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EPA's Roadmap for Mercury

VI. Conducting Mercury Research and Monitoring

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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 child-bearing-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.