs identify needed reductions in air deposition of mercury. TMDLs such as those in Georgia and California also incorporate

mercury characterization and minimization provisions for water discharge (NPDES) permit holders. To assist states in developing mercury TMDLs, EPA has conducted two pilot projects in cooperation with Florida and Wisconsin to examine approaches that could be used in developing TMDLs for water bodies impaired by atmospheric mercury.

Within the Great Lakes basin, the states have adopted water quality standards to implement the Water Quality Guidance for the Great Lakes System, including a mercury criterion of 1.3 nanograms per liter (ng/l), based on protection of fish-eating wildlife.[24] Initial results in POTW effluent using the low level analytical method have averaged around 4 ng/l, and it is expected that most POTWs will not meet this criterion.[25] As a result, EPA expects the states in the Great Lakes region (EPA Regions 2, 3 and 5) will be utilizing statewide or individual variances from applicable water quality standards, which will involve setting mercury limits in NPDES permits based on a lowest technically achievable concentration, and requiring the POTW to implement a Pollutant Minimization Program (PMP) to address mercury-contributing sectors within its system. Region 5 has developed a PMP guidance document to promote a consistent approach to PMPs throughout its states.

EPA has provided sophisticated air modeling results to states to better identify the mercury contributions to water bodies from different air sources and geographic areas. The Agency has developed analytical tools that can be used to estimate the impact of air emission and deposition reductions on freshwater fish tissue concentration. These tools relate changes in mercury air emission and deposition rates to changes in mercury fish tissue concentrations.[26] By using such methods during the development of a TMDL, states may be able to determine how much of a reduction in air deposition is needed in order to meet water quality standards, and whether other actions in addition to anticipated air deposition reductions will lead to achievement of the water quality standard.

The Clean Water Act directs EPA to develop national technology-based regulations placing limits on the pollutants that are discharged by categories of industry to surface waters (termed "effluent guide-

EPA's Toxics Release Inventory (TRI)

In 1986, the U.S. Congress enacted the Emergency Planning and Community Right-to-Know Act (EPCRA) and in 1990 passed the Pollution Prevention Act (PPA). Section 313 of EPCRA and §6607 of PPA require certain industrial facilities to submit reports each year on the amounts of toxic chemicals released or otherwise managed as waste. Amounts released are reported separately for air, land, water, and offsite disposal. The reported information is compiled and presented annually as the Toxics Release Inventory (TRI).

In 1998, several new industry sectors were required to file reports for the first time. The new sectors included metal mining, electric utilties and hazardous waste treatment facilities. These new TRI reports have improved EPA's understanding of releases of mercury and mercury compounds. In 2000, the TRI program reduced the use threshold that triggers mercury reporting from 10,000 pounds to 10 pounds. As a result, small users of mercury and mercury compounds are now required to report. TRI information and mapping capability can be publicly accessed at www.epa.gov/triexplorer.

In this document, "TRI releases" refer to quantities of mercury- or mercury compound-bearing wastes that are released into the environment or otherwise disposed, and include, but are not limited to, releases to air, water and land, and to landfills, surface impoundments and underground injection. Even though disposals may be subject to regulatory and permitting requirements, disposal of mercury in waste to landfills, surface impoundments and underground injection is termed a "release" under TRI.

lines") or to POTWs (termed "pretreatment standards"). Pretreatment standards ensure that pollutants do not pass through or interfere with the safe and effective operation of these POTWs. CWA §307(b) requires that EPA revise or establish pretreatment standards from time to time, as control technologies, processes, operating methods, or other alternatives change.[27] As part of its pretreatment standards review process, EPA is reviewing industrial sources of mercury for potential technology-based options for controlling mercury discharges to POTWs. In addition, POTWs are beginning to implement best management practices for collecting mercury from other industrial sources.

Many states have initiated efforts to reduce mercury in wastewater by focusing on the dental sector. Mercury in dental wastewater can be removed by relatively inexpensive amalgam separators and/or by using other pollution prevention practices. Amalgam separators currently on the market can capture more than 95 percent of the mercury particles in wastewater.[28] In addition to outreach and education to dentists on safe handling and disposal practices for mercury-containing dental amalgam, some local efforts are offering incentives to encourage the use of amalgam separators. For example, the city of San Francisco, California has a goal of installing amalgam separators in all 900 dental offices located in the city and is offering assistance and incentives to dental offices least able to afford the separators—specifically those serving low-income communities.[29]

Future focus. EPA will continue to work with its state and tribal partners to identify approaches to TMDLs for water bodies impaired by atmospheric mercury in order to make progress toward achieving state water quality standards. Potential approaches include regional-scale TMDLs and approaches which take into account comprehensive state mercury reduction programs.

Releases to Land

Sources. TRI provides the best single source of information on releases of mercury to land. Based on TRI,[30] the total amounts of mercury that were released to land decreased by about 18 percent between 2002 and 2003 (from 2,554 to 2,079 metric tons per year). Although these amounts are relatively large, based on existing information, such releases are generally not considered to be as environmentally harmful as releases to air because the mercury may be less mobile and less likely to reach surface waters and fish. Nevertheless, because of the large quantities of mercury in waste being placed on the land, it is prudent for EPA to conduct further investigations to determine the risks associated with these releases.

The vast majority of U.S. land releases are the result of mining activities. Mercury is no longer mined domestically in the U.S., but is a byproduct of metals mining, particularly gold mining. The 2004 TRI data indicate that 2079 metric tons of mercury were released to the land. Of that, 1.461 million pounds were released to "other surface impoundments"[31] and 2.620 million pounds were released to "other land disposal".[32] Three metal mining facilities accunted for over 74 percent of the total mercury land releases in 2004. The majority of TRI land releases is due to gold, silver, and zinc mining, and may continue to rise over the next few years due to increased gold production.

The Agency is beginning to investigate and characterize mercury releases and

risks from mine tailings and mining processes, as well as other land releases. EPA plans to use the latest TRI data to evaluate trends for how mercury is being released to land.

A small percentage of releases to land reported in TRI are not related to mining activities. The majority of these releases is attributed to the disposal of mercury in waste in hazardous or non-hazardous regulated landfills or surface impoundments.

Progress to date. EPA has made substantial progress reducing the volume of mercury-containing devices disposed of in landfills since 1990. This progress is largely due to the Battery Act[33] which places limits on mercury used in batteries. The promulgation of the Municipal Incinerator Rules[34] also helped reduce the amount of mercury going into the waste streams by limiting mercury emissions from these incinerators, which in turn encouraged localities to begin collection and recycling programs for mercury-containing devices. The Universal Waste Rule[35] is another example of a regulation helping to facilitate proper management of mercury-containing devices to keep them out of incinerators and landfills. In August 2005, EPA finalized its proposal to add mercury-containing devices (e.g., thermometers and switches) to the federal Universal Waste Rule.[36] For these widely-generated hazardous wastes, this rule streamlines entry into the waste management system, encourages recovery and recycling, and keeps wastes out of the municipal waste stream. States and localities have made substantial progress promoting recycling of discarded mercury-containing products. Many states are also involved in banning certain mercury-containing devices and actively promoting the use of mercury substitutes, where available.

Future focus. Because there is a steady increase in reported land releases, the Agency will expand its efforts to better characterize and address land releases of mercury from the mining sector. The Agency intends to evaluate these releases to determine whether further action is needed.

Using the latest TRI data, EPA will continue to analyze long-term trends and monitor sectors that are not addressing their mercury releases to assess appropriate voluntary or regulatory avenues for addressing mercury releases.

EPA will continue to address mercury releases at remediation sites with significant mercury contamination consistent with the priorities set by the Superfund National Priorities List[37] and the RCRA Corrective Action baseline for high-priority facilities.[38] EPA will continue to coordinate with states to assist in cleaning up serious spills of mercury in order to protect public health. In addition, EPA is looking into mercury issues associated with abandoned mines relative to downstream water quality.

EPA will continue to work toward reducing risk associated with mercury from the nation's waste streams and from potential releases to land by promoting cost-effective reductions in mercury use in products and processes and by promoting the collection and recycling of discarded mercury-containing products.

State, Tribal, and Local Government Release Reduction Efforts

Many state, tribal, and local governments have been leaders in addressing mercury

releases. States have developed innovative mercury release and use reduction laws and regulations that supplement, and in some cases provide a model for, national efforts.

For example, the state of Maine passed a law requiring removal of mercury convenience lighting switches from automobiles prior to crushing the automobiles for scrap metal.[39] The purpose of the legislation is to reduce mercury releases from Electric Arc Furnaces (EAFs) used to melt scrap metal for steel production. The source of mercury from EAFs has been determined to be mercury components contained in the scrap metal melted by such furnaces. Scrap automobiles are the largest mercury-containing feedstock for these furnaces.[40] Several other states are pursuing their own auto switch removal programs, including Pennsylvania, New York, New Jersey, Illinois, Colorado, Washington, Oregon, and Idaho. As a result of this state leadership, auto manufacturers no longer install mercury switches for convenience lighting and are actively investigating ways to keep mercury out of vehicles. In addition, EPA is engaging in discussions with various stakeholders, including auto dismantlers, shredders, steel makers, auto manufacturers, environmental groups, and states, with the aim of developing a collaborative national approach to removing mercury switches from the large inventory of autos in use today prior to their disposal, crushing, and smelting.

States, tribes, and local governments have played a key role in outreach to the business community and to the general public about the importance of properly disposing of mercury-containing products and about alternatives to such products. Many states and local governments have sponsored mercury collection programs for businesses and households. For example, cities such as San Francisco, California, and states, such as Florida and New Hampshire, are conducting outreach to dentists on the proper handling and disposal of mercury-containing dental amalgam, including efforts to promote increased use of dental amalgam separators that reduce the amount of mercury discharged into the POTWs from dental wastewater.

Priority Activities for Addressing Mercury Releases

- ***Standard for Coal-Fired Power Plants*** – On March 15, 2005, EPA finalized the Clean Air Mercury Rule which establishes standards of performance for electric power plants based on a market-based cap-and-trade methodology. This rule will build on EPA's Clean Air Interstate Rule (CAIR) to significantly reduce emissions from coal-fired power plants. The standards address mercury air emissions from new and existing coal-fired electric utility steam generating units. When fully implemented, these rules will reduce power plant emissions of mercury from 48 tons per year to 15 tons per year, a reduction of nearly 70 percent.[41] **Timeline: CAMR will reduce emissions from 48 tons to 31 tons beginning 2010 and declining thereafter until emissions are reduced to 15 tons when the program is fully implemented**

- ***MACT Standard for Industrial Boilers*** – EPA promulgated a MACT standard for mercury air emissions from industrial boilers in September 2004. This effort should result in a 17 percent reduction in mercury emissions from this sector since 1990. **Timeline: Implementation by 2007**

- ***MACT Standard for Hazardous Waste Combustors*** – In October 2005, EPA published emission standards for mercury and other hazardous air pollutants for incinerators, cement kilns, lightweight aggregate kilns, industrial/commercial/institutional boilers and process heaters, and hydrochloric acid production furnaces that burn hazardous waste. An interim standard that took effect in 2003 has already reduced mercury emissions from levels in 2000 for incinerators, cement kilns, and lightweight aggregate kilns. The final MACT standard is estimated to further reduce mercury air emissions from all hazardous waste combustors by an additional 39 percent (from 2.4 tons/year to 1.5 tons/year).[42] **Timeline: Implementation by 2008**

- ***MACT Standard for Chlor-Alkali Sector*** – In December 2003, EPA promulgated a rule to regulate emissions of mercury from mercury-cell chlor-alkali plants.[43] Mercury-cell chlor-alkali plants produce chlorine and caustic soda (used to neutralize acidic compounds) using mercury cells. The rule will also require rigorous work practice standards that will reduce mercury emissions from fugitive sources. Although EPA is not able to accurately quantify the reductions associated with these work practice standards, the requirements will reduce mercury air emissions industry-wide. **Timeline: Implementation by December 2006**

- ***MACT Standard for Iron and Steel Foundries*** – In 2004 EPA issued a final rule to reduce toxic air emissions, including mercury, from iron and steel foundries. Iron and steel foundries melt scrap, ingot, and other forms of iron and steel and pour the resulting molten metal into molds to produce shaped products. The rule includes emission limits for manufacturing processes and pollution prevention-based requirements to reduce air toxics from furnace materials and coating/binder formulations. Implementation of the rule is expected to reduce mercury emissions by 1.4 tons—an 80 percent reduction from current levels.[44] **Timeline: Implementation by 2007**

- ***Area Source Program*** – Under the Urban Air Toxics Strategy, EPA is developing standards to control emissions of toxic air pollutants (hazardous air pollutants or HAP) from area sources. Area sources are those sources that emit less than 10 tons annually of a single HAP or less than 25 tons annually of a combination of HAP.

  The Clean Air Act (CAA) requires EPA to identify a list of at least 30 HAP that pose the greatest potential health threat in urban areas, and in the 1999 strategy, EPA identified 33 such pollutants. Of those 33 identified pollutants, EPA determined that 30 stem from area source emissions. Through three separate listings (including a list in the Urban Air Toxics Strategy), EPA has identified a total of 70 area source categories which represent 90 percent of the aggregate emissions of the 30 listed area source HAP. Of these 70 area source categories, 16 have been regulated, and EPA is currently collecting data and information for many other source categories. **Timeline: Ongoing**

- ***Rule on Electric Arc Furnaces (EAFs)*** – In 2006, EPA plans to propose a comprehensive rule for steel mills that

use EAFs to address emissions of mercury, lead, and other metals and organic hazardous air pollutants. EPA will also pursue voluntary programs in parallel with the development of regulations to ensure mercury emissions reductions. These actions collectively should greatly reduce mercury air emissions from EAFs and other scrap consumers over the course of the next 10 years. **Timeline: Propose rule in 2006**

- ***Mercury Automobile Switches*** – Many pre-2003 domestic passenger vehicles have mercury-containing switches in convenience light assemblies and anti-lock braking systems (ABS). Building on and coordinating with successful state and local automotive switch removal efforts, EPA hopes to develop a partnership with automobile dismantlers, scrap shredders, steelmakers, and the automotive industry to remove mercury switches from scrapped autos in the U.S. prior to disassembly, shredding, and melting in steelmaking furnaces. **Timeline: 2006**

- ***Characterize Mining Releases*** – EPA is examining the issue of mercury-bearing materials being placed on land at active gold mines and any subsequent releases which are not covered by TRI (air, surface, water, or ground water) associated with that placement. An effort is underway to assess the releases and their potential impact to determine if further action is warranted. **Timeline: 2006**

- ***Characterize Mercury Discharges to Surface Water*** – As mentioned in the progress to date section, EPA recently developed a new analytical method for use in water discharge permitting programs that will improve EPA's understanding of point source mercury contributions to surface waters. Based on that information, EPA is providing guidance to Publicly Owned Treatment Works (POTWs) on how to characterize sources of mercury to the collection system and how to develop mercury minimization measures where appropriate. Mercury in POTW collection systems may come from the medical sector, dental offices, schools, and certain industries. EPA is continuing to explore opportunities for pollution prevention in the dental sector and other sources. **Timeline: Ongoing**

- ***Issue Mercury Water Quality Criterion Implementation Guidance*** – EPA currently intends to issue implementation guidance to states and tribes for the fish-tissue-based mercury water quality criterion and how to incorporate it into permits and TMDLs. Once states and tribes adopt the water quality criterion into their water quality standards, officials can incorporate appropriate controls where necessary into TMDLs and watershed management decisions. State environmental officials can incorporate appropriate controls where necessary into permits and enforce these requirements. **Timeline: 2007**

- ***Improve Tools for Tracking Mercury in Fish Tissue*** – EPA continues to improve its models for tracking methylmercury in fish tissue and air deposition trends.[45] EPA will also begin to estimate the expected effectiveness of proposed Hg source reduction activities in terms of reduced fish tissue methylmercury concentrations. This effort may involve the continued evolution of the Mercury Maps model-

ing framework, and its integration with sophisticated air deposition model outputs (e.g., CMAQ [Community Multiscale Air Quality]). In addition, EPA will continue to refine its air emission inventories to provide an assessment of emission reductions gained through implementation of its regulatory programs. **Timeline: To be determined**

- ***Develop Alternative Approaches and Tools for Identifying Mercury Impairments and Developing Mercury TMDLs*** – EPA will work with states, tribes, and stakeholders to determine how best to use TMDLs to provide a basis for reducing mercury releases to water, including those from air deposition, to meet state water quality standards and Clean Water Act goals. EPA will provide updated mercury deposition modeling results to states for use in TMDLs, including the major sources of mercury deposition to each state. EPA will also evaluate approaches for identifying mercury impairments and developing mercury TMDLs, such as regional-scale TMDLs and approaches that acknowledge strong state mercury reduction programs, in order to make progress toward attaining state water quality standards. **Timeline: Ongoing**

- ***Promote The Proper Collection and Recycling of Dental Office Amalgam Waste*** – EPA is currently developing a dental office amalgam recycling program called its "gray bag" program. This program will assist dentists in properly collecting and managing dental amalgam wastes generated in their offices to minimize mercury releases to air, land, and water. This program also will ensure that dental amalgam is sent to responsible recyclers who can adequately minimize mercury releases by keeping the amalgam waste out of the wastewater stream and out of municipal and medical incinerators. **Timeline: In 2006**

- ***Fluorescent Lamp Recycling*** – EPA is administering a grant program to increase the recycling rate of mercury-containing lamps. Grants are used to create lamp recycling outreach programs targeting commercial and industrial users of mercury-containing lamps. State environmental agencies, tribes, non-profit organizations, lamp manufacturers, and recyclers are all partners in implementing this program. EPA is currently providing national coordination of these efforts as well as technical expertise on regulatory issues. EPA will build upon the results of this grant program to increase the national rate of bulb recycling. EPA is also working with Regions and states to develop guidance on the conditions under which drum top crushing of waste lamps can be permitted without unacceptable mercury releases or danger to personnel who operate the crushers. **Timeline: In 2006**

- ***Analyze Sectors and Trends for Mercury Releases in the TRI/NEI Databases*** – EPA will continue to evaluate the "other" smaller sources, as appropriate, that cumulatively release significant amounts of mercury to the environment. EPA will monitor existing data on how mercury is managed onsite and/or off-site and will examine potential sectors for expanding voluntary mercury reduction programs. **Timeline: Ongoing**

II. ADDRESSING MERCURY USES IN PRODUCTS AND PROCESSES

OVERVIEW

Addressing uses of mercury in products and processes is a component of preventing mercury releases to air, water, or land. These releases may occur during manufacturing and industrial processes, or during the disposal or recycling of mercury-containing products and wastes. Addressing mercury use in products also reduces the demand for mercury by product manufacturers, thereby reducing demand for new mercury mining. Mercury mining still occurs in other countries and causes further releases to the global environment. Addressing demand for and use of mercury is critical to breaking the cycle of mercury being transferred from one environmental medium to another.

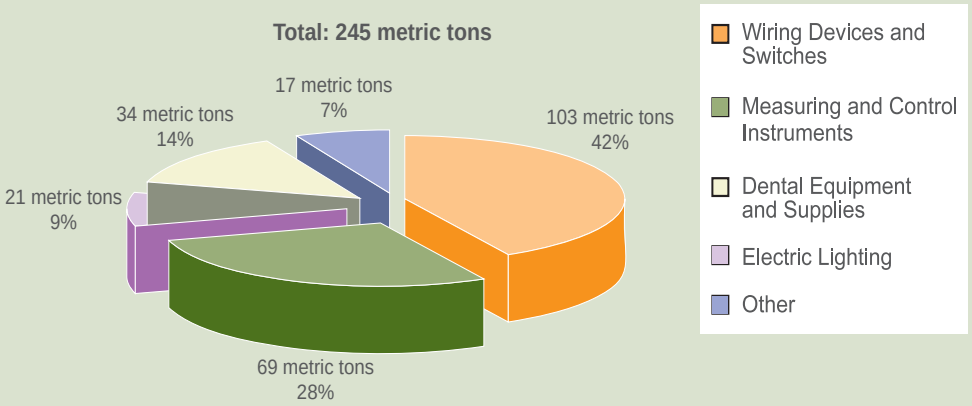
EPA's long-term goal is to reduce risks associated with mercury. EPA recognizes that to reduce risks associated with mercury, the Agency must first understand what contributes to the risk and what the appropriate mechanisms of risk reduction might be. EPA will take action to identify exposed populations, minimize exposures through outreach efforts, and appropriately address 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 reduction would justify the cost, even where cost-effective substitutes do not exist; and work to identify and encourage

Uses Can Contribute to Releases

Mercury use in products can lead to mercury releases through:

- Manufacturing of product
- Spills/breakage
- Recycling/collection
- Disposal

FIGURE 3. Total 2001 U.S. Mercury Use in Products[2]



development of alternatives to essential uses of mercury that lead to risk.

Sources. In 1980, the three largest U.S. industrial uses of mercury were in batteries (1,052 metric tons), the chlor-alkali manufacturing process (358 metric tons), and paint (326 metric tons).[1] Mercury use in products accounted for an estimated 245 metric tons in 2001. As Figure 3 illustrates, the dominant use of mercury in products in 2001 was in switches and wiring devices at 42 percent (103 metric tons), followed by measuring and control devices at 28 percent (69 metric tons), dental amalgam at 14 percent (34 metric tons), and electrical lighting at 9 percent (21 metric tons).

Mercury is also found in laboratories, including school science labs. Breakage or spillage of mercury supplies and mercury-containing lab equipment creates the potential for inhalation exposure to airborne mercury indoors. Mercury in schools can pose a significant exposure concern for children and adults.

In 2001, the largest use of mercury in manufacturing processes was by the chlor-alkali industry (producers of chlorine and caustic soda), estimated at 38 metric tons, or 12 percent of overall mercury use by U.S. industry.[3]

Progress to date. Over the past two decades there has been a dramatic drop in mercury use by industries in the United States, decreasing 83 percent between 1980 and 1997, from 2,225 metric tons to 381 metric tons (see Figure 4).[4] This reduction in use was due in large part to state and congressional limits placed on mercury use in batteries, EPA's regulatory ban on mercury in paint, closure of some mercury-cell chlor-alkali manufacturing plants, and progress made under the U.S./Canada Great Lakes Binational Toxics Strategy, a voluntary agreement which set forth a goal of 50 percent reduction in the deliberate use of mercury nationwide by 2006.[5]

The lamp industry has made significant progress in reducing use of mercury. The National Electrical Manufacturers Association (NEMA) reported that its members have significantly reduced use of mercury in lamps while increasing their production of lamps. In 1990, NEMA estimates that its lamp members used 23.6 tons of mercury in slightly fewer than 500 million mercury-containing lamps. After a concerted effort to reduce mercury use, this mercury usage declined to 7 tons by 2003. In the same timeframe, sales by NEMA lamp members have increased to 650 million mercury-containing lamps. The Association of Mercury and Lamp Recyclers reports that lamp recycling has increased from fewer than 10 million lamps in 1990 to 156 million lamps in 2003.[6]

As a result of a voluntary commitment to mercury reduction made by the U.S. Chlorine Institute under the Great Lakes Binational Toxics Strategy, the chlor-alkali industry has made significant progress in reducing its mercury use since 1995. The U.S. Chlorine Institute's Ninth Annual Report to EPA showed a 91 percent reduction between 1995 and 2005 in mercury used in the U.S. production of chlorine and caustic soda, after adjusting for shut down facilities.[7]

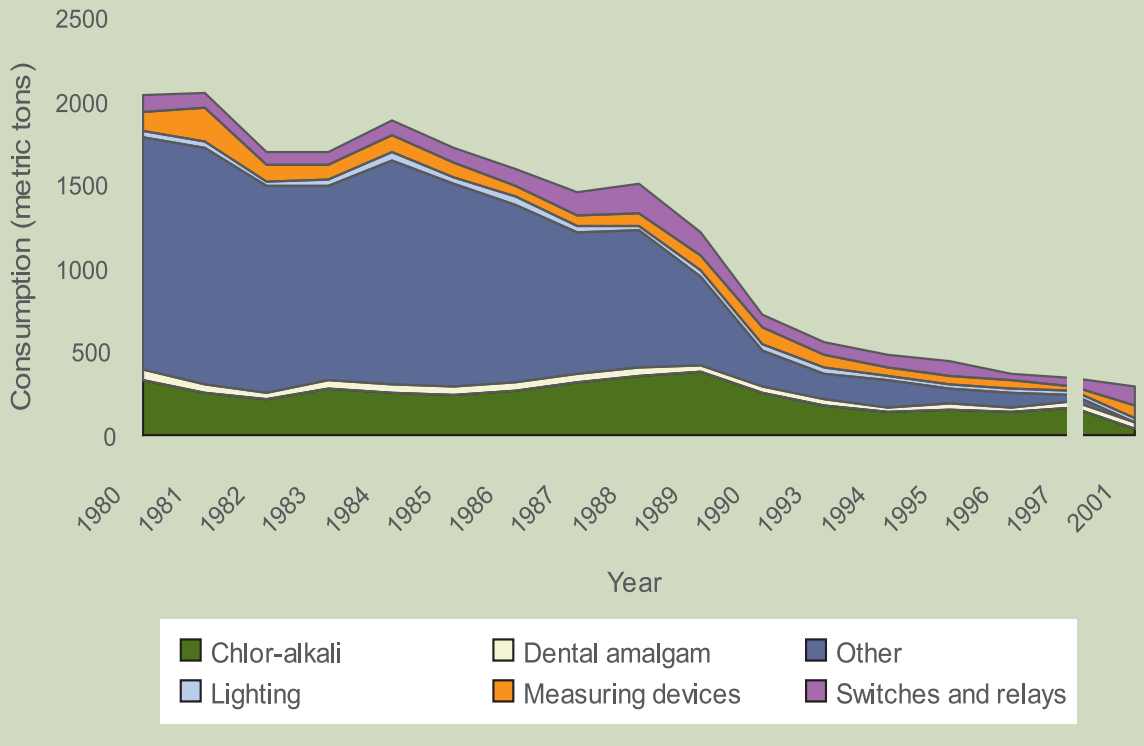
EPA's Hospitals for a Healthy Environment (H2E) program is a partnership among EPA, the American Hospital Association (AHA), the American Nurses Association, and Health Care Without Harm to encourage hospitals to eliminate the use and purchase of mercury-containing products such as measurement and control devices.[8] Under H2E, these health care facilities have pledged to eliminate mercury use and waste whenever possible by 2005 and to reduce all types of waste by 2010.

State, Tribal, and Local Government Use Reduction Efforts

Many state, tribal, and local governments have been leaders in reducing mercury use. States have developed innovative mercury use and release reduction laws and regulations that supplement, and in some cases provide a model for, national efforts. For example, all of the New England states have adopted legislation to reduce mercury use in products.[9]

States, tribes, and local governments have played a key role in outreach to the business community and to the general public about the importance of properly disposing of mercury-containing products and

FIGURE 4. U.S. Mercury Product and Process Use Trends



about alternatives to such products. Many states and local governments have sponsored mercury collection/replacement programs for businesses and households for products such as mercury thermometers. They have also made special efforts to educate and encourage hospitals and schools to eliminate the use of mercury and mercury-containing products. For example, over the past few years, the northeast states, in conjunction with the eastern Canadian provinces, have collected over 2,000 pounds of mercury from cleanout efforts at over 200 schools.[10] These efforts have been key to the progress made to date on reducing mercury use in school science laboratories.

Likewise, several states such as Maine, Texas, and localities such as Alameda County, California have built green purchasing requirements that specify the use of non-mercury alternatives into their state procurement systems.

Future focus. During the next ten years, EPA 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 by working with state and tribal partners, industry, and non-governmental organizations. The Agency's use reduction activities will be conducted in the context of the global market for commodity-grade elemental mercury and the need for global use reductions. (See Section III for further discussion of the mercury commodity market.) EPA will continue to support and build on successful state and local efforts by funding selected mercury projects, providing information about mercury sources and reduction opportunities, and coordinating joint efforts to further progress on addressing mercury use. EPA will also continue to work with other countries and international organizations to address global demand for and use of mercury as discussed further in Section V on international mercury sources.

Need for a National Mercury Use Database

Reliable and publicly available data on mercury use is a prerequisite to gauging the success of EPA initiatives to reduce the use of mercury. In 1998 the U.S. Geological Survey discontinued its annual reporting of mercury use, due to low voluntary response from mercury-using manufacturers. More recently, other limited sources of mercury use information have emerged: (1) the U.S. Chlorine Institute's annual report to EPA on mercury usage by the chlor-alkali industry;[11] and (2) the Northeast Waste Management Officials' Association's (NEWMOA) database on mercury-containing products, housed in NEWMOA's Interstate Mercury Education and Reduction Clearinghouse (IMERC).[12] The IMERC database contains annual data (beginning with 2001) required from manufacturers by the states of Connecticut, Maine, New Hampshire, and Rhode Island on national sales of specific mercury-containing products that are sold in these four states. The IMERC database is updated every three years. The base year for data is 2001; companies are required to report on 2004 data in 2005. EPA is evaluating how best to build upon this information as it is developing its database for mercury use in products and processes nationwide. A national use database will enable EPA and its partners to evaluate the effectiveness of its outreach activities.

Priority Activities for Reducing Mercury Uses

To further progress in reducing risks associated with mercury use, EPA will continue to pursue a number of priority activities. These activities are based on considerations of the quantity of mercury used by specific industry categories; opportunities to provide national leadership; and opportunities to work in partnership with industries, other federal agencies, state, tribal and local governments, other institutions, and public interest groups.

Industrial Processes

- ***Track Reductions by Mercury-Cell Chlor-Alkali Facilities*** – EPA will continue to monitor the use of mercury by the chlor-alkali industry through the EPA/U.S. Chlorine Institute voluntary agreement on use reporting for the remaining U.S. mercury-cell chlor-alkali plants. **Timeline: Ongoing through 2006**

Mercury-Containing Products

- ***Further Reduce Risks Associated with Mercury Use Using TSCA Authorities and Voluntary Mechanisms*** – EPA will focus its new reduction efforts on switches, relays, and measuring devices because these sectors represent the majority of mercury use in products, and cost-effective alternatives are available for many uses in these categories. EPA will conduct a preliminary market analysis of mercury switches, relays, and measurement devices to identify candidate product manufacturers to partner with the Agency to reduce mercury use. Building upon successful state regulatory programs, EPA will pursue further use reductions in this product area using TSCA and voluntary mechanisms. **Timeline: Proposed auto switch significant new use rule in 2006**

- ***Develop Database to Track Reductions in Mercury Use by Key Sectors*** – EPA is compiling and assessing information on mercury use and substitutes from existing data sources. The Agency will explore using various mechanisms to improve the comprehensiveness and reliability of its national database on mercury use, supply, and substitutes. This information also will allow EPA to evaluate the effectiveness of its outreach activities on mercury-containing products. **Timeline: Data collection is ongoing; database in 2007**

- ***Promote Procurement of Non-Mercury Products by Federal Agencies*** – EPA is compiling a list of alternative non-mercury products with a special emphasis on those that contain non-mercury switches, relays, and measuring devices. EPA will compile and convey information—such as federal, state, and local bid specifications—to federal purchasers using its Environmentally Preferable Products (EPP) Database.[13] The intent is to harness the large federal buying power to increase demand for non-mercury products. EPA will also make such information available to other interested purchasers, including state, tribal, and local governments; large industrial purchasers currently using mercury switches and relays (such as manufacturers of cars, airplanes, and appliances); institutional purchasers such as hospitals and schools; and individual consumers. **Timeline: Ongoing**

- ***Partner with Automobile Manufacturers to Eliminate Mercury*** – EPA will work with the auto manufacturers on

additional mercury use reduction and elimination of mercury from products, such as high-intensity discharge (HID) headlights. EPA will provide auto manufacturers with information on non-mercury alternatives to auto components through its Green Suppliers Network, an EPA partnership effort with manufacturers and their supply chains.[14] **Timeline: Enhance partnership efforts on auto products in 2006**

- ***Reduce Mercury in Health Care Facilities*** – EPA will continue partnerships with the American Hospital Association (AHA), the American Nurses Association, and Health Care Without Harm to encourage hospitals to eliminate the purchase of mercury-containing products such as measurement and control devices, and properly dispose of mercury-containing products currently in health care facilities. EPA will expand these efforts by recruiting additional facilities. **Timeline: Recruit 2,000 new facilities by 2007**

- ***Promote Mercury Reduction in Schools*** – Building upon the successful work of the mercury-in-schools projects throughout the country by states and EPA regions, EPA will continue to work with school administrators and policy makers to promote the substitution of mercury with environmentally preferable chemicals through procurement policy guidelines and the use of green chemistry; the removal of elemental mercury, mercury reagents, and mercury waste products from school laboratories; the replacement of mercury-containing devices with safer non-mercury-containing devices in all school facilities; and the use of software to educate school maintenance workers and decisionmakers about potential environmental hazards in schools and ways to reduce them. EPA is developing a handbook, "Chemical Management for Schools: Recommended Actions for Administrators," which will help schools safely manage chemicals, including mercury. This guidance will help school officials ensure the health and safety of the students and school employees. **Timeline: Finalize Chemicals Management Document in 2006**

- ***Schools Chemical Cleanout Campaign (SC3)*** – Existing stocks of outdated, unknown, excessive or unnecessarily hazardous chemicals—are present in schools across the country. These chemicals can pose safety and health risks to students and staff, and a number of widely reported incidents involving such chemicals have resulted in school closures and costly clean-ups. To reduce the number of these incidents, the Agency has initiated the Schools Chemical Cleanout Campaign (SC3)[15] which promotes removal of existing stocks of hazardous chemicals from secondary schools; safe chemical management; and national awareness. The ultimate goal of the SC3 is to create a chemically safer school environment in which chemicals are purchased wisely, stored safely, handled by trained personnel, used responsibly, and disposed of properly. In the summer of 2004, EPA launched ten SC3 pilots, one in each EPA region. EPA provided funding for an additional eight pilots in 2005. Outreach materials are now available on the website at www.epa.gov/sc3. **Timeline: Ongoing**

- ***Promote Mercury Product Use Reduction Partnerships*** – Many

current mercury uses in products have cost-effective, mercury-free alternatives. EPA is currently inviting companies to voluntarily commit to mercury product use reduction and phaseout goals and to become partners in EPA's National Partnership for Environmental Priorities (NPEP) Program. As a component of these partnerships, EPA is promoting mercury-containing product take-back/recycling programs and providing technical assistance to industry in achieving their NPEP goals. **Timeline: Ongoing**

- ***Promote the Mercury Challenge*** – EPA is currently inviting companies to commit to establish inventories of mercury; remove mercury and mercury-containing equipment from their plants; and institute purchasing policies to reduce mercury use. This mercury challenge is a component of the NPEP program.[16]

III. MANAGING COMMODITY-GRADE MERCURY SUPPLIES

OVERVIEW

The Agency expects that an excess supply of elemental, commodity-grade mercury will emerge on the market over the coming years as various secondary sources of mercury—especially the expected phase-out of mercury-cell chlor-alkali plants—overtake a shrinking demand for mercury-containing products and industrial use of mercury. As a result, there will be an increasing need to safely manage mercury supplies for the long term. Ultimately, it will be important to look at ways to permanently "retire" most supplies of mercury that will eventually have little or no economic value. EPA estimates that current world demand for mercury is approximately 2,000 metric tons per year (mt/yr). Although highly variable from one year to the next, the amount of mercury available in commerce globally is also estimated at 2,000 mt/yr.[1] Other estimates prepared for the European Union (EU) indicate that the global mercury supply may be over 3,300 metric tons.[2] It is important to note that supply and demand numbers for countries outside the U.S. and Europe are very rough estimates. In the absence of efforts to retire mercury supplies, there is a danger that supplied mercury will find uses that have already been banned or eliminated in some countries, particularly in the developing world, possibly leading to unnecessary releases.

Sources. In recent years, approximately one-half of the world mercury supply has come from mercury mines in Spain, Algeria, and Kyrgyzstan (although Spain is no longer mining mercury). China has also mined mercury to meet its domestic demand.[3] There have been no active mercury mines in the U.S. since 1990. The remaining half of the world's mercury supply comes from secondary sources, such as industrial wastes and scrap products, as byproduct from gold mines in the U.S. and abroad, and from

closing mercury-cell chlor-alkali plants. The secondary mercury produced from these other sources is price-insensitive because the mercury results from environmental regulations and polices that require or encourage recovery (e.g., RCRA land disposal restrictions), and from industrial process conversions to non-mercury processes. Environmental regulations and polices that require mercury recovery can override the market's natural tendency over the long term to match supply with demand. Whereas the long-term trend for mercury mining has been one of decline, secondary production has remained relatively constant. It may even increase as mercury continues to be recycled/recovered and more mercury-cell chlor-alkali plants close, thereby making more mercury available to the secondary market.

The most significant factor driving the timing of a global mercury surplus is the rate at which remaining U.S. and international mercury-cell chlor-alkali plants close and liquidate their stocks of some 22,000 metric tons. Of these stocks, mercury-cell chlor-alkali plants in the U.S. account for about 2,600 metric tons of mercury stocks.[4] Mercury-cell chlor-alkali plants are being closed at the end of their useful life in the U.S. and abroad due to the industry's conversion to non-mercury technologies, a shrinking customer base, and high energy costs.

Progress to date. The Department of Defense (DoD) has mercury stocks that are being stored. The DoD has 4,436 metric tons of mercury in its strategic stockpile. DoD has sold some of its mercury stocks in the past, but since 1994 DoD has been storing its mercury in response to requests from EPA, states, and non-governmental organizations (NGOs). On April 30, 2004, the Defense National Stockpile Center (DNSC) published its final Mercury Management Environmental Impact Statement regarding the disposition of its mercury.[5] The DNSC decided to store its mercury at one location for at least a 40-year period. In addition, the Department of Energy has a known supply of 1,306 tons of mercury.

State and local governments have promoted public and private collection programs for both bulk elemental mercury and discarded mercury-containing products. Some businesses are also collecting unwanted mercury or mercury-containing products (e.g., thermostats). The total amount of mercury collected through these programs is unclear. Most of this mercury is sent to retorters, and it is likely that the supply of mercury will increase due to successful collection programs and efforts to eliminate mercury from schools, laboratories, and businesses.

The Environmental Council of the States (ECOS) and the Quicksilver Caucus (QSC), a coalition of state associations concerned with mercury pollution, have indicated that states do not have the resources or desire to manage surplus mercury for the long term and are looking to the federal government to address this issue.[6] Environmental groups and the U.S. Chlorine Institute are also looking to the federal government to address or assume responsibility for all private sector commodity-grade mercury that exceeds U.S. demand.

In addition, EPA's Office of Research and Development conducted research and published a report in 2005 on the technical and economic feasibility of selected land disposal technologies in a monofill context, as compared to above-ground storage for elemental mercury.[7]

Future focus. The issue of whether the federal government, states, or the private sector should take responsibility for managing commodity-grade mercury supplies from state and private sources is an important policy decision. Decisions regarding the disposition of commodity-grade mercury should be made in light of the global mercury market; data and research needs; public policy, statutory, and economic considerations; and the views of Congress, states, tribes, and non-governmental organizations.

Ultimately, it will be important to look at ways to permanently "retire" non-federally owned or managed commodity-grade mercury that will eventually have little or even negative economic value. Disposal of commodity-grade mercury would require regulatory changes, as current regulations under the Resource Conservation and Recovery Act (RCRA) require high concentration mercury wastes to be retorted for mercury recovery and reuse.[8]

Additional information on mercury supplies and flows would allow for more informed policy choices and decisions on this issue, and to better estimate when the global mercury surplus may occur. EPA, states, tribes, and the private sector must continue efforts, domestically and internationally, to address exposure, potential reduction strategies, and the quantity of mercury that will ultimately need to be stored or land disposed permanently.

Priority Activities for Addressing Mercury Supplies

Address Data Gaps on Mercury Supplies

- ***Publish Initial Report and Assemble Existing Data on Domestic and Global Commodity Mercury Production and Use*** – EPA will explore with industry and other federal agencies ways to fill information gaps on annual production and use of commodity mercury.
  Timeline: 2006

Safe Storage Practices for Disposal of Mercury

- ***Establish a Process to Address Mercury Surplus Issues*** – In 2006, EPA will work with other agencies to initiate a process with technical experts and interested parties to discuss options for addressing the expected mercury surplus over the next 10–30 years, and how to encourage the phase-out of mercury mining abroad.
  Timeline: Initiate discussion in 2006

IV. COMMUNICATING TO THE PUBLIC ABOUT MERCURY EXPOSURE RISKS

OVERVIEW

While the Agency is pursuing regulatory and voluntary activities aimed at industrial reduction of mercury releases and uses, EPA will also increase its risk communication and outreach activities to help people avoid or reduce their exposure to mercury in the near term. The most common way people in the U.S. are exposed to mercury is by eating fish containing methylmercury (an organic mercury compound). Consumption of fish with higher methylmercury levels can lead to elevated levels of methylmercury in the bloodstream of unborn babies and young children and may harm their developing nervous system.[1] The primary tool for reaching and educating affected populations has been through fish consumption advisories issued by states, tribes, and FDA. For example, in March 2004, EPA and FDA issued a joint federal fish consumption advisory for mercury in fish and shellfish that helps consumers understand the benefits of fish consumption, the risks of consumption to certain sub-populations (e.g., groups with routinely high consumption), and mercury levels in certain fish.

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. Research shows that most people's fish consumption does not cause a health concern.

EPA and FDA have issued fish consumption advice to help consumers understand the connection between the benefits of fish and possible risks of methylmercury

What You Need to Know About Mercury in Fish and Shellfish

U.S. Food and Drug Administration and U.S. Environmental Protection Agency Advice for

Women Who Might Become Pregnant, Women Who Are Pregnant, Nursing Mothers, and Young Children

1. Do not eat:
   - Shark
   - Swordfish
   - King Mackerel
   - Tilefish

They contain high levels of mercury.

2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.
   - Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
   - Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers and coastal areas.

   If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week. Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

   For more information, please visit:
   www.epa.gov/waterscience/fishadvice/advice.html
   (See full text of Joint Fish Advisory in Appendix A)

exposure. Elevated methylmercury in the blood stream of unborn babies and young children may harm the nervous system, impairing the child's ability to learn and process information. Certain sub-populations may be 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).

Although people are exposed to methylmercury via the dietary route, there are also some non-dietary sources of mercury exposure. Many consumers are not aware that mercury has been used for years in common household products such as thermostats. Releases from the manufacture of mercury-containing products and inappropriate disposal of these products have contributed to mercury entering the environment and ultimately the food chain. Misuse of or accidental breakage of some products can create indoor air health risks and expose consumers to dangerous levels of mercury. In addition, certain cultural or religious uses of mercury may also result in harmful mercury exposure. The number of individuals exposed in the U.S. in this way is very small.

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.

Progress to date. EPA has directed most of its mercury risk communication activities toward raising awareness about dietary practices. The FDA-EPA national advisory, *What You Need to Know About Mercury in Fish and Shellfish*, provides advice for women who might become pregnant; women who are pregnant; nursing mothers; and young children.[2] This advisory represents the first time FDA and EPA have combined their advice into a single uniform advisory. During the summer and fall of 2004, the two agencies distrib-

uted brochures about the advisory to approximately 200,000 medical providers in the U.S.

In September 2005, EPA sponsored the Eighth Annual National Forum on Contaminants in Fish ("Fish Forum"). The forum provided an opportunity for people who have an interest in the subject of advisories, from both the public and private sectors, to discuss scientific and policy issues, risks and benefits, and communication strategies associated with exposure to chemical contaminants in sport- and subsistence-caught fish and shellfish. In September 2005, the 13th straight year, EPA released its National Listing of Fish Advisories, a summary of information on locally-issued fish advisories and safe-eating guidelines.[3] This information is provided to EPA annually by states, territories, and tribes.

States and tribes issue fish consumption advisories if elevated concentrations of chemicals such as mercury are found in local fish. States monitor their waters by sampling fish tissue for persistent pollutants that bioaccumulate. States issue their advisories and guidelines voluntarily and have flexibility in what criteria they use and how the data are collected. As a result, there are significant variations in the number of waters tested, the pollutants tested for, and the threshold for issuing advisories. Based on self-reporting, the national trend is for states to monitor different waters each year, generally without retesting waters monitored in previous years.[4] As new waters are tested and results are added to previous years' findings, the number of fish advisories continues to rise. EPA makes information on the fish advisories, as well as Fish Forum proceedings, easily accessible to the public on its website.

Although most of EPA's risk communication efforts have been directed to increasing awareness of mercury in the food chain, the Agency has also investigated non-dietary sources of mercury exposure about which the public should be aware. Risk communication has been conducted in conjunction with mercury reduction activities, such as school clean-outs or thermometer collection programs. In many cases, critical mercury outreach to schools and communities would not otherwise occur without EPA assistance. For example, EPA's Region 6 has identified a particular need for such support in communities on the U.S./Mexico border.

EPA's national efforts on mercury risk communication have been aimed at making information widely available to the public and at co-sponsoring national conferences that bring together people from across the country to share information on mercury risk communication. A unique exposure concern is raised by ritualistic use of mercury in certain cultural communities. For this reason, in January 1999, EPA and the U.S. Agency for Toxic Substances and Disease Registry

(ATSDR) convened the Task Force on Ritualistic Uses of Mercury to recommend an appropriate course of action regarding the use of elemental mercury as part of certain folk practices and religious traditions. The Task Force prepared a report in 2002 which recommended approaches that rely primarily on community outreach and education activities to inform mercury suppliers and the public about mercury's risks, and encourage the use of safer alternatives.[5]

In January 2005, EPA launched its consolidated website on mercury, www.epa.gov/mercury.[6] This new website, organized by subject matter and geographic region, provides one location to find information about mercury in a useful format for the American public. Because the most effective mercury risk communication activities will be carried out at the state and local level, another important contribution to mercury risk communication is the provision of grants, cooperative agreements, and other types of funding for state, tribal, and local mercury risk communication activities.

States, tribes, and local governments have also conducted outreach activities in conjunction with most of the mercury collection programs mentioned in Sections I and II on addressing mercury releases and uses in processes and products. In order to get a high rate of participation in these voluntary programs, it is important to educate the public on the risks of mercury exposure, the need for proper disposal of mercury-containing products, and the availability of safe, non-mercury alternatives. For example, in an innovative project, the state of Minnesota trained a dog to locate mercury in buildings by sense of smell. Minnesota's Mercury-Free Zone Program is modeled after a Swedish program that uses dogs to detect mercury in schools.[7] Schools that take the mercury-free pledge are eligible to receive a visit from Clancy the mercury dog. Clancy has received media coverage which has raised general awareness of the dangers of mercury and the need to dispose of mercury responsibly. States, tribes, and local governments are in the best position to develop material tailored to local populations. For example, the state of Washington is using an EPA grant to conduct a survey of fish consumption among Asian/Pacific Islander populations in the Puget Sound region. As part of this project, the state will identify community groups to educate these populations in a culturally sensitive manner by tailoring messages and translating documents.

Future focus. As long as mercury is present in the environment and in food and consumer products, consumers will need reliable risk information about mercury exposure; about making informed choices regarding the benefits of fish consumption, the risks of consumption for certain groups, and mercury levels in certain fish; and about the purchase, use, and disposal of mercury-containing products and mercury-free alternatives. EPA will continue to provide support for national and local outreach and education programs on the effects of mercury and consumer choices. EPA will also support risk communication and outreach efforts about mercury through its international activities and programs.

Priority Activities for Mercury Risk Communication

- ***Continue Assistance in Implementing Fish Advisories*** – EPA will continue to work closely with FDA to implement the 2004 joint EPA-FDA national fish advisory for methylmercury across the

U.S. EPA will also work with FDA to continue targeted outreach efforts to the U.S. medical community to provide information on dietary risks of methylmercury exposure, and ways that medical professionals can help patients and their families reduce exposure to mercury while maintaining a healthy diet. EPA will continue to assist the states and tribes with development and communication of their fish advisories through the National Forum on Contaminants in Fish (held every 15–18 months), updating of risk communication guidance documents, and updating the National Listing of Advisories.
Timeline: Ongoing; Biennial Fish Forums

- ***Maintain Centralized Mercury Portal Website*** – EPA will provide up-to-date information on all aspects of the risk of mercury exposure through food consumption and product use by maintaining its electronic Mercury Portal Website, which will be EPA's primary mechanism for communicating with the public about mercury.
Timeline: Ongoing

- ***Assist State, Tribal, and Local Government Mercury Outreach Activities*** – EPA will continue to assist and support state, tribal, and local government efforts to conduct mercury risk communication and outreach, research and mitigation activities addressing important routes of mercury exposure, and actions that can be taken by individual consumers to reduce mercury exposure and pollution. **Timeline: Ongoing**

- ***Outreach Activities to Consumers on Mercury-containing Products and Mercury-free Substitutes for Use in the Home*** – Building upon the information already available from states and other groups about consumer products that contain mercury, EPA will develop an inventory of mercury-containing products and mercury-free substitutes. EPA will also identify information gaps. EPA will make the information available on its website.
Timeline: 2006

- ***Outreach to Health Professionals and Health Care Associations*** – Health professionals are an important partner in the dissemination of mercury risk information. EPA is working to educate health professionals about a variety of children's environmental health issues, including mercury. For example, EPA is coordinating an interagency effort to work with the Pediatric Environmental Health Speciality Units to provide pediatric consultative services covering mercury and other key concerns for children's environmental health. EPA will also partner with health care associations and universities to disseminate mercury risk information and increase proper mercury disposal in health care facilities. Through the Hospitals for a Healthy Environment (H2E) program, EPA and its regions will continue to work with universities to educate future health professionals in proper disposal of chemicals in hospitals.
Timeline: Ongoing

- ***Outreach to Schools on the Need to Remove Mercury*** – As part of its national project to work with science teachers, curriculum developers, facilities managers, and pollution prevention professionals to promote mercury reduction in schools, EPA will work to make school officials and staff

aware of the risks of exposure to mercury and the availability of mercury-free alternatives. This includes the use of software to educate school decisionmakers about potential environmental hazards in schools and ways to reduce them. **Timeline: Ongoing**

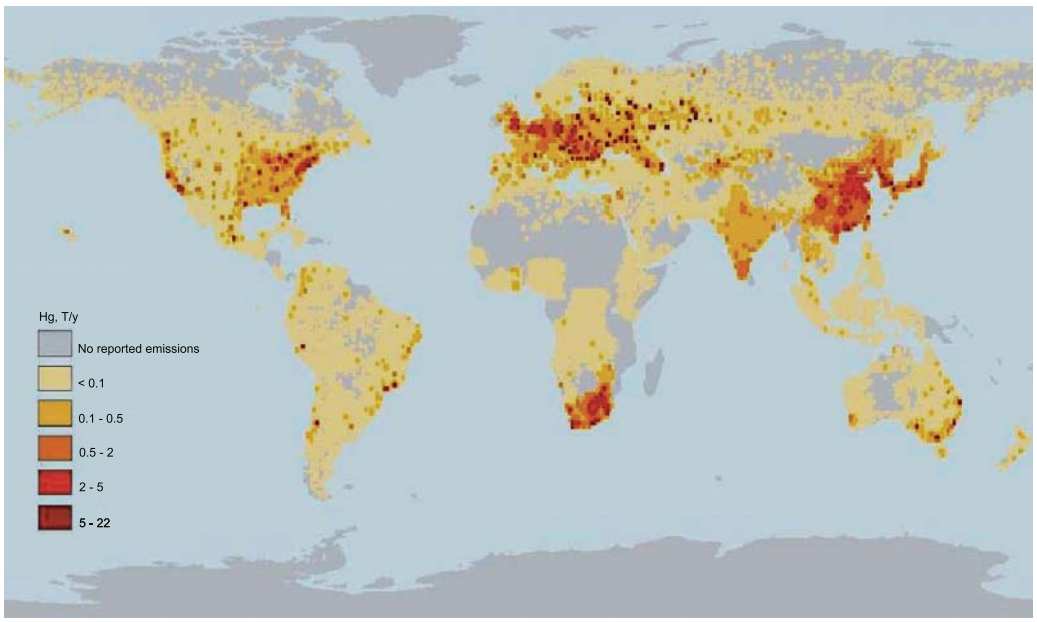
- ***Conduct Public Awareness Evaluation for Dietary Issues*** – To better educate the U.S. public on how to make informed dietary choices, FDA, with assistance from EPA, is conducting surveys to evaluate how well the U.S. public understands the effects of methylmercury exposure from eating certain fish and shellfish. **Timeline: Surveys conducted and completed during 2006/2007**

V. ADDRESSING INTERNATIONAL MERCURY SOURCES

OVERVIEW

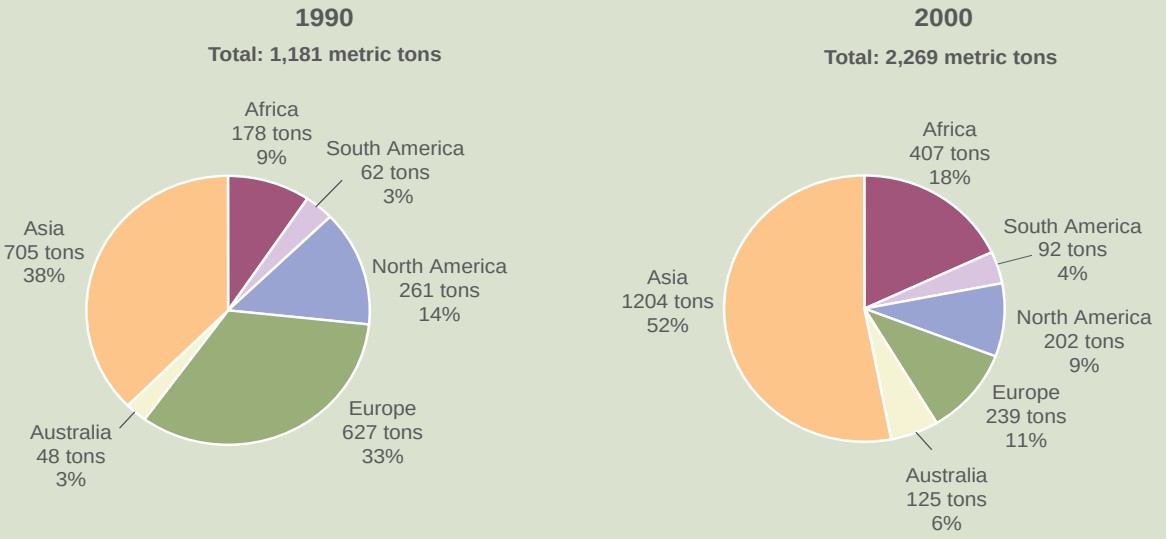
EPA is actively engaged and collaborating with international organizations and partners to address risks associated with mercury uses, releases, and exposure. As previously discussed, the greatest mercury exposure to the general population is from eating fish containing methylmercury, including marine fish. 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 modeling indicates that a substantial variation in mercury deposition occurs

FIGURE 5. Where are Man-Made Mercury Emissions Originating?[1]



1995, metric tons per year.

FIGURE 6. Man-Made Air Emissions of Mercury: Distribution by Region in 1990 and 2000[3]



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 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.[2] International collaboration is critical to refining our understanding of global mercury sources, international transport pathways, and environmental impacts, and most importantly, for addressing the adverse impacts of mercury on human health and the environment globally.

Sources. 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. The United Nations Environment Program (UNEP) estimates that the total global emissions of mercury (anthropogenic and natural to the atmosphere) range from 4,400 to 7,500 metric tons per year.[4] EPA estimates that 50–70 percent of current global anthropogenic atmospheric emissions come from fuel combustion, and much of this is from China, India, and other Asian countries.[5] Coal consumption in Asia is expected to grow significantly over the next 20 years. This source of mercury emissions may grow substantially if left unaddressed.[6] Small-scale "artisanal" gold and silver mining is an important mercury emissions source in numerous Asian, South American, and African countries. Atmospheric mercury emissions from artisanal gold mining have been estimated by UNEP to be about 300 metric tons per year,[7] but some experts estimate that total mercury releases from artisanal gold mining are between 650 and 1,000 metric tons per year on a global basis.[8] An estimated 13 million people in 55 countries work and

are affected by occupational exposures in artisanal mining.[9]

Using data presented in the 2002 United Nations Environment Program Global Mercury Assessment, EPA has calculated that mercury-cell chlor-alkali factories are the third largest source of atmospheric mercury releases to the global environment. While the number of mercury-cell chlor-alkali facilities has been greatly reduced in the United States and Europe over the last two decades, the process is prevalent in many parts of the world including Russia, several South American countries, and India, which is estimated to have the most plants of any developing country.[10] EPA estimates that there may be 135–170 mercury-cell plants globally, with half located in developing countries.[11]

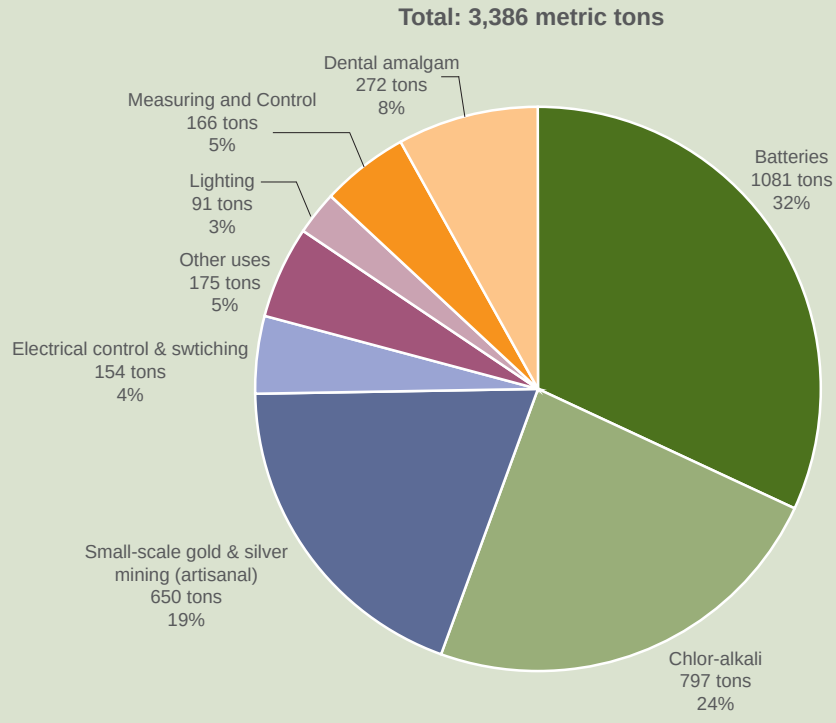
Global estimates for mercury use in processes and products range from 2,000–3,400 metric tons per year.[12] Mercury-cell chlor-alkali facilities are among the principal users of mercury in the world. In addition to industrial uses, mercury has been used in numerous products, including household appliances, electronics, batteries, automobile switches, dental amalgam, and thermometers. While mercury use in pesticides, fungicides, paints, and most batteries has been banned or phased-out in the U.S. and other developed countries, these uses are continuing in developing countries. For example, battery production accounts for an estimated one third of global mercury use in products (see Figure 7).[13]

Progress to date. EPA is currently engaged in the implementation of a wide range of bilateral, regional, and international programs and agreements to address mercury uses, releases, and the resulting exposure around the globe. These include:

- ***U.S./Canada Great Lakes Binational Toxics Strategy,*** which provides a framework for actions to reduce or eliminate mercury and other persistent toxic substances. The Strategy sets forth challenge goals to reduce mercury use by 50 percent and to reduce releases by 50 percent by 2006 (from the 1990 baseline). The use goal has been met. The releases goal has almost been met. Mercury releases have decreased by 47 percent. By 2006, additional regulations and voluntary activities are expected to reduce mercury emissions by at least 50 percent, meeting the release goal as well.[14]

- ***New England Governors/Eastern Canadian Premiers Regional Mercury***

FIGURE 7. Global Mercury Use, 2000



Action Plan, which establishes long-term and short-term regional mercury reduction goals. The plan addresses mercury emission reductions; source reduction and safe waste management; outreach and education; and research, analysis and strategic monitoring. Due to successfully reaching the goal of 50 percent reduction of emissions by 2003, the Governors and Premiers are now working on meeting a 75 percent reduction goal for emissions by 2010.[15]

- ***Commission for Environmental Cooperation (CEC) North American Regional Action Plan for Mercury,*** which aims to reduce man-made mercury releases to the North American environment through appropriate international and national initiatives to amounts that are attributable to naturally-occurring levels and fluxes. The U.S. has made considerable progress in implementing the provisions of the plan regarding mercury air emissions; processes, operations, and products; and waste management; as well as research, monitoring, modeling, and inventories; and communication activities.[16]

- ***United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution Protocol on Heavy Metals*** is a legally-binding agreement that targets emissions of cadmium, lead, and mercury. The U.S. is a party to the Heavy Metals Protocol, which went into effect in December 2003. The protocol aims to cut emissions from industrial sources, combustion processes, and waste incineration through application of best available technologies and emission limit values for new and existing stationary sources. The protocol also requires mandatory mercury concentration limits for certain types of batteries, and encourages parties to consider various management measures to address use of mercury in other products. The U.S. meets the provisions of the Heavy Metals Protocol.[17]

- ***UNEP Mercury Program,*** which was created at the February 2003 meeting of the United Nations Environment Program (UNEP) Governing Council. The United States government was instrumental in providing much of the initial funding and leadership for the creation of the UNEP Mercury Program. This program is based on the key finding of the *2002 UNEP Global Mercury Assessment* that there is sufficient evidence of significant global adverse impacts from mercury and its compounds to warrant international action to reduce the risks to human health and the environment. Supported by the 130 nations attending the Governing Council meeting, the UNEP Mercury Program endorses immediate actions to reduce mercury uses and releases, assist developing countries to create mercury emissions inventories, raise awareness, and provide technical assistance. The U.S. government has been involved in all of these efforts, and has funded the majority of the UNEP Mercury Program to date. EPA funded technical staff to work in the UNEP Mercury Program for two years, provided technical review of UNEP draft mercury guidance, and sent experts to conduct training at the UNEP regional mercury workshops.[18]

  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 reduce mercury exposure, releases, and uses. The Governing Council urged governments, intergovernmental and non-governmental organizations, and the private sector to develop and implement partnerships in a clear, transparent, and accountable manner to reduce the risks of mercury to human health and the environment.[19]

The U.S. initiated five mercury partnerships for: (1) artisanal and small-scale gold mining; (2) chlor-alkali manufacturing; (3) products; (4) coal combustion; and (5) fate and transport research. EPA held consultative meetings with other countries and domestic and international stakeholders on the first three partnerships in 2005. 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.[20]

- ***United Nations Industrial Development Organization (UNIDO) Global Mercury Project,*** which provides training on best management practices to reduce occupational exposures, to reduce emissions, and to reduce the amount of mercury used in small-scale "artisanal" gold and silver mining operations around the world. EPA has provided funding and technical expertise to assist in this effort.[21]

- ***Arctic Mercury Project,*** which was developed in the context of the Arctic Council Action Plan (ACAP) and the Arctic Monitoring and Assessment Program (AMAP). EPA has worked to strengthen capacity building and technical cooperation programs among the Arctic countries, particularly to assist Russia in the development of Russia's mercury action plan.[22] In 2005, two ACAP mercury reports were issued. The first, an "Arctic Mercury Releases Inventory," summarizes current releases, usage, and disposal of mercury within all eight Arctic countries. The second, an "Assessment of Mercury Releases from the Russian Federation," represents the first comprehensive assessment of mercury releases at the national level by that country. With the cooperation of the Russian authorities, a limited number of point sources in the Russian Federation are being evaluated in terms of their potential as sites for mercury demonstration projects. The Agency is coordinating U.S. federal government involvement, which includes the U.S. Geological Survey, Department of Energy, Department of State, and National Oceanic and Atmospheric Administration.

Future focus. EPA will continue to work with the U.S. Department of State and other federal agencies to provide international leadership in addressing mercury in international fora, including the CEC, UNECE, Arctic Council, and UNEP. Consistent with the 2005 UNEP Governing Council Decision on mercury, the goal of the U.S. government is to reduce human and ecosystem risks associated with the use and emissions of mercury from international sources. Global mercury reductions can be accomplished by addressing all major aspects of the global mercury problem and collaborating on the develop-

ment of partnerships and specific results-oriented projects to reduce mercury uses and emissions nationally, regionally, and globally. It is critical to more fully engage developed and developing countries, industry, environmental groups, international organizations, and funding institutions to bring needed technical expertise and financial resources to address the global mercury problem.

Priority Activities to Reduce Global Mercury Sources and Releases

The following is a list of important components to an international approach to facilitate global reductions in mercury use, releases, and exposure, followed by brief descriptions, and EPA's priority actions in each area. These activities build upon and complement existing actions under UNEP, UNECE, Arctic Council, UNIDO, and multi-lateral and bilateral agreements, and may include the development of or participation in specific partnerships and projects in the following areas:

- Increase international awareness of mercury risks and risk communication approaches
- Improve global understanding of international emissions sources, releases and transport mechanisms
- Address mercury emissions from point sources
- Address mercury use in products and processes where there is an opportunity to reduce risk
- Address mercury supply issues
- Improve management of mercury-containing wastes and surplus mercury

- ***Increase International Awareness of Mercury Risks and Risk Communication Approaches*** – There is a need to enhance international awareness and understanding of mercury sources (national, regional, and global) and risks to the general public. It is important to develop and share key health messages and methods regarding exposure from dietary sources (e.g., fish consumption advisories, testing methods, and protocols for determining the level of mercury in fish) and non-dietary sources (e.g., consumer products) and the need to use mercury alternatives.

  EPA will work with its federal, state, non-governmental, and international partners to:

  - Share sampling and analysis protocols that have been developed to determine the level of mercury in fish. **Timeline: Ongoing**
  - Support international outreach efforts to communicate risk. **Timeline: Ongoing**

- ***Improve International Understanding of Global Emissions Sources, Releases, and Transport Mechanisms*** – International cooperation has helped shape understanding of mercury cycling on local, regional, and global scales, and determine the effects of mercury exposure on human health. Working with international partners is critical to improving understanding of mercury's global impacts. Areas of collaboration will include transport and fate research; development of production, use, source, and emissions data.

EPA will work with its federal, state, non-governmental, and international partners to:

- Coordinate monitoring research and measurement work in Asia and elsewhere. **Timeline: Ongoing**

- Continue to conduct high altitude research in the U.S. to continue to transect with ongoing long-range transport monitoring in other parts of the world by the U.S. and other countries. **Timeline: Ongoing**

- Develop and implement workplans with UNEP, United Nations Institute for Training and Research (UNITAR) and other countries for assessment/inventory of mercury emissions and use. **Timeline: 2006**

- Support the development of a global partnership on mercury fate and transport research. **Timeline: Initiate in 2006**

- ***Address Mercury Emissions from Point Sources*** – Mercury is emitted to the air from combustion of fossil fuels, metal production, mining, mercury-cell chlor-alkali plants, waste incinerators, zinc smelters, and other point sources. International efforts to build on a number of existing techniques to reduce mercury emissions from these point sources by sharing information and expertise on air control technologies and multi-pollutant approaches will be key.

  EPA will work with other federal agencies and departments to:

  - Build on bilateral agreements to improve inventories and introduce control technologies in China, India, and Russia. **Timeline: Ongoing**

  - Achieve reductions of global mercury emissions from the coal-fired power sector through voluntary partnerships. **Timeline: Initiate in 2006**

  - Raise awareness and knowledge of the applicability, effectiveness and cost of newly emerging mercury and multi-pollutant control technologies. **Timeline: Ongoing**

  - Coordinate with the Chinese government, the private sector, Japan, and Canada to follow up on the workshop conducted in Beijing, China in November 2005 to provide information on coal-fired power plant multi-pollutant strategies and mercury control techniques, and to establish mechanisms to ensure continued information exchange with China and other countries. **Timeline: Ongoing**

  - Review data on emissions from international large-scale metals mining operations in areas with high mercury content ore and explore options for transfer of EPA Region 9's Mining Voluntary Partnership Program. **Timeline: 2006/2007**

- ***Address Mercury Use in Products and Processes*** – Mercury is used globally in a variety of products and industrial processes. For most products and processes, there are cost-effective

alternatives available that could replace mercury, which would reduce demand and emissions. There is a need for several sector-oriented approaches, including: (1) developing an industry partnership on chlor-alkali best management practices to reduce mercury use and emissions in countries or regions that use or emit the largest amounts of mercury; (2) reducing global demand for commodity-grade mercury through the use of inventories and partnering with national and international stakeholders to share information and approaches for mercury reductions and substitutes, particularly for measuring devices, batteries, and products used in the health care sector; and (3) promoting artisanal mining techniques that are safer and that eliminate or reduce the input of mercury.

EPA will work with its federal, state, non-governmental, industry, and international partners to:

- Develop a multi-stakeholder global partnership on mercury-cell chlor-alkali sector. The partnership would include pilot projects; information exchange on best management practices and conversion to non-mercury processes; and use reporting, to reduce mercury releases from facilities that use or emit the largest amounts of mercury, including facilities in Mexico, India and Russia. **Timeline: Initiated in 2005**

- Develop a multi-stakeholder global partnership for reducing or eliminating mercury use in products where there are cost-effective substitutes through pilot projects and activities, such as:

  - Sharing information and approaches for mercury reductions and substitutes (e.g., batteries and other products).

  - Conducting a mercury product workshop to build capacity in Mexico and other countries in the Caribbean, Central and South America through the CEC Mercury Task Force (U.S., Canada, and Mexico) in Merida, Yucatan, Mexico in 2006.

  - Developing country-specific use inventories, e.g. the Americas, Africa.

  - Transferring successful reduction programs, such as EPA's successful Hospitals for a Healthy Environment program and the U.S. Green Suppliers Network to other countries, e.g., China. **Timeline: Initiate in 2006**

  - Expand upon the UNIDO work on best management practices for artisanal mining to develop a multi-stakeholder global partnership on artisanal and small-scale gold mining to address use, exposure, and releases from this sector. Activities include the development of pilot projects, training, and monitoring, among others. **Timeline: Initiated in 2005**

- ***Address Mercury Supply Issues*** – Given declining demand in many developed countries, ongoing primary

mercury mining, and growing global supplies from secondary sources, prices for mercury are expected to decline. A global mercury market surplus is expected by 2020 (but may occur earlier), keeping the price of mercury low and potentially discouraging its safe storage and management, the implementation of best management practices, substitution, and phase-out. The 2005 Governing Council Decision 23/9 requests that the UNEP prepare a report on mercury supply, trade, and demand information for consideration of possible further action. The Decision also requests governments, the private sector, and international organizations to take actions to reduce risks posed on a global scale by mercury in products and processes, such as considering curbing primary mercury production (mining) and introduction of mercury into commerce.

EPA will work with the U.S. Department of State, other federal agencies, and international partners to:

- Share U.S. data on mercury imports and exports with UNEP. **Timeline: 2006**

- Explore mechanisms for facilitating the phase-out of primary mercury mining. **Timeline: Initiate in 2007**

- ***Improve Management of Mercury-Containing Wastes and Surplus Mercury*** – Mercury-containing wastes present significant challenges, where municipal, hazardous, and medical waste management systems are ill-equipped to separate mercury from the waste stream. In addition, the global supply of commodity-grade mercury will increase as various secondary sources of mercury overtake the shrinking demand. There will be an increasing need to safely manage mercury supplies for the long term. Actions may include: (1) sharing information on successful approaches and best management practices for storage of commodity-grade mercury and safe treatment, retorting, and disposal of waste, including discarded mercury-containing products; (2) coordinating waste management activities with the Basel Convention's capacity-building program for waste management to avoid duplication and to leverage resources;[23] and (3) as technologies come on-line, building capacity to create waste disposal/recycling programs for mercury-containing batteries, lamps, scrap metal, etc.

EPA will work with its federal and state partners, non-governmental organizations, and international partners to:

- Share U.S. best management practices for automobile switch removal, collection, and recycling programs. **Timeline: 2006**

- As previously discussed in the Commodity section of the Roadmap, EPA will establish a stakeholder process to address the mercury surplus issue. **Timeline: Initiate in 2006**

VI. CONDUCTING MERCURY RESEARCH AND MONITORING

MERCURY RESEARCH OVERVIEW

There is much mercury research underway to investigate the occurrence and impact of mercury in the environment. EPA is actively engaged in a variety of research activities. In 2000, EPA's Office of Research and Development (ORD) published its *Mercury Research Strategy*,[1] which provides broad strategic directions for EPA's mercury research program.

The overarching goal of the research strategy is to provide information and data that reduce scientific uncertainties limiting the Agency's ability to assess and manage mercury and methylmercury risks. The strategy provides a rationale and framework for setting future mercury research priorities, which are reflected in EPA's Mercury Research Multi-Year Plan (MYP) covering the period 2002–2010.[2] This implementation plan contains long-term goals to: (1) reduce and prevent release of mercury into the environment; and (2) understand the transport and fate of mercury from release to the receptor and its effects on the receptor.

In conducting its mercury research program, ORD's in-house efforts are coupled with those of its Science to Achieve Results (STAR) Grants Program,[3] which sponsors extramural research on many topics by academic institutions and other not-for-profit entities. In addition, some of EPA's research is undertaken in cooperation with other organizations such as the U.S. Department of Energy (DOE) and the U.S. Geological Survey (USGS). Important coordination occurs among federal agencies and state, tribal, and local governments, through science forums such as the EPA/USGS Mercury Roundtable.[4] It is also important to note that additional

mercury research activities are conducted by EPA headquarters and regional offices that are not described in ORD's Mercury Multi-Year Plan.

The primary exposure route addressed in the ORD Mercury Research Strategy involves fish consumption where deposited mercury is converted to methylmercury in water bodies, consumed by fish, and then accumulated in mammals, including humans that eat fish. Within the context of this primary exposure route, EPA has analyzed various scientific questions, including the following.

Key Scientific Questions

- How much methylmercury in fish consumed by the U.S. population is contributed by U.S. emissions relative to other sources of mercury (such as natural sources, emissions from sources in other countries, and re-emissions from the global pool)? How much, and over what time period, will levels of methylmercury in fish in the U.S. decrease due to reductions in environmental releases from U.S. sources?

- How much can mercury emissions from coal-fired power plant boilers and other combustion systems be reduced with innovative mercury-specific and multi-pollutant control technologies? What is the relative performance and cost of these approaches compared to currently available technologies?[5]

- What is the magnitude of contributions of mercury releases from non-combustion sources? How can the most significant releases be minimized?[6]

- What critical changes in human health are associated with exposure to environmental sources of methylmercury in the most susceptible human populations? How much methylmercury are humans exposed to, particularly women of child-bearing age and children among highly-exposed population groups? What is the magnitude of uncertainty and variability of mercury and methylmercury toxicokinetics in children?[7]

- What are the most effective means for informing susceptible populations of the health risks posed by mercury and methylmercury contamination of fish and seafood?[8]

EPA based the proposed and final §112(n) Revision Rule and the Clean Air Mercury Rule on the current state of the science.[9] In the context of these rules, EPA, among other things, identified the pertinent health endpoints associated with methylmercury contamination, considered the primary exposure pathways for ingestion of methylmercury, analyzed mercury control technologies, and considered the effectiveness and costs associated with reducing mercury emissions from coal-fired power plants. EPA recognizes that there remain scientific uncertainties associated with some of the above-noted questions and is committed to continuing to work to advance the science in these areas.

Progress to date. Research results provide important information to support EPA's air, water, waste, and toxics programs in their ongoing efforts to address mercury. In recent years the major emphasis of research activities has been to support EPA's regulatory efforts to control mercury from coal-fired power plants, and to increase the Agency's understanding of

mercury fate and transport. The following are major research results from the period 2001–2004.

EPA researchers have developed the methodology and instrumentation to make semi-continuous ambient measurements that distinguish among mercury forms—elemental gaseous mercury, divalent mercury (also referred to as reactive gaseous mercury [RGM]), and particulate phase mercury. The resulting speciated data have improved the understanding of atmospheric transport and fate and enhanced the ability to attribute the relative contributions of local, regional, and global sources of mercury to domestic and global deposition.[10]

EPA has produced a state-of-the-science atmospheric simulation model which incorporates the current understanding of chemical and physical processes involving mercury, including complex interactions with other atmospheric pollutants. This model uses highly efficient formulations and numerical methods, and has recently been used to simulate a full year of atmospheric mercury transport and fate over most of North America. Notwithstanding these recent advances in modeling atmospheric fate, transport, and deposition of mercury, there remain difficult scientific challenges to resolve. The Agency is currently working with international groups to better quantify atmospheric chemistry kinetics in Community Multiscale Air Quality (CMAQ) and to readily assess the impacts of these model adjustments to the fate, transport, and deposition of mercury.[11]

EPA has developed and tested mass balance models that use speciated atmospheric mercury deposition fluxes to calculate expected watershed mercury loadings, water body concentrations, and concentrations in fish. EPA's STAR grant research program, in addition to its research in other areas, has furthered the understanding of the reduction-oxidation balance between aquatic mercury and atmospheric mercury, and the effect of this cycling on the total mercury presence in freshwater and marine systems.

EPA's research program has provided extensive support to Agency program offices and the Administrator on mercury control technologies, including:

- Several comprehensive reports that document the development, cost and effectiveness of various mercury-specific control technology options (including sorbent injection), and evaluate co-control reductions that can be achieved using existing technologies including sulfur dioxide (SO2) scrubbers and selective catalytic reduction (SCR)-based nitrogen oxide (NOx) emissions control systems;[12]

- A White Paper, placed in EPA's coal-fired power plant rulemaking regulatory docket, summarizes the status of control technology options and outlines what can be achieved in the future using various alternative mercury removal technologies. This White Paper was updated to support EPA's Office of Air and Radiation and enable stakeholders to identify optimal management approaches.[13] In particular, these research results provide state agencies, industry, and others with the most current technology performance and cost information to inform their implementation decisions.

EPA has developed a report describing the impact of selected mercury control technologies on the characteristics of coal combustion residues and how selected utilization/disposal practices impact the fate of mercury residues. As part of this effort, ORD has generated a standard protocol that will be used to establish the leaching and thermal stability for the range of environmental conditions that coal combustion residues are exposed to during storage, land disposal, and use in commercial applications.[14]

EPA has evaluated the performance of continuous emission monitors (CEMs) for coal-fired power plant boilers as one possible tool for measuring total and speciated forms of mercury emitted from plants under different operating conditions.[15] Based on that evaluation, the Agency has concluded that CEMs are suitable regulatory tools. EPA's evaluation entailed a series of pilot-scale combustion experiments, representing realistic coal-fired power plant boiler measurement environments, that allowed controlled investigation of specific measurement issues associated with mercury CEM operation. Measurement results were obtained rapidly so that timely feedback could be provided to the monitor manufacturers in order to optimize their instruments. The improvements accomplished during the pilot-plant tests resulted in these same mercury CEMs participating in three full-scale utility boiler field evaluations that demonstrated their performance and capabilities. These results also apply to hazardous waste incinerators.

EPA has conducted a literature review to assess mercury methylation processes in aquatic sediments to inform selection and implementation of risk management strategies. This provided the technical foundation for subsequent products including a literature review of the sources and remediation of mercury-contaminated sediments and a model for evaluating the effects of remedial actions on mercury speciation and transport.[16] This work demonstrated how the introduction or exclusion of oxygen via risk management strategies impacted the fate and transport of mercury in sediments.

EPA has evaluated the effectiveness of several risk management strategies to address mercury-contaminated sediments, including dredging, capping, and monitored natural recovery. Work has focused on the Lavaca Bay, Texas Super-fund site.

EPA, as part of its effort to develop treatment alternatives for waste from sites contaminated with mercury mining wastes, has completed a study describing leaching profiles of mercury-containing waste rock and roaster tailings from a Superfund site in California.[17] These results were used to predict the fate and stability of mercury present, and will be used to assess the suitability of any applicable remediation treatment.

To support EPA's efforts to address issues associated with the long-term storage of mercury, the Agency has: (1) completed a report that describes a systematic method for comparing options for the long-term management of surplus elemental mercury in the U.S.,[18] and (2) collected information on state-of-the-art practices for macro-encapsulation and micro-encapsulation of mercury-contaminated hazardous wastes.

EPA has evaluated the effectiveness of some existing and future risk communication tools in a variety of formats, using 18 focus groups. Results show clear age,

gender, and risk-related trends, which indicate that different risk communication tools will be required for each of these audiences, and that no one tool will be optimally effective across the board. The results of this work will be published in 2006/2007, and will add to the body of work outlining risk communication as an important tool for reducing environmental risk and protecting human health.

EPA is working with states to conduct research on fish tissue. For example, Region 8 has collected over 500 fish samples over the last three years from the Cheyenne River Sioux Tribal lands in stock ponds and in the Cheyenne, Moreau, and Missouri Rivers. Data from Region 8 showed that fish from small ponds have high levels of methylmercury. This may be a function of a biogeochemically favorable environment for methylmercury production (i.e., methylation of elemental mercury) in these environments, although further research is needed to confirm this hypothesis.

Region 8 has also used the data to determine Exposure Point Concentrations (EPC) for several species.[19] The regional office is working with the tribe to make recommendations on fish stocking in stock dams, and also on recommendations about how many meals per month should be eaten for each species according to the mercury EPC for that species.

Future focus and priority activities. EPA will continue to support the long-term goals described in the *Mercury Multi-Year Plan* and this *Roadmap*. The major emphasis of the mercury research program will continue to be the control of utility emissions, because utilities represent the most significant source of mercury release to the atmosphere in the United States.

- ***Toxic Metals Fate Report*** – EPA will develop a report on the fate of toxic metals from land disposal and commercial use of coal combustion residues from plants equipped with multi-pollutant control technologies. **Timeline: 2008**

- ***Sources of Mercury Emissions*** – EPA will develop information on sources of mercury emissions including the regional/global atmospheric fate and transport of such emissions. **Timeline: 2008**

How EPA Will Track Progress and Key Trends

1. **Air Emissions**
   - National Emissions Inventory (EPA)
     - EPA's primary source for air emissions data
   - Toxics Release Inventory (EPA)
2. **Ambient Air and Air Deposition**
   - Mercury Deposition Network (MDN) (joint federal/state program)
   - New England Mercury Monitoring Network (joint EPA/state program)
   - Long Range Transport Monitoring (joint EPA/NOAA activity)
3. **Water Quality/Fish Tissue**
   - National Fish Tissue Study (baseline study) (EPA)
   - National Listing of Fish Advisories (EPA)
   - National Coastal Assessment ecological monitoring (EPA)
   - Commercial fish monitoring (FDA)
4. **Human Biomonitoring**
   - National Health & Nutrition Examination Survey (CDC)

- ***Integrated Multimedia Modeling*** – EPA will develop an integrated multimedia modeling framework for the scientific understanding of mercury. **Timeline: 2010**

MERCURY MONITORING OVERVIEW

There are many ongoing monitoring projects and programs that measure mercury in various media. These projects and programs are conducted by other federal agencies, states and tribal governments, and in academia. Access to routine, ongoing monitoring information is needed to track environmental and health trends and to measure program effectiveness.

A basic strategy for routine mercury monitoring is to focus on the most efficient points to monitor along the major transport and exposure path of air-to-water-to-fish-to-humans, in order to determine trends in environmental and health levels and whether they are responding to control and reduction measures. Based on this mercury transport and exposure path, the four most important media of concern are: (1) air emissions, (2) ambient air and air deposition, (3) fish tissue, and (4) human tissue. The Centers for Disease Control and Prevention (CDC) collects data on human tissue, which includes blood, hair, and urine. Data on emissions and deposition allow EPA to detect changes quickly that reflect program activities with great relevance to long-term health and the environment. Data on fish and human tissue allow EPA to measure longer-term changes that are slower to respond to control measures but are better indicators of environmental quality and human health. EPA will continue to work with other federal agencies, states, and tribal governments to coordinate and enhance data collection for these four key indicators of long-term trends and program results for mercury.

Progress to date. Much progress has been made by EPA and others to establish monitoring and reporting systems to collect data on mercury releases and contamination. During the last five years, in particular, EPA has encouraged and supported increased national monitoring of mercury in both fish tissue and human blood and hair samples, which is discussed in more detail below. The following discussion provides information on current monitoring programs conducted or supported by EPA, and on recent EPA reports that highlight significant new data from various mercury monitoring activities.

Air Emissions Monitoring

Atmospheric transport is the primary focus for mercury monitoring and modeling, as it is the dominant means for cycling mercury from anthropogenic sources, such as coal-fired power plant combustion sources, into other media. Emissions inventories provide information about the sources of mercury, and the relative contributions of those sources to total releases. Routine air emissions monitoring is needed to track long-term trends of mercury emissions over time and geographic space in the U.S. Such information is essential to evaluating the success of EPA's programs for reducing mercury air emissions from specific sources.

Two key EPA reporting efforts for air emissions are the *National Emissions Inventory (NEI)* and the *Toxics Release Inventory (TRI)*. These databases have been modified and improved over time so that the Agency has the latest information necessary to measure program effective-

ness and track environmental trends. (For further information, see Section I.)

Ambient Air and Air Deposition Monitoring

Both ambient air monitoring and air deposition networks provide information on mercury once it has been emitted. This monitoring information is needed to track long-term mercury contamination in ambient air, and to provide input to ongoing research and modeling activities to improve scientific understanding of mercury transport and fate in the environment; stationary and mobile sources of mercury; and the relative contributions of those sources to total mercury releases to the environment.

Major routine monitoring activities for mercury in ambient air and air deposition include the following:

- ***Mercury Deposition Network (MDN)***[20] – Formed in 1995, the MDN is part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN), a nationwide network of over 70 precipitation monitoring sites that collect weekly data on the chemistry of precipitation for monitoring of long-term geographical and temporal trends. The network is a cooperative effort among state agricultural experiment stations, the U.S. Geological Survey, U.S. Department of Agriculture, EPA, and numerous other governmental and private entities. Information from the MDN is being used to develop a national database of weekly concentrations of total mercury in precipitation and the seasonal and annual flux of total mercury in wet deposition. However, there are some gaps in the current geographic coverage of MDN which may limit the analysis. Also, the MDN does not collect data on dry deposition for either elemental or divalent mercury. At present, no adequate field routine measurement method exists. EPA and others recognize that dry deposition data are important—in some areas such data are as important as wet deposition in understanding total deposition. For these reasons, EPA announced in December 2005 a request for proposals to stimulate development of such methods.

- ***New England Mercury Monitoring Network*** – EPA and the New England states have established a mercury monitoring network. A number of monitoring field studies have been initiated in New England to measure mercury deposition and ambient concentration of atmospheric mercury. These studies provide baseline information on mercury deposition to support regional efforts to control mercury contamination and to evaluate the ecological effects of mercury contamination.

- ***Long Range Transport Monitoring*** – EPA, in collaboration with the U.S. National Oceanic and Atmospheric Administration (NOAA), is working with other countries on characterization, modeling, and speciation of ambient and source level mercury related to mercury emissions transport and deposition on local, regional, and global scales. As part of this effort, high and low altitude monitoring is being conducted at various sites, including Mauna Loa, Hawaii. (For further information, see Section V.)

Fish Tissue Monitoring

Monitoring of fish tissue provides essential information about the levels of mercury consumed by the human population. Routine monitoring of marine and freshwater fish consumed in the U.S. diet is needed to track trends in the level of likely mercury exposure by the U.S. population, as well as trends in mercury concentrations in fish in U.S. water bodies over time and geographic space. Information on mercury concentrations in fish tissue from U.S. water bodies is essential to evaluating the success of EPA's programs for addressing mercury releases from air, water, and land sources. EPA has recently developed a new water quality criterion for mercury that is based on the amount of mercury found in fish tissue rather than the amount in water bodies. Fish tissue data are also needed as input to research and modeling activities to improve scientific understanding of mercury transport and fate in the environment; sources of mercury in water bodies; and the relative contributions of those sources to total mercury releases to the environment.

Many governmental organizations provide important monitoring data on fish, such as FDA's commercial fish monitoring program.[21] EPA's major monitoring activities include the following:

- ***EPA's National Lake Fish Tissue Study***[22] – The National Study of Chemical Residues in Lake Fish Tissue (or National Lake Fish Tissue Study) is being conducted by EPA's Office of Water (OW). It is a one-time screening-level study to sample contaminants in fish tissue in freshwater lakes and reservoirs in the contiguous U.S., including mercury as well as other chemicals. EPA will use the study results to develop the first national estimates of the mean concentrations of mercury and 267 other chemicals in lake fish, to define a national fish contamination baseline to track progress of pollution control activities, and to identify areas where contaminant levels are high enough to warrant further investigation. Sampling has been conducted for four years at a total of 500 locations, or about 125 sites annually. EPA has worked with 47 states, three tribes and two other federal agencies to collect fish for the study. While planning for the study began in 1998, fish sampling began in 2000 and ended in November 2003. EPA has released all 4 years of raw data to the public. Agency analysis of the cumulative 4-year data set will be completed, and the final report will be completed in December 2006.

- ***EPA's National Listing of Fish Advisories***[23] – This database contains all fish advisory information provided to EPA by the states, tribes, and Canada. It also contains information on mercury in fish tissue that states and tribes collect as part of their fish advisory programs. States monitor their waters by sampling fish tissue for persistent pollutants that bioaccumulate. States issue their guidelines voluntarily and have flexibility in what criteria they use and how the data are collected. As a result, there are significant variations in the number of waters tested, the pollutants tested for and the threshold for issuing advisories. Based on self-reporting, the national trend is for states to monitor different waters each year, generally without retesting waters monitored in previous years. States issue fish consumption advisories to

the public if elevated concentrations of chemicals such as mercury are found in local fish. EPA makes information about fish advisories easily accessible to the public on its website.

- ***EPA's Ecological Monitoring to Characterize the Condition of U.S. Estuarine Resources*** – As part of its National Coastal Assessment, EPA's Office of Research and Development seeks to characterize the ecological condition of U.S. estuarine resources through the collection and analysis of fish tissue for mercury (and various other contaminants) from estuaries throughout the U.S., at about 35–100 sites per year for each of twenty-three coastal states and Puerto Rico. The National Coastal Assessment data is a relatively new program in the Office of Research and Development, which is beginning to provide information on fish tissue toxics concentrations from selected U.S. estuaries. ORD is currently reviewing these data to determine their usefulness for integration with existing EPA approaches for assessing fish tissue mercury concentrations and their changes over time due to both emissions and deposition changes.

States are also actively engaged in monitoring fish levels of methylmercury in their waters. For example, the Alaska Department of Environmental Conservation has been conducting a multi-year study of safety of fish and seafood resources in Alaska waters with respect to contaminants. EPA Region 10 secured funding for Alaska to perform additional PBT organic analyses, including methylmercury, and a final report is pending. This monitoring project is ongoing.

Human Biomonitoring

Routine monitoring of human tissue samples is needed to track long-term trends in the levels of mercury exposure of people in the U.S. over time and geographic space. CDC collects data on human tissue, including blood, hair, and urine. Such human biomonitoring may be the most meaningful long-term indicator of the effectiveness of programs for reducing risks associated with mercury releases and exposure. It is also useful in setting priorities for future research and for risk communication strategies and activities to reduce mercury exposure in the short-term.

The level of methylmercury in blood is the best available indicator of human exposure to methylmercury through fish consumption. Mercury blood levels in women of childbearing age is an especially useful indicator of mercury exposure, since this measure indicates both the actual exposure of adult women and the potential for exposure of fetuses through the transfer of maternal blood through the placenta. Other types of human tissue have been sampled for mercury such as hair, but so far they have been found less useful than blood levels. At the present time there is insufficient understanding of the relationship of mercury in blood and hair to mercury levels found in these other tissues.[24]

The only source of nationwide information on methylmercury in humans is the *National Health and Nutrition Examination Survey (NHANES)*, which is conducted by the U.S. Centers for Disease Control and Prevention (CDC) with financial support from EPA and other agencies. NHANES is a continuous survey of the health and nutritional status of the civilian, non-

institutionalized U.S. population, and data are released and reported in 2-year cycles.[25]

In 1999 NHANES began measuring mercury levels in blood, hair, and urine for the first time in a national sample of childbearing-aged women and in children aged 1–5 years in the U.S. The CDC's report, published in 2003, provided the first nationally representative estimates of U.S. women's and children's exposures to mercury based on biologic measures.[26]

In November 2004, the CDC published an updated summary of NHANES data for the four-year period 1999 to 2002.[27] These updated findings confirm that blood mercury levels in women of childbearing age are usually below levels of concern, but that approximately six percent of childbearing-aged women had levels at or above EPA's Reference Dose (RfD).

CDC plans to continue this NHANES mercury monitoring in future years. NHANES 2005–2006 will include measurements of mercury species (methyl, ethyl, and inorganic) in blood in order to define more precisely the exposure to various sources of mercury. Blood mercury levels will be measured in persons (male and female) one-year and older, while urinary mercury will be measured in persons six years of age and older.[28]

Recent EPA Reports Utilizing Mercury Monitoring Data

- ***America's Children and the Environment: Measures of Contaminants, Body Burden, and Illness***[29] – Published in February 2003, this is EPA's second report on trends in environmental factors related to the health and well-being of children in the U.S. The report brings together, in one place, quantitative information from a variety of sources to show trends in levels of environmental contaminants in air, water, food, and soil; concentrations of contaminants measured in the bodies of children and women; and childhood illnesses that may be influenced by exposure to environmental contaminants. This second report provides mercury information for the first time. The section on body burdens includes a new measure of mercury in the blood of women of child-bearing age, using NHANES data. A new section on emerging issues presents information about important aspects of children's environmental health for which data had recently become available, including mercury in fish as an important source of mercury exposure for people in the U.S.

- ***EPA's Draft Report on the Environment 2003***[30] – Published in June 2003, the report presents EPA's first national picture of the U.S. environment, including mercury contamination. This report was the first step in the Agency's Environmental Indicators Initiative, launched in November 2001, which seeks to identify better indicators that EPA can use to measure and track the state of the environment and support improved environmental decisionmaking.

Future focus and priority activities. EPA will continue to need reliable sources of routine mercury monitoring data. Since monitoring activities are resource intensive, EPA will continue its current strategy of focusing primarily on monitoring for a small number of key environmental and health indicators, and to leverage resources by looking for opportunities to collaborate with other governmental and

non-governmental entities where appropriate. In addition, the Agency plans to publish the following documents:

- ***Final Results of EPA's National Lake Fish Tissue Study*** – The final report will be published in 2006. EPA will use the study results to develop the first national estimate of mean concentrations for mercury and 267 other chemicals in fish, to provide a baseline to track progress of pollution control activities, and to identify areas where contaminant levels are high enough to warrant further investigation.

- ***EPA's Report on the Environment 2007*** – Under EPA's Environmental Indicators Initiative, the Agency will continue working to identify better indicators that EPA can use to measure and track the state of the environment and support improved environmental decisionmaking. The next report to present a national picture of the U.S. environment, planned for publication in 2007, will be providing additional emphasis on mercury indicators and information.

APPENDIX

The Facts

Fish and shellfish are an important part of a healthy diet. Fish and shellfish 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. So, women and young children in particular should include fish or shellfish in their diets due to the many nutritional benefits.

However, nearly all fish and shellfish contain traces of mercury. For most people, the risk from mercury by eating fish and shellfish is not a health concern. Yet, some fish and shellfish contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) are advising women who may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish and eat fish and shellfish that are lower in mercury.

For further information about the risks of mercury in fish and shellfish call the U.S. Food and Drug Administration's food information line toll-free at **1-888-SAFEFOOD** or visit FDA's Food Safety website **www.cfsan.fda.gov/seafood1.html**.

For further information about the safety of locally caught fish and shellfish, visit the Environmental Protection Agency's Fish Advisory website **www.epa.gov/ost/fish** or contact your State or Local Health Department. A list of state or local health department contacts is available at **www.epa.gov/ost/fish**. Click on Federal, State, and Tribal Contacts. For information on EPA's actions to control mercury, visit EPA's mercury website at **www.epa.gov/mercury**.

EPA-823-F-04-009

What You Need to Know About Mercury in Fish and Shellfish

Advice for

Women Who Might Become Pregnant
Women Who are Pregnant
Nursing Mothers
Young Children

from the
U.S. Food and Drug Administration
U.S. Environmental Protection Agency

3 Safety Tips

By following these 3 recommendations for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury.

1. Do not eat:

- **Shark**
- **Swordfish**
- **King Mackerel**
- **Tilefish**

They contain high levels of mercury.

2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.

- Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
- Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas.

If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

Visit the Food and Drug Administration's Food Safety Website www.cfsan.fda.gov or the Environmental Protection Agency's Fish Advisory Website www.epa.gov/ost/fish for a listing of mercury levels in fish.

Frequently Asked Questions *about Mercury in Fish and Shellfish:*

What is mercury?

Mercury occurs naturally in the environment and can also be released into the air through industrial pollution. Mercury falls from the air and can accumulate in streams and oceans and is turned into methylmercury in the water. It is this type of mercury that can be harmful to your unborn baby and young child. Fish absorb the methylmercury as they feed in these waters and so it builds up in them. It builds up more in some types of fish and shellfish than others, depending on what the fish eat, which is why the levels vary.

I'm a woman who could have children but I'm not pregnant - so why should I be concerned about methylmercury?

If you regularly eat types of fish that are high in methylmercury, it can accumulate in your blood stream over time. Methylmercury is removed from the body naturally, but it may take over a year for the levels to drop significantly. Thus, it may be present in a woman even before she becomes pregnant. This is the reason why women who are trying to become pregnant should also avoid eating certain types of fish.

Is there methylmercury in all fish and shellfish?

Nearly all fish and shellfish contain traces of methylmercury. However, larger fish that have lived longer have the highest levels of methylmercury because they've had more time to accumulate it. These large fish (swordfish, shark, king mackerel and tilefish) pose the greatest risk. Other types of fish and shellfish may be eaten in the amounts recommended by FDA and EPA.

Note:
If you have questions or think you've been exposed to large amounts of methylmercury, see your doctor or health care provider immediately.

I don't see the fish I eat in the advisory. What should I do?

If you want more information about the levels in the various types of fish you eat, see the FDA food safety website www.cfsan.fda.gov/~frf/sea-mehg.html or the EPA website at www.epa.gov/ost/fish.

What about fish sticks and fast food sandwiches?

Fish sticks and "fast-food" sandwiches are commonly made from fish that are low in mercury.

The advice about canned tuna is in the advisory, but what's the advice about tuna steaks?

Because tuna steak generally contains higher levels of mercury than canned light tuna, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of tuna steak per week.

What if I eat more than the recommended amount of fish and shellfish in a week?

One week's consumption of fish does not change the level of methylmercury in the body much at all. If you eat a lot of fish one week, you can cut back for the next week or two. Just make sure you average the recommended amount per week.

Where do I get information about the safety of fish caught recreationally by family or friends?

Before you go fishing, check your Fishing Regulations Booklet for information about recreationally caught fish. You can also contact your local health department for information about local advisories. You need to check local advisories because some kinds of fish and shellfish caught in your local waters may have higher or much lower than average levels of mercury. This depends on the levels of mercury in the water in which the fish are caught. Those fish with much lower levels may be eaten more frequently and in larger amounts.

ENDNOTES

Introduction

1. "EPA Releases 12th Annual National Listing of Fish Advisories." Press release. August 24, 2004.

2. EPA, 2005c. U.S. Environmental Protection Agency. National Listing of Fish Advisories. Fact Sheet, Sep. 2005. EPA-823-F-05-004. Accessible at: http://epa.gov/waterscience/fish/advisories/fs2004.pdf.

3. Table 1: National Air Emissions Inventory for Mercury. Source: EPA, 1999a.

4. Figure 1: The Mercury Cycle. Adapted from EPA, 1997. Mercury Study Report to Congress. EPA-452/R-97-003, December 1997. Accessible at: www.epa.gov/ttn/oarpg/t3/reports/volume1.pdf.

5. EPA, 2001a.

   NRC, 2000. National Research Council. Toxicological Effects of Methylmercury. Committee on The Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology. Accessible at: http://books.nap.edu/books/0309071402/html/1.html.

6. EPA, 1997. Mercury Study Reprot to Congress. EPA-452/R-97-003, December 1997. Accessible at: www.epa.gov/ttn/oarpg/t3/reports/volume1.pdf.

7. EPA, 1997.

8. EPA, 1997.

9. EPA, 2005a. Technical Support Document, Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants From Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the §112(c) List: Reconsideration, Oct. 21, 2005. Accessible at: www.epa.gov/ttn/atw/utility/TSC-112finaL.pdf.

10. A Community Multiscale Air Quality (CMAQ) modeling run was performed to estimate the impact of global sources on U.S. deposition estimates. For this analysis, all non-U.S. mercury input species to the model were set to zero. By comparing the results of this analysis with the 2001 Clean Air Mercury Rule (CAMR) base case run, which included all U.S. and global mercury species, the percent of total mercury deposition attributable to global sources can be estimated. The model estimated that over 80 percent of total mercury deposition in the U.S. is attributable to global sources.

    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.

11. EPA, 2005a.

I. Addressing Mercury Releases

1. EPA, 1999a. 1999 National Emissions Inventory Documentation and Data—Final Version 3.0. Accessible at: www.epa.gov/ttn/chief/net/1999inventory.html.

2. EPA, 1999a.

3. Table 1: National Air Emissions Inventory for Mercury. Source: EPA, 1999a.

4. President's Clear Skies Legislation of 2003. For information, see: www.epa.gov/air/clearskies/.

5. EPA. Clean Air Act rules on mercury emissions. For information on EPA's activities to control power plant emissions, see: www.epa.gov/mercury/control_emissions/index.htm.

6. EPA, 1999b. Residual Risk Report to Congress. EPA 453/R-99-001, March 1999. Accessible at: www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf.
   For information about EPA's Residual Risk Program, see: www.epa.gov/ttn/atw/rrisk/residriskpg.html.

7. EPA. Nevada Mining Partnership Program. For information, see: www.epa.gov/Region9/cross_pr/innovations/mining.html.

8. EPA, 2004a. 2003 Report on Success of Voluntary Mercury Reduction Program (VMRP) with Nevada Gold Mines, October, 2004. Accessible at: www.epa.gov/region9/toxic/mercury/goldmine.pdf.

9. 64 Federal Register 38705, 7/19/99.

10. EPA. Area Source Standards. For information, see: ww.epa.gov/ttn/atw/urban/arearules.html.

11. Ecology Center, 2001. Ecology Center, Great Lakes United, and University of Tennessee Center for Clean Products and Clean Technologies. Toxics in Vehicles: Mercury. Accessible at: www.cleancarcampaign.org/pdfs/toxicsinvehicles_mercury.pdf.

12. The estimate is based on data gathered from industry by EPA during the initial phase of EAF area source rulemaking which is still under development.

13. EPA. National Pollutant Discharge Elimination System (NPDES) Permits. For information about this program, see: http://cfpub.epa.gov/npdes/.

14. Alpers, C.N. and M.P. Hunerlach, 2000. Mercury contamination from historic gold mining in California. USGS Fact Sheet FS-061-00. Accessible at: http://ca.water.usgs.gov/mercury/fs06100.html.

15. EPA, 2005b. 2003 Toxics Release Inventory (TRI) Public Data Release eReport, May, 2005. Accessible at: www.epa.gov/tri/tridata/tri03/2003eReport.pdf.

16. EPA, 2005b.

17. EPA, 2001b. Water Quality Criterion for the Protection of Human Health: Methylmercury. EPA-823-R01-001. Accessible at: www.epa.gov/waterscience/criteria/methylmercury/.

18. EPA, 2001a.

19. 40 Code of Federal Regulations 130.7.

20. These statistics were compiled from data received by EPA and available on its Total Maximum Daily Loads (TMDL) webpage accessible at: http://oaspub.epa.gov/waters/national_rept.control.

21. EPA, 2005c.

22. EPA, 2001b.

23. These statistics were compiled from data received by EPA and available on its TMDL webpage accessible at: http://oaspub.epa.gov/waters/national_rept.control.

24. 40 Code of Federal Regulations 132 Table 4.

25. The average was developed by EPA based on effluent data reported by the EPA Region 5 states: Illinois, Indiana, Ohio, Michigan, Minnesota and Wisconsin. States discuss effluent data in reports on their web sites. For example:
Michigan: www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11384—,00.html.
Wisconsin: http://dnr.wi.gov/org/caer/cea/mercury/potw.htm.
Minnesota: www.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html.

26. Cocca, P. 2001. Mercury Maps: National Report on Human Exposure to Environmental Chemicals. Publication No. 01-0379.

27. Clean Water Act (Federal Water Pollution Control Act, as amended) §307(b); 33 United States Code §1317.

28. LWA, 2002. Larry Walker Associates. Mercury Source Control and Pollution Prevention Evaluation, Final Report, March 2002, amended July 2002. Prepared for: Association of Metropolitan Sewerage Agencies. Accessible at: www.amsa-cleanwater.org/advocacy/mercgrant/finalreport.pdf.

29. San Francisco Public Utilities Commission. For information about the San Francisco Dental Mercury Reduction Program, see: http://sfwater.org/main.cfm/MC_ID/4/MSC_ID/85.

30. EPA, 2005b.

31. Surface impoundments include natural topographic depressions, man-made excavations and diked areas that primarily are made of earthen materials and which hold liquid wastes. These uncovered areas are commonly used to volatilize and/or settle materials. **Other surface impoundments are surface impoundments other than those which are authorized under the Resource Conservation and Recovery Act (RCRA) to accept hazardous waste for disposal.**

32. Other land disposal is the disposal of the toxic chemical to land at the facility that does not fall into one of the other on-site land release categories found in Section 5.5.1 through 5.5.3 of the TRI Form R. **Other disposal includes such activities as placement in waste piles and spills or leaks.** Data from Section 5.5.4 on the TRI Form R.

33. Mercury -Containing and Rechargeable Battery Act, 42 United States Code 14301, and EPA Universal Waste Rule. For information, see: www.epa.gov/epaoswer/hazwaste/id/univwast/regs.htm.

34. EPA. Municipal Incinerator Rules. For information about Large Municipal Waste Combustors, see: www.epa.gov/ttn/atw/129/mwc/rimwc.html.
For information about Small Municipal Waste Combustors, see: www.epa.gov/ttn/atw/129/mwc/rimwc2.html.

35. EPA. Universal Waste Regulations. For information, see: www.epa.gov/epaoswer/hazwaste/id/univwast/regs.htm.

36. 70 Federal Register 45508, 8/5/05.

37. EPA. Superfund National Priorities List. For information on NPL Site Listing Process, see: www.epa.gov/superfund/sites/npl/npl_hrs.htm.

38. EPA. RCRA Corrective Action Program. For information on the program, see: www.epa.gov/epaoswer/hazwaste/ca/backgnd.htm#5.

39. Maine. An Act to Prevent Mercury Emissions When Recycling and Disposing of Motor Vehicles. Provision to remove mercury switches found at Sec. 3.38 Me.Rev.Stat.Ann.tit. §1665-A.3. Accessible at: http://janus.state.me.us/legis/ros/lom/LOM120th/5Pub651-700/Pub651-700-05.htm.

40. Ecology Center, 2001.

41. EPA, 2005d. Clean Air Mercury Rule (CAMR) and Clean Air Interstate Rule (CAIR). For information, see: www.epa.gov/air/mercuryrule/.

42. 69 Federal Register 21198, 4/20/04.

43. 68 Federal Register 70903, 12/19/03.

44. 69 Federal Register 21906, 4/22/04.

45. Cocca, P. 2001.

    64 Federal Register 38705, 7/19/99.

II. Addressing Mercury Uses in Products and Processes

1. Jasinski, S.M., 1994. The Materials Flow of Mercury in the United States. U.S. Bureau of Mines, Information Circular 9412. Accessible at: http://pubs.usgs.gov/usbmic/ic-9412/.

2. Figure 3: Total 2001 U.S. Mercury Use in Products. Source: Lawrence, Bruce, 2001. Bethlehem Apparatus Company, Inc. Personal communication, June 22, 2001.

3. Lawrence, 2001 and The Chlorine Institute, Inc., 2-006.

4. Figure 4: U.S. Mercury Product and Process Use Trends. Sources: For 1980 through 1997: USGS. U.S. Geological Survey. Minerals Yearbook: Mercury, 1994–2001. Accessible at: http://minerals.usgs.gov/minerals/pubs/commodity/mercury/. For 2001: Lawrence, 2001 and The Chlorine Institute, Inc., 2006.

5. Environment Canada and EPA, 1997. The Great Lakes Binational Toxics Strategy. Accessible at: www.epa.gov/glnpo/p2/bns.html.

6. Environment Canada and EPA, 2004. Great Lakes Binational Toxics Strategy 2004 Annual Progress Report. Accessible at: http://binational.net/bns/2004/index.html.

7. The Chlorine Institute, Inc., 2006. Ninth Annual Report to EPA for the Year 2005, May 15, 2006. Accessible at: www.epa.gov/region5/air/mercury/9thcl2report.pdf.

8. H2E. Hospitals for a Healthy Environment. For information, see: www.h2e-online.org/.

9. For information about legislation to reduce mercury in the New England states, see: IMERC. Interstate Mercury Education and Reduction Clearinghouse at: www.newmoa.org/newmoa/ntdocs/prevention/mercury/imerc.cfm.

10. Conference of New England Governors and Eastern Canadian Premiers, 2002. Summary of School Mercury Programs in New England and Eastern Canada. August 2002. Accessible at: www.cap-cpma.ca/images/pdf/eng/10-mtf_school_survey_e.pdf.

11. The Chlorine Institute, Inc., 2006.

12. IMERC. For information, see: www.newmoa.org/Newmoa/htdocs/prevention/mercury/imerc.cfm.

13. EPA. Environmentally Preferable Purchasing, Database of Environmental Information for Products and Services. For information, see: http://yosemite1.epa.gov/oppt/eppstand2.nsf/Pages/Homepage.html?Open.

14. EPA. Green Suppliers Network. For information, see: www.epa.gov/p2/programs/gsn.htm.

15. EPA. Schools Chemical Cleanout Campaign (SC3). For information, see: www.epa.gov/epaoswer/osw/conserve/clusters/schools/index.htm.

16. EPA. National Partnership for Environmental Priorities (NPEP) Program, The Mercury Challenge. For information, see: www.epa.gov/epaoswer/hazwaste/minimize/mercchall.htm.

III. Managing Commodity-Grade Mercury Supplies

1. Lawrence, Bruce, 2002. Bethlehem Apparatus Company, Inc. World Mercury Market(s) From the Supply Side. Presentation at conference: Breaking the Mercury Cycle, Boston, MA, May 1–3, 2002. Accessible at: www.newmoa.org/Newmoa/htdocs/prevention/mercury/breakingcycle/toc.cfm.

2. Maxson, P.A., 2004 Mercury Flows Report: Mercury Flows in Europe and the World, The Impact of Decommissioned Chlor-alkali Plants. European Commission. Accessible at: http://europa.eu.int/comm/environment/chemicals/mercury/pdf/report.pdf.

3. Maxson, 2004.

4. The Chlorine Institute, Inc., 2006.

5. 69 Federal Register 23733, 4/30/04.

6. Quicksilver Caucus, 2003. Mercury Stewardship Storage of Mercury, October 2003. Accessible at: www.ecos.org/files/721_file_QSC_STOR_Oct_03.pdf

7. EPA, 2005f. Economic and Environmental Analysis of Technologies to Treat Mercury and Dispose in a Waste Containment Facility. See: www.epa.gov/ORD/NRMRL/pubs/600r05157/600r05157.pdf.

8. EPA. Mercury Laws and Regulations. For information on how mercury is regulated under RCRA, see: www.epa.gov/epaoswer/hazwaste/mercury/reg_stand.htm.

IV. Communicating to the Public About Mercury Exposure Risks

1. Figure 1: The Mercury Cycle. Adapted from EPA, 1997. Mercury Study Report to Congress. EPA-452/R-97-003, December 1997. Accessible at: www.epa.gov/ttn/oarpg/t3/reports/volume1.pdf.

2. EPA and FDA, 2004. What You Need to Know About Mercury in Fish and Shellfish. EPA-823-F-04-009. Accessible at: www.epa.gov/waterscience/fishadvice/advice.html.

3. EPA, 2005c.

4. "EPA Releases 12th Annual National Listing of Fish Advisories." Press release. August 24, 2004.

5. EPA, 2002a. Task Force on Ritualistic Uses of Mercury Report, Dec. 2002. EPA-540-R-01-005. Accessible at: www.epa.gov/superfund/action/community/mercury.pdf.

6. EPA. Mercury Web site. For information, see: www.epa.gov/mercury/.

7. Minnesota Pollution Control Agency. Mercury-Free Zone Program. For information, see: www.pca.state.mn.us/programs/mercury-free/.

V. Addressing International Mercury Sources

1. Figure 5: Where are Man-Made Mercury Emissions Originating? Source of figure: Pacyna, J., S. Wilson, F. Steenhuisen and E. Pacyna. 2005. Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere. Accessible at: (www.amap.no/Resources/HgEmissions/). Original figure presented courtesy of AMAP, Arctic Monitoring and Assessment Programme, Oslo, Norway.

2. EPA, 2005a.

3. Figure 6: Man-Made Air Emissions of Mercury: Distribution by Region in 1990 and 2000. Source: Pacyna, J. and J. Munthe, 2004. Summary of research projects on mercury conducted by researchers in Norway and Sweden. Presentation at Workshop on Mercury, Brussels, March 29–30, 2004. Accessible at: www.ivl.se/nytt/konferenser/mercury/pacyna.pdf.

4. UNEP, 2002. United Nations Environment Programme. Global Mercury Assessment. Accessible at: www.chem.unep.ch/mercury/Report/GMA-report-TOC.htm.

5. EPA estimate based on UNEP 2002.

6. EIA, 2004. Energy Information Administration. International Energy Outlook 2004 (annual report). Report #DOE/EIA-0484(2004), April, 2004. Accessible at: www.eia.doe.gov/oiaf/ieo/.

7. UNEP, 2002.

8. Veiga, M. and R. Baker, 2004. Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-scale Gold Miners, Report to the Global Mercury Project: Removal to Barriers of Introduction to Cleaner Artisanal Gold Mining and Extraction Technologies, GEF/UNDP/UNIDO, Vienna, Austria, 170. Accessible at: www.unites.uqam.ca/gmf/intranet/gmp/files/doc/gmp/Protocols_for_Environmental%20_Assessment_2005_08_11.pdf.

9. Veiga, M.M. and J.J. Hinton, 2002. Abandoned Artisanal Gold Mines in the Brazilian Amazon: A Legacy of Mercury Pollution. Natural Resources Forum, February, 2002.

10. UNEP, 2002.

11. This estimate is based on communication with The Chlorine Institute and review of the following two pamphlets: The Chlorine Institute, Inc., 2004b. Pamphlet 10, North American Chlor-Alkali Industry Plants and Production Data Report 2003, Updated June, 2004. The Chlorine Institute, Inc., 2004c. Pamphlet 16, Chlor-Alkali Plants Outside North America, Updated October 2004.

12. Source of 2,000 estimate is Lawrence, 2002. Source of 3,400 estimate is Maxson, 2004.

13. Figure 7: Global Mercury Consumption, 2000. Source: Maxson, 2004.

14. Environment Canada and EPA, 2005. Great Lakes Binational Toxics Strategy: Assessment of Level 1 Substances, Summary Report. Accessible at: http://binational.net/bns/2005/iindex.html.

15. Conference of New England Governors/Eastern Canadian Premiers, 2003. Report to the New England Governors and Eastern Canadian Premiers on Mercury Projects, August 2003. Accessible at: http://cap-cpma.ca/images/pdf/eng/2003reportmercury.pdf.

16. CEC. Commission for Environmental Cooperation. North American Regional Action Plan on Mercury. Accessible at: www.cec.org/programs_projects/pollutants_health/smoc/merc134.cfm?varlan=english.

17. UNECE, 1998. United Nations Economic Commission for Europe. Convention on Long-Range Transboundary Air Pollution. Protocol on Heavy Metals. Accessible at: www.unece.org/env/lrtap/hm_h1.htm.

18. UNEP Mercury Programme. For information, see: www.chem.unep.ch/mercury/default.htm.

19. UNEP, 2005. Results of the Governing Council's discussions on chemicals management, including mercury programme, at its 23rd session in February, 2005. Accessible at: www.chem.unep.ch/mercury/GC23-results.htm.

20. UNEP Mercury Programme Partnerships. For information, see: www.chem.unep.ch/mercury/partnerships/default.htm.

21. UNIDO. United Nations Industrial Development Organization. Global Mercury Project. For information, see: www.unido.org/en/doc/4571.

22. AMAP. Arctic Monitoring and Assessment Programme. For information, see: www.amap.no/.

23. UNEP. Basel Convention. For information, see: www.basel.int/index.html.

VI. Conducting Mercury Research and Monitoring

1. EPA, 2000. Mercury Research Strategy. EPA-600-R-00-073. Accessible at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20853.

2. EPA, 2003a. Mercury Research Multi-Year Plan. Accessible at: www.epa.gov/osp/myp/mercury.pdf.

3. EPA. Science To Achieve Results (STAR) Program. For information, see: http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/recipients.display/rfa_id/109. http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/research.display/rpt/abs/rfa_id/2.

4. USGS. The Mercury Roundtable. For information, see: http://minerals.usgs.gov/mercury/roundtable.html.

5. EPA, 2003d. Performance and Cost of Mercury and Multipollutant Emission Control Technology Applications on Electric Utility Boilers; EPA/600/R-03/110; October, 2003.

   Srivastava, R.K., J.E. Staudt, and W. Jozewicz, 2004. Preliminary Estimates of Performance and Cost of Mercury Emission Control Technology Applications on Electric Utility Boilers: An Update. Prepared for presentation at The Combined Power Plant Air Pollutant Control Mega Symposium, Washington, DC, August 30–September 2, 2004.

6. EPA, 2005a.

7. EPA, 2005a.

8. www.epa.gov/mercury.

9. Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants From Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the Section 112(c) List" (The Section 112(n) Revision Rule) (70 FR 15994 (Mar. 29, 2005) and "Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units" ("The Clean Air Mercury Rule" or "CAMR") (70 FR 28606 (May 18, 2005).

10. Landis, M.S., R.K. Stevens, F. Shaedlich, and E.M. Presbo, 2002. Development and Characterization of an Annular Denuder Methodology for the Measurement of Divalent Inorganic Reactive Mercury in Ambient Air. Environmental Science Technology 26: 3000–3009.

11. Bullock, R. and Brehme, K. 2002. "Atmospheric Mercury Simulation Using the CMAQ Model: Formulation, Description, and Analysis of Wet Deposition Results", Atmos. Envi., 36, pg. 2135-2146.

12. EPA, 2003d.

    Srivastava, R.K., J.E. Staudt, and W. Jozewicz, 2004.

13. EPA, 2005e. Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: an Update, 02/18/05. Accessible at: www.epa.gov/ttn/atw/utility/ord_whtpaper_hgcontroltech_oar-2002-0056-6141.pdf.

14. Kosson, D.S., H.A. van der Sloot, F. Sanchez, F. and A.C. Garrabrants, 2002. An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials. Environmental Engineering Science 19(3):159–204.

    Thorneloe, S., 2003. Presentation to EPA Science Advisory Board, Environmental Engineering Committee, Washington, D.C., June 17, 2003.

    Potential for Cross-media Transfers from Management of Mercury-enriched Coal Combustion Residues. Feb. 18, 2005. Available through www.regulations.gov at EPA-HQ-OAR-2002-0056/6139.

15. EPA. Mercury Continuous Emission Monitors. For information, see: www.epa.gov/etv/verifications/vcenter1-11.html.

16. Wang, Q., D. Kim, D. Dionysiou, G. Sorial and D. Timberlake, 2004. "Sources and Remediation for Mercury Contamination in Aquatic Sediments—A Literature Review," Environmental Pollution 131 (2004) 323–336.

    Kim, D., Q. Wang, G. Sorial, D. Dionysiou and D. Timberlake, 2004. "A Model Approach for Evaluating Effects of Remedial Actions on Mercury Speciation and Transport in a Lake System," Science of the Total Environment 327 (2004) 1–15.

17. Randall, P.M., Chattopadhyay, S., and Ickes, J.A, 2004. Influence of pH and Oxidation-Reduction (Eh) Potential on the Dissolution of Mercury-Containing Mine Wastes from the Sulfur Bank Mercury Mine, Minerals & Metallurgical Processing Journal 21:93–98, May 2004.

18. Randall, P.M, L. Brown, L. Deschaine, J. Dimarzio, G. Kaiser, and J. Vierow, 2004. Application of the Analytic Hierarchy Process to Compare Alternatives for the Long-Term Management of Surplus Mercury, Journal of Environmental Management 71(1):35–43. Accessible at: http://dx.doi.org/10.1016/j.jenvman.2004.01.004.

    Porter, S., et al., 2004. Toxic Metals in the Environment: Thermodynamic Considerations for Possible Immobilization Strategies for Pb, Cd, As, and Hg, Critical Reviews in Environmental Science and Technology, 34:395–604.

    EPA, 2002b. Preliminary Analysis of Alternatives for the Long Term Management of Excess Mercury. EPA/600/R-03/048. Accessible at: www.epa.gov/ORD/NRMRL/Pubs/600R03048/600R03048.html.

19. Discussions of the fish sample data gathered by Region 8 will be included in the Human Health and Ecological Risk Assessment for the Cheyenne River Basin Site.

20. MDN. Mercury Deposition Monitoring Network. NADP. National Air Deposition Monitoring Program. For information see: http://nadp.sws.uiuc.edu/mdn/.

21. FDA. U.S. Food and Drug Administration. Mercury in Fish: FDA Monitoring Program. For information, see: www.cfsan.fda.gov/~frf/seamehg2.html.

22. EPA. National Fish Tissue Study. For information, see: www.epa.gov/waterscience/fishstudy/.

23. EPA, 2005c.

24. Mahaffey, K.R., 2005. Exposures to Mercury in the Americas. In: Pirrone, N. and K.R. Mahaffey, Dynamics of Mercury Pollution on Regional and Global Scales. Springer-Verlag, New York.

25. CDC. National Health and Nutrition Examination Survey, (NHANES). For information, see: www.cdc.gov/nchs/about/major/nhanes/growthcharts/charts.htm.

26. CDC, 2003. Mercury, PP. 17-19 in Second National Report on Human Exposure to Environmental Chemicals, January 2003. Accessible at: www.cdc.gov/exposurereport/2nd/.

27. CDC, 2004. Blood Mercury Levels in Young Children and Childbearing–Aged Women—United States, 1999–2002. Morbidity and Mortality Weekly Report, November 5, 2004/53(43):1018–1020. Accessible at: www.cdc.gov/mmwr/preview/mmwrhtml/mm5343a5.htm.

28. NHANES 2005-2006 Ethics Review Board Protocol. CDC, National Center for Health Statistics, Division of Health and Nutrition Examination Survey.

29. EPA, 2003b. America's Children and the Environment: Measures of Contaminants, Body Burden, and Illness. EPA 240-R-03-001, February 2003. Accessible at: www.epa.gov/envirohealth/children/.

30. EPA, 2003c. Draft Report on the Environment. Accessible at: www.epa.gov/indicators/roe/html/roeTOC.htm.