U.S. Environmental Health Effects and Treatment of Mercury Exposure

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Abstract:
The various methods of treatment to mercury toxicity in the human body have been studied and investigated with somewhat mixed conclusions. This paper discusses the various types of mercury, the cycle of mercury in the environment, human exposure to mercury and treatment, and methods of reducing mercury pollution and its effect in the human population in the U.S.

Keywords: Methylmercury, exposure to mercury.

The effect of mercury on humans has been observed for centuries now. The 80th element in the periodic table has been historically used for various purposes over the history of man, from making felt hats to thermometers and medical equipment. Dental fillings in the past were made using mercury amalagams. However, in addition to explaining and exploring the effects of mercury toxicity in the human body, it is equally vital to understand possible ways to both treat and reduce exposure of mercury to vulnerable human populations. These topics have not been well studied over time. This paper will explore these areas and include recommendations for areas where mercury exposure should be reduced.

Mercury is found in nature in two main molecular forms, an organic and an inorganic form. It is manufactured by the reduction of cinnabar, which is a reaction where oxygen and cinnabar (HgS) are reacted to produce mercury (Hg) and sulfur dioxide (SO_2). Both forms are dangerous and toxic in both a liquid and vapor state, however the inorganic form poses a higher risk to humans for the risk of poisoning. This is because it more easily permeates cell membranes and can accumulate in the brain. The organic form - produced from inorganic mercury by bacteria in the water system after it enters it - is a neurotoxin that can cause serious nervous system damage and the brain. This form is often caused by linking the mercury metallic ion with a methyl side group, making a methylmercury compound. This form of mercury especially poses a danger to the developing fetus and comes from the ingestion of fish. The inorganic form, commonly used in medical equipment and dental fillings, is also a neurotoxin and particularly affects the liver. Toxicity cases of this form come most commonly from inhalation during manufacturing processes or after a spill.

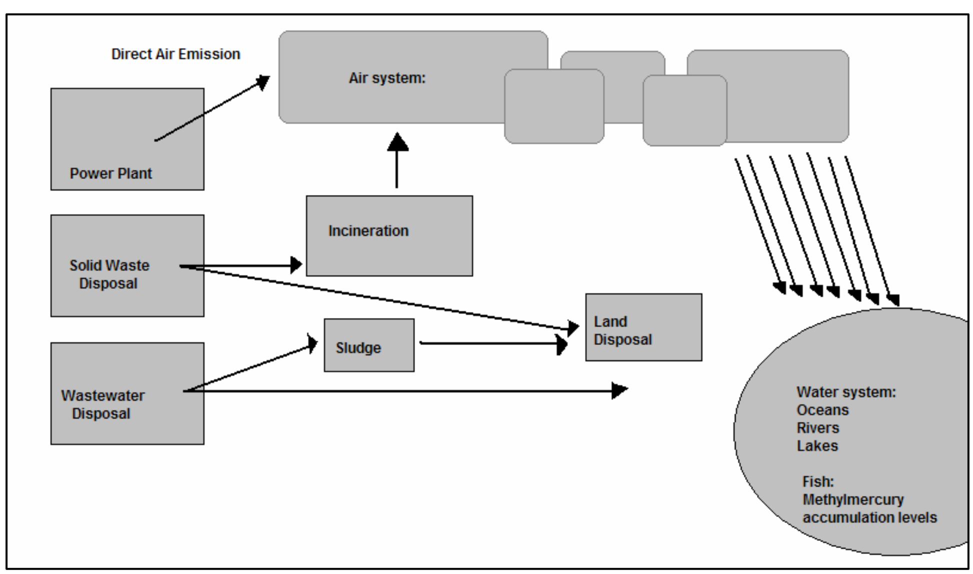

Fig. 1. Mercury cycle in the environment.

Figure 1 is pictorial representation of the production, flow, and accumulation of mercury in the atmosphere. fish with the highest concentration of mercury levels are at the top of the hydrospheric food chain.

The single largest source of mercury pollution in the atmosphere is due to the burning of coal in electrical production facilities. The mercury that exists naturally in the bituminous coal and cinnabar is released into the atmosphere at a much higher concentration than background levels expected to be seen from natural geological processes. Studies estimate that close to 75% of global mercury emissions are attributable to human activity. Once mercury has been emitted into the atmosphere, it is often deposited into aqueous bodies, such as lakes and oceans. Divalent mercury, an ionic form of inorganic mercury, is more easily bonded to particles and quickly dissolves in water. Soon after being deposited into water, microorganisms transform this form into the aforementioned methylmercury. It is important to mention that methylmercury can be converted back into its elemental form and then reemitted into the atmosphere, causing this cycle to continue.

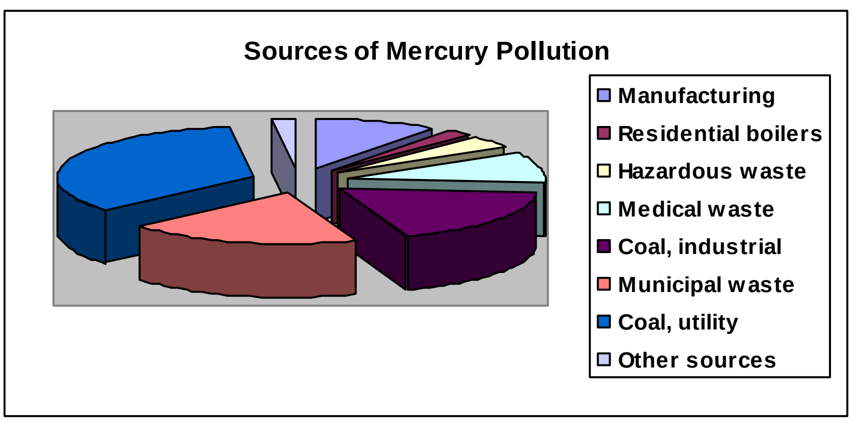

Fig. 2 Sources of mercury pollution.

Figure 2. indicates sources of mercury pollution. As visible, the burning of coal for both utility and industrial purposes account for 52% of total mercury emission.

The ability of mercury to travel long distances through its water cycle and air cycle have an unexpected effect on areas that lack heavy industry; a particular region may have low-level contamination of mercury without any mercury-related human activity; for instance, a case in the woods of Wisconsin pose one such example, where moderate levels of mercury were found despite the lack of any possible sources of mercury pollution.

Once in the hyrdrosphere, methylmercury can accumulate at extremely high concentrations in the tissues of freshwater biological creatures. These organisms eat plants that often contain mercury and are exposed to mercury in the water. The concentration of mercury in a shellfish often can be more than ten thousand times the concentration found in the water in its environment. This is due to the fact that methymercury accumulates as the organism filters water through its body and continually consumes smaller mercury-containing creatures. Larger creatures including predatory fish, birds, and humans continue to accumulate more and more amounts of mercury in their bodies as they eat these fish. One EPA report to Congress indicated that up to 30% of the male loon population in the U.S. northeast could have mercury levels high enough to cause adverse health effects.

Figure 3 is the USGS map of deposition of mercury from the atmosphere in the United

States. It is evident that the northern and eastern parts of the United States have especially higher amounts of mercury deposition.

Exposure to Mercury

There exist three major areas of contamination of mercury that pose serious risks to human populations. First, hospitals and health-care facilities have medical equipment that contains mercury. Secondly, manufacturing and power plants burn coal and sludge, directly producing mercury. Incineration of solid waste also is another source of mercury from this area. Lastly, the direct consumption of freshwater and seawater fish is a possible risk source.

The first source of mercury contamination is most especially a risk to those with occupations in biomedical facilities. The inhalation of mercury vapors due to spills can lead to serious health consequences; as a spill can cause mercury concentrations in the indoor air to quickly become much higher than recommended levels. Biomedical experiments involving methylmercury have also been shown to be potentially fatal. One mentioned case involved a researcher that was exposed to several drops of methylmercury onto her gloved hand during a laboratory experiment – she developed neurological toxicity symptoms after two months and died despite aggressive treatment. A recent study in Turkey also indicates that dentists have significant exposure mercury vapor and are most likely subject to long-term adverse affects due to mercury toxicity. Levels of mercury in urine of the dentists were about three times the amount of control subjects in the study (Karahalil 2005).

The last source, the consumption of fish, is the most common source of mercury toxicity. Because mercury ions bind tightly to the sulfur-containing side groups of amino acids in the body, the high-protein density parts of the fish – muscle – there is no way to prepare or cook fish to reduce the amount of mercury in a dish or meal.

Exposure to mercury is potentially deadly to all organisms; however, more serious is the subtle, chronic exposure to low levels of mercury in the diet. This exposure poses special risks to human fetuses, infants, and children, possibly causing serious obstacles to natural neurological development. Studies have established tenuous links between IQ, memory, attention, and language skill development of children and exposure to moderate levels of methylmercury during their gestation period (NIH 2006). However, there is still extensive debate and research into these connections. A study of the Faroe Islands by Grandjean appears to link the lowered IQ with the effects of mercury, while other studies by Myers (2003) and Kjellstrom (1989) have shown mixed conclusions on the matter. It appears that additional studies and research are required to establish firm relationships between IQ levels and exposure to mercury.

Immediate symptoms of mercury toxicity include the following common neurological symptoms: impairment of the peripheral vision; numbness and the loss of feeling; tingling sensations along the limbs; lack of coordination of movement; the impairment of speech, hearing, walking; muscle weakness; dramatic mood swings; memory loss; mental disturbance.

It is usually quite easy to recognize the symptoms of high-level mercury poisoning; however, the mid-level mercury toxicity often can go undiagnosed or misdiagnosed.

Exposure Treatment:

Immediate exposure to mercury requires treatment as soon as possible and medical attention. For eye contact, it is recommended to wash the eyes quite rigorously for 15 minutes and then receive medical attention. For direct skin contact, it is recommended to rinse the area continuously for 15 minutes and remove all contaminated clothing and get medical treatment as soon as possible. For inhalation of mercury vapor, it is imperative to find a fresh air source and receive artificial respiration if breathing stops. In the case of ingestion, vomiting should be induced immediately.

The toxicity limit for mercury in the adult human body is about 3 pg/g of creatinine. Concentrations of mercury well beyond this amount can cause considerable adverse long-term health effects. Most detoxification techniques attempt to lower mercury concentration well under this level.

These detoxification techniques involve removing mercury from the body using ‘chelation,’ complexing the mercury to a bigger molecule. The three different main chelation techniques involve different molecules: DMPS, EDTA, DMSA. These detoxification techniques are used as a diagnostic tool to determine concentration of Hg in blood and decrease overall mercury concentration. The idea behind chelation involves a molecule used as a chelator, because Hg is usually embedded in cell walls. The chelator picks up Hg by attachment to a sulfur-side group and then exchanges Hg-molecule for a metal with a higher stability constant. The chelator picks up mercury molecules and safely takes it through intestines until excretion.

For the case of DMPS and EDTA, the technique is conducted by delivering the powdered form of the molecule in solution by intravenous (IV) infusion, while for DMSA, an IV is usually not required. DMPS is the common chelation technique for adults while DMSA is used to treat mercury toxicity in children. The DMPS technique appears to have been originally developed in China, and can also be used to remove other heavy metals from the human body (Smith 2005).

During chelation procedure, several supplements are recommended for consumption, including prochitosan - increases the rate of digestion, garlic - increases sulfur concentration, and cilantro, vitamin C, and vitamin E – decrease side effects of ‘chelation.’ It is also recommended to eat a high-protein diet during chelation while avoid foods high in sugar. The sulfur-side groups in the amino acids from protein help facilitate chelation.

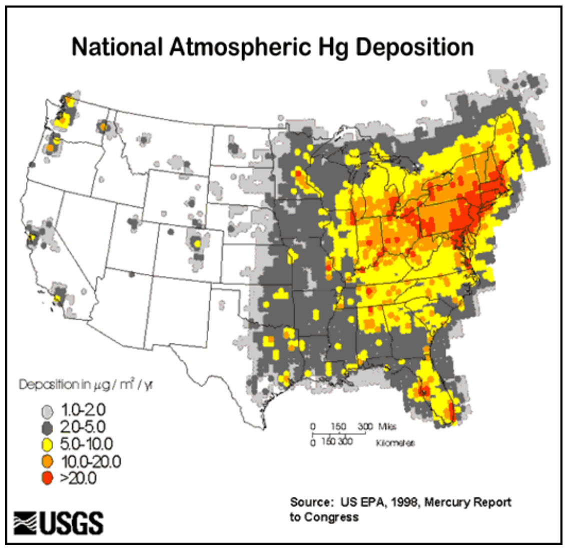

Fig. 3 Natural Atmospheric Mercury Deposition.

Recommendations:

The U.S. Environmental Protection Agency has issued specific diet recommendations for expecting mothers and young children in regard to the consumption of fish and shellfish. Adherence to these recommendations will help ensure that these women and children will avoid harmful exposure to the effects of mercury toxicity. First, the consumption of predatory fish – shark, tilefish, swordfish, king mackerel, albacore tuna – should be avoided. They contain the highest concentrations of mercury out of all fish. Second, refrain from eating more than 12 ounces of fish and shellfish that are lower in mercury – shrimp, light tuna, salmon, and pollock - concentration in a week. Lastly, keep track of the latest advisories issued about the mercury content of fish caught locally (EPA 2004).

Mercury was banned in the United States as a paint additive in both exterior and interior paints in 1990 and 1991. The EPA is also working to phase mercury out of batteries.

The Great Waters program and its reports to Congress have been useful to gathering information about specific mercury levels and deposition in the United States (EPA 2000). Additionally, alternative metals to mercury are being implemented in medical equipment. The EPA has also prepared a power plant mercury regulation plan to reduce emission of mercury in the United States (EPA 2000). In my opinion, the most logical way to reduce exposure of mercury to the human population may be to increase testing abilities for mercury levels in fish and water sources and to increase overall awareness of fish dietary recommendations to women of child-bearing age. Any other method may be vastly more expensive and difficult.

Zeller and Booth have suggested that by overall cost-benefit analysis of mercury regulation, we may see that over a 15-year period the nation would face losses ranging from $60 billion to $1 billion due to loss in children's IQ affecting the national net income (Zeller and Booth 2005).

Conclusions:

From the studies and research of the effects of mercury on both human populations and the environment, it is evident that mercury toxicity is a serious problem that can not be easily overlooked. The long-term effects of low-level exposure to mercury through fish consumption need to be seriously considered. It is also equally important to continue to try to understand possible ways to both treat and reduce exposure of mercury to human populations. These topics have not been well studied over time and more research should shed more light on this topic in the future. Additionally, this paper focused on environmental health effects and treatment of mercury exposure in the United States; it may well be the case that situations are much serious in other parts of the world were coal-burning and the production of mercury near water sources is more common, such as China.

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