OVERVIEW

This Mercury Study is a Report to Congress prepared by the U.S. Environmental Protection Agency. It fulfills the requirements of section 112(n)(1)(B) of the Clear Air Act, as amended in 1990. The Report provides an assessment of the magnitude of U.S. mercury emissions by source, the health and environmental implications of those emissions, and the availability and cost of control technologies. As the state-of-the-science for mercury is continuously and rapidly evolving, this Report should be viewed as a "snapshot" of our current understanding of mercury. This Report does not quantify the risk from mercury exposure because of scientific uncertainty in a number of important areas. The Report identifies areas where further research is needed to provide a quantitative risk assessment.

Mercury cycles in the environment as a result of natural and human (anthropogenic) activities. The amount of mercury mobilized and released into the biosphere has increased since the beginning of the industrial age. Most of the mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year, and hence can be widely dispersed and transported thousands of miles from likely sources of emission. Most of the mercury in water, soil, sediments, or plants and animals is in the form of inorganic mercury salts and organic forms of mercury (e.g., methylmercury). The inorganic form of mercury, when either bound to airborne particles or in a gaseous form, is readily removed from the atmosphere by precipitation and is also dry deposited. Wet deposition is the primary mechanism for transporting mercury from the atmosphere to surface waters and land. Even after it deposits, mercury commonly is emitted back to the atmosphere either as a gas or associated with particles, to be re-deposited elsewhere. As it cycles between the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood.

Mercury accumulates most efficiently in the aquatic food web. Predatory organisms at the top of the food web generally have higher mercury concentrations. Nearly all of the mercury that accumulates in fish tissue is methylmercury. Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body than methylmercury, does not tend to bioaccumulate.

Mercury Emissions and Deposition in the U.S.

The best point estimate of annual anthropogenic U.S. emissions of mercury in l994-1995 is 158 tons. Roughly 87 percent of these emissions are from combustion sources, including waste and fossil fuel combustion. Contemporary anthropogenic emissions are only one part of the mercury cycle. Releases from human activities today are adding to the mercury reservoirs that already exist in land, water, and air, both naturally and as a result of previous human activities. The flux of mercury from the atmosphere to land or water at any one location is comprised of contributions from the natural global cycle including re-emissions from the oceans, regional sources, and local sources. Local sources could also include direct water discharges in addition to air emissions. Past uses of mercury, such as fungicide application to crops are also a component of the present mercury burden in the environment. One estimate of the total annual global input to the atmosphere from all sources including natural, anthropogenic, and oceanic emissions is 5,500 tons. Based on this, U.S. sources are estimated to have contributed about 3 percent of the 5,500 tons in 1995.

A computer simulation of long-range transport of mercury suggests that about one-third (~ 52 tons) of U.S. anthropogenic emissions are deposited, through wet and dry deposition, within the lower 48 States. The remaining two-thirds (~ 107 tons) is transported outside of U.S. borders where it diffuses into the global reservoir. In addition, the computer simulation suggests that another 35 tons of mercury from the global reservoir is deposited for a total deposition of roughly 87 tons. Although this type of modeling is uncertain, the simulation suggests that about three times as much mercury is being added to the global reservoir from U.S. sources as is being deposited from it. What is not uncertain is that additional emissions to air will contribute to levels in the global reservoir, and concomitant deposition to water bodies.

The highest deposition rates from anthropogenic and global contributions for mercury are predicted to occur in the southern Great Lakes and Ohio River valley, the Northeast and scattered areas in the South, with the most elevated deposition in the Miami and Tampa areas. The location of sources, the chemical species of mercury emitted and the climate and meterology are key factors in mercury deposition. Humid locations have higher deposition than arid locations.

Public Health Impacts

Epidemics of mercury poisoning following high-dose exposures to methylmercury in Japan and Iraq demonstrated that neurotoxicity is the health effect of greatest concern when methylmercury exposure occurs to the developing fetus. Dietary methylmercury is almost completely absorbed into the blood and distributed to all tissues including the brain; it also readily passes through the placenta to the fetus and fetal brain. The reference dose (RfD) is an amount of methylmercury, which when ingested daily over a lifetime is anticipated to be without adverse health effects to humans, including sensitive subpopulations. At the RfD or below, exposures are expected to be safe. The risk following exposures above the RfD is uncertain, but risk increases as exposures to methylmercury increase.

Extrapolating from the high-dose exposures that occurred in the Iraq incident, the U.S. EPA derived a RfD for methylmercury of 0.1 µg/kg bw/day. While the U.S. EPA has been advised by scientific reviewers to employ this RfD for this analysis, new data are emerging. Currently ongoing are two large epidemiology studies in the Seychelle Islands and in the Faroe Islands that were designed to evaluate childhood development and neurotoxicity in relation to fetal exposures to methylmercury in fish-consuming populations. Because of various limitations and uncertainties in all of the available data, the U.S. EPA and other Federal agencies intend to participate in an interagency review of the human data on methylmercury, including the most recent studies from the Seychelle Islands and the Faroe Islands. The purposes of this review are to refine the estimates of the level of exposure to mercury associated with subtle neurological endpoints and to further consensus between all of the Federal agencies. After this process, the U.S. EPA will determine if a change in the RfD for methylmercury is warranted.

Fish consumption dominates the pathway for human and wildlife exposure to methylmercury. This study supports a plausible link between anthropogenic releases of mercury from industrial and combustion sources in the United States and methylmercury in fish. However, these fish methylmercury concentrations also result from existing background concentrations of mercury (which may consist of mercury from natural sources, as well as mercury which has been re-emitted from the oceans or soils) and deposition from the global reservoir (which includes mercury emitted by other countries). Given the current scientific understanding of the environmental fate and transport of this element, it is not possible to quantify how much of the 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 and re-emissions from the global pool). As a result, it cannot be assumed that a change in total mercury emissions will be linearly related to any resulting change in methylmercury in fish, nor over what time period these changes would occur. This is an area of ongoing study.

Critical elements in estimating methylmercury exposure and risk from fish consumption include the species of fish consumed, the concentrations of methylmercury in the fish, the quantity of fish consumed, and how frequently fish is consumed. The typical U.S. consumer eating fish from restaurants and grocery stores is not in danger of consuming harmful levels of methylmercury from fish and is not advised to limit fish consumption. The levels of methylmercury found in the most frequently consumed commercial fish are low, especially compared to levels that might be found in some non-commercial fish from fresh water bodies that have been affected by mercury pollution. While most U.S. consumers need not be concerned about their exposure to methylmercury, some exposures may be of concern. Those who regularly and frequently consume large amounts of fish -- either marine species that typically have much higher levels of methylmercury than the rest of seafood, or freshwater fish that have been affected by mercury pollution -- are more highly exposed. Because the developing fetus may be the most sensitive to the effects from methylmercury, women of child-bearing age are regarded as the population of greatest interest. In this Report, an analysis of dietary surveys led the U.S. EPA to conclude that between 1 and 3 percent of women of child-bearing age (i.e., between the ages of 15 and 44) eat sufficient amounts of fish to be at risk from methylmercury exposure, depending on the methylmercury concentrations in the fish. These consumers should be aware of the Food and Drug Administration and State fish advisories that suggest limiting the consumption of contaminated fish. Advisories in the United States have been issued by 39 states and some Tribes, warning against consumption of certain species of fish contaminated with methylmercury.

To the extent that concern is focused on high-end fish and seafood consumers, research is needed on the actual consumption patterns and estimated methylmercury exposure of this subpopulation. In addition, the findings from such research should be validated by analysis of hair samples from a representative sample of members of this subpopulation.

Environmental Impacts

The pattern of mercury deposition nationwide influences which eco-regions and eco-systems will be more highly exposed. Piscivorous (fish-eating) birds and mammals are more highly exposed to mercury than any other known component of aquatic ecosystems. Adverse effects of mercury on fish, birds and mammals include death, reduced reproductive success, impaired growth and development, and behavioral abnormalities.

Mercury contamination has been documented in the endangered Florida panther and the wood stork, as well as populations of loons, eagles, and furbearers such as mink and otter. These species are at high risk of mercury exposure and effects because they either are piscivores or eat piscivores. Concentrations of mercury in the tissues of wildlife species have been reported at levels associated with adverse health effects in laboratory studies with the same species. However, field data are insufficient to conclude whether piscivorous wading birds or mammals have suffered adverse effects due to airborne mercury emissions. Modeling analyses conducted for this Report suggest that it is probable that individuals of some highly exposed wildlife subpopulations are experiencing adverse effects due to airborne mercury emissions.

Mercury Control Technologies

Mercury is widely used in industry because of its diverse properties and serves as a process or product ingredient in several industrial sectors, however, industrial demand for mercury has declined by about 75 percent between l988 and l996, due largely to the elimination of mercury additives in paints and pesticides and the reduction of mercury in batteries. Most of the emissions of mercury are produced when waste or fuel containing mercury is burned. The U.S. EPA has already finalized emission limits for municipal waste combustors and medical waste incinerators. As a result, by the year 2000, emissions from these categories will decline at least 90 percent from 1995 levels. In addition, mercury emission limits have been proposed for hazardous waste incinerators.

The largest remaining identified source of mercury emissions are coal-fired utility boilers. Although a number of mercury control technologies are being evaluated for utility boilers, most are still in the research stages, making it difficult to predict final cost-effectiveness as well as the time required to scale-up and commercialize the technologies. Because the chemical species of mercury emitted from boilers varies from plant to plant, there is no single control technology that removes all forms of mercury. There remains a wide variation in the end costs of control measures for utilities and the possible impact of such costs on utilities. Preliminary estimates of national control costs for utility boilers (based on pilot scale data) are in the billions of dollars per year. Ongoing research, as well as research needs related to mercury controls for utilities, are described in the document.

Cost-effective opportunities to deal with mercury during the product life-cycle, rather than just at the point of disposal, need to be pursued. A balanced strategy which integrates end-of-pipe control technologies with material substitution and separation, design-for-environment, and fundamental process change approaches is needed. In addition, international efforts to reduce mercury emissions as well as greenhouse gases will play an important role in reducing inputs to the global reservoir of mercury.