

Exposure to mercury and health risks

The Impact of Mercury on Human Health and Environment

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Abstract

Exposure to mercury vapor and methyl –mercury may lead to serious health problems and life-threatening conditions. Fetuses and children are the most affected. The interference with many physiological processes makes prediction of the effects very difficult. People must be aware that the symptoms of intoxication with mercury compounds have a delay of weeks and more. To minimize the exposure to mercury compounds the level of mercury must be stated on foodstuff like fish and fish products.

Keywords: Mercury, methyl mercury, bioaccumulation, pharmacology, toxicology

Introduction

Mercury and mercury derived compounds may have an enormous impact on the environment and human health. Fetuses and children are mostly affected by these compounds because of the high risk of impairment of the central nervous system (CNS) functions¹⁻⁹. They may increase liver intoxication from therapeutics and cause or exaggerate cardiovascular problems.¹⁻⁹

The accumulation of some mercury compounds may also lead to a reduction of food yield in some areas.¹⁻⁴ Therefore, thoroughly conducted scientific investigations are needed to establish the impact of the use of mercury in Suriname in, among others gold mining activities.^{2,8,10}

The exposure of mercury concerns people in the gold mining industry but also the fish consuming population.^{4,7,8-11} This paper presents data from the literature about these issues. It is neither the intention to exaggerate the impact on the environment nor to ignore the detrimental effects it may have on human health.

A lot of data have been produced to show the global impact of mercury deposit. For any substance that accumulates in organisms it is not possible to predict the fate (pharmacokinetic) and the effect (pharmacodynamic) if relevant pharmacological data are not available. This is still the case for mercury and its compounds..

Like with any other substance people are exposed to mercury only when they come into contact with it. People may be exposed by breathing, eating, or drinking the substance or by skin contact. Many factors, including the dose, the duration, and how people come into contact with it, determine whether one will be harmed. Moreover, additional chemicals to which people are exposed, as well as age, sex, diet, family traits, lifestyle, and state of health, may influence the health effects of mercury and mercury compounds.

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Available on-line December 16, 2015

What is mercury?

Mercury is an existing element of our planet. It is found in air, water and soil. Pure mercury is a liquid metal; sometimes referred to as quicksilver that volatilizes readily. As shown in table 1 mercury exists in several forms.

Table1.

A few known examples of mercury compounds is depicted; amalgam, calomel, cinnabar and methyl mercury. N.B.: Amalgam is a mixture of elemental Hg with another metal.

elemental mercury	Hg^0	amalgam
inorganic mercury	Hg_2^{2+} Hg^{2+}	calomel Hg_2Cl_2 cinnabar HgS
organic mercury	$[\text{CH}_3\text{Hg}]^+$	methyl mercury

All these forms produce toxicity or death with less than a gram, except elemental liquid mercury for which even injection fails to produce toxicity. In its zero oxidation state Hg^0 , elemental mercury, exists as vapor or as liquid metal, in its mercurous state Hg_2^{2+} exists as inorganic salts, and in its mercuric state Hg^{2+} may form either inorganic salts or organomercury compounds; the three groups vary in toxicological effects.

Exposure to mercury

Humans can be exposed to mercury in several ways, for example elemental mercury used in gold mining activity, amalgam used in dentistry, and methyl mercury (MeHg) in foodstuff. Since mercury salts and organic mercury compounds are far less volatile than liquid mercury under most conditions, it is unlikely

that vapors of these products are the source of exposure. The most likely way to be exposed to these products is through intestinal absorption.

Mercury can enter and accumulate in the food chain. The only form of mercury that accumulates in the food chain is methyl mercury, an organic mercury compound. Therefore, most people are exposed to mercury when they eat foodstuff contaminated with methyl-mercury, such as fish or shellfish.

Fate of mercury

Mercury and mercury compounds occur naturally. Therefore, we cannot avoid to be exposed to these substances. However, human actions have contributed to a much greater exposure, which have led to some very great disasters. These disasters could have been prevented, but not the continuously exposure to mercury and mercury compounds. This may have great impact on morbidity and mortality in societies where exposure is high and on those people consuming products that are contaminated with these compounds.

Metallic mercury used in the gold mining industry will produce adverse effects only when its vapor is inhaled; however, it is this vapor from which methyl-mercury ultimately is formed as shown in figure1 adapted from "Methyl-mercury contamination in fish and shellfish" by Laura Griesbauer.⁹

In short, this process is $\text{Hg}^0 \rightarrow \text{Hg}^{2+}$ (atmosphere oxidative processes); in aquatic sediments inorganic mercury is converted to methyl-mercury (MeHg) by microorganisms.

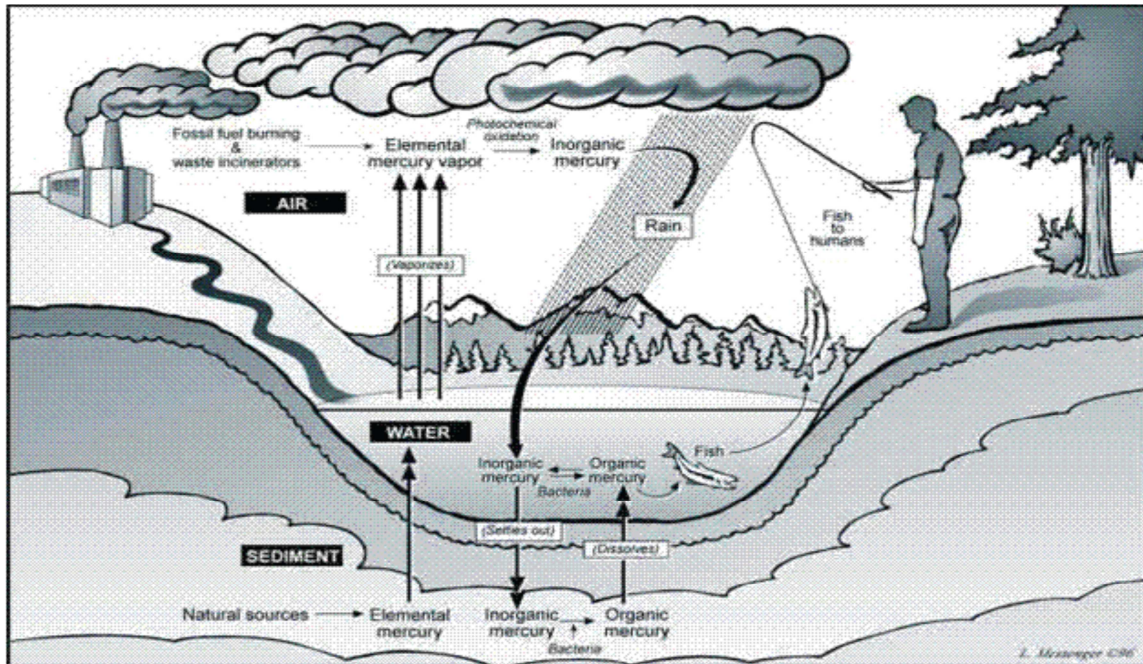


Figure1. Formation of methyl mercury. In the atmosphere mercury vapor (Hg^0) is slowly converted to oxidative processes to divalentmercury. The divalent mercury reaches water and soil by rainfall. In aqueous setting inorganic mercury is converted to MeHg by microorganisms in the sediments by a process called methylation.⁹

When measuring mercury in the environment, in fish and other aquatic species, it is very important to distinguish between MeHg and other forms of mercury, because MeHg

accumulates in these organisms as is illustrated in fig.2 adapted from “Methyl-mercury contamination in fish and shellfish” by Laura Griesbauer.⁹

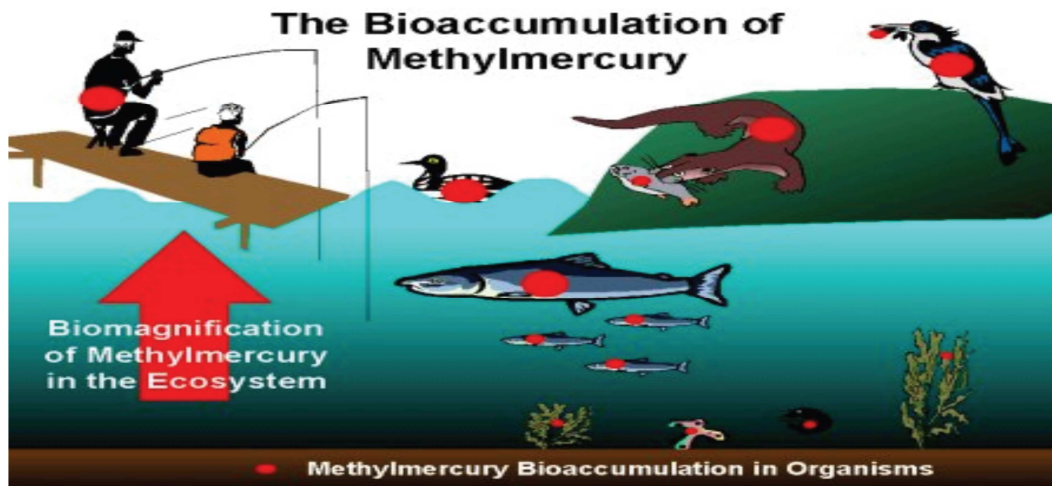


Figure 2. The accumulation of methyl mercury in organisms. Bioaccumulation of methyl mercury may lead to high level of mercury in organisms as is shown by the red circles.⁹

Relation of level of mercury exposure and effects¹²

Although scientists do not know exactly what level of mercury in blood is related to toxic effects, some agencies have given guidelines about the determination of mercury. It is very important to consider that mercury has to increase to a peak value to produce effects, which have a latency of more than 1 month. For measuring mercury levels in blood it is suggested that the test should be performed 5 days or more after a person stopped eating fish or products containing mercury.

The limits for total mercury are:

- in blood 5 ng/mL
- in urine 20 ng/mL.

Blood mercury levels between 30 and 40 ng/mL in mothers may cause delayed development and subtle nervous system effects in their children. Blood mercury levels >100 ng/mL produce mercury poisoning, meaning necessary steps have to be taken to reduce the effects of the poisoning such as discontinuing the extraordinary exposure to the source of mercury, starting a reliable treatment and regular monitoring of the victim(s).

The minimum lethal dose of MeHg for an average adult person is between 20 and 60 mg/kg.

A chronic inhalation minimal risk levels for metallic mercury of the human population (including sensitive subgroups) is established to be about $0.2\mu\text{g}/\text{m}^3$. This may result in accumulation of mercury in the body and permanent damage to the nervous system and kidneys.

Pharmacology/toxicology of mercury and its compounds

Substances can enter tissues in several ways, through passive transfer, active transfer and facilitated transfer. They or their metabolites

may interact with structures in those tissues and consequently produce effects. Like every other substance that enters the circulation, mercury and its compounds will be transported by plasma to tissues in the body. Physiological factors and physicochemical properties of the substance will determine if the substance will enter tissues. The greater the regional blood flow, the larger the amount of the compound that the tissue will receive initially. Not well-perfused tissue will receive the substance slower. Uptake into the tissues is mainly related to lipid solubility of mercury and its organic- and anorganic derivatives.

Mercury and its derivatives may produce effects in humans and other species. It is assumed that these effects are produced by similar mechanisms. The differences in effects observed are the result of different kinetics (rates of uptake into, distribution over or elimination from the body) of the initial compound.^{2,6}

The intensity and the variety of the effects depend on the amount, duration of exposure, how the compound has been absorbed, and the age of the person. Moreover, the various effects observed reflect the different ways the active form has received the site of action. It is accepted that the form of mercury that produces the effects in organisms is mercuric ion. When this ion has been produced, mercury can effectively be trapped into cells.⁸

Mercury and mercury compounds ultimately interact mainly with sulfur containing structures in the body and are highly reactive with selenium. Selenium is an essential element many enzymes are dependent on. Inhibiting selenium-dependent enzymes irreversible in addition to the binding to sulfur containing substances may produce several effects. These endogenous substances are present in several tissues.^{8,14,15,16.}

It is not surprising that the effects first observed of mercury and mercury compounds are on the CNS, lung, liver, kidney and gastro-intestinal tract as summarized in table 2.⁹

Table2. Organs effected by mercury. Well-perfused tissue are effected the most by mercury.

Chemical form of mercury		Target organ
elemental mercury	Hg ⁰	Brain, kidney, lung
inorganic mercury	Hg ²⁺	Kidney
organic mercury	[CH ₃ Hg] ⁺	Brain, fetal brain

The binding to selenium make cells vulnerable to reactive oxygen products, because a smaller amount of selenium is available for the synthesis of selenoenzymes that protect tissues against oxidative damage. The inactivation of the sulfur containing S-adenosyl-methionine may lead to cumulation of catecholamines resulting in tachycardia, hypertension and other effects.^{8,14-16} Another essential endogenous sulfur containing compound affected is glutathione.^{8,14-16} Glutathione is important in the liver for binding reactive metabolites. By depleting the liver of glutathione, mercury and its compounds increase liver toxicity. Many medicines used in general practice are metabolized in the liver into reactive metabolites, which may increase the toxicity of mercury compounds.

Two mercury compounds will be discussed briefly because of the concern about their far-reaching consequences for health and environment.

Elemental mercury(metallic mercury; liquid mercury)^{9, 10,15,16}

Liquid mercury stays on the surface of sediments and will not pass to underground

water. This liquid is easily converted to mercury vapor, which is colorless and odorless. The concentrations of mercury in the air of the general environment are too low to have any threat to human health; however, in the industries where mercury vapor is produced the concentration will be much higher.

From inhaled vapor about 80% is absorbed through the lungs and enters the circulatory system. It can pass through the blood-brain barrier and accumulate in the brain where enzymes converse it to mercuric ion. In the elimination process of gaseous mercury, mercuric ion is formed, which accumulates also in the kidney and can cause kidney damage.

Methyl mercury

As mentioned above MeHg is a toxic substance that accumulates in organisms of the environment. Fish, other aquatic species and fish eating predators may have significant levels of MeHg. MeHg forms a complex in the gastro-intestinal tract with the amino acid cysteine.⁸⁻¹⁰ This complex resembles the amino acid methionine and is transported by amino acid transporting proteins throughout the body. It is therefore easily and completely absorbed after oral ingestion and could cross the blood-brain barrier and placenta. These kinetic properties of MeHg together with the strong binding to proteins and other structures cause it to be eliminated very slowly. Deposited MeHg undergoes demethylation to inorganic mercury. The half-life of mercury in human blood varies from 50-70 days. When exposed to mercury it will take about a year to be excreted almost completely from the body.

MeHg is secreted as a MeHg-glutathione complex in the bile through a glutathione carrier protein. The enterohepatic recycling of this complex may prolong significantly the presence of MeHg and its effects within the body prior to elimination. Ultimately, MeHg is excreted as mercuric mercury in the feces, although in time

the contribution of urinary excretion of this ion increases.^{4,9}

The latency of the toxic effects is weeks to months after acute exposure to MeHg.^{3,15}

Clinical aspects of mercury and mercury compounds^{2,4,6,7-10,12,16}

Exposure to high concentrations of elemental mercury may exhibit many acute health effects. Accumulation in the body after repeated or continuous exposure to lower concentrations of mercury may also result in toxic effects.

The kind of effects produced by mercury and its compounds are in general not predictable. This is mainly dependent on their pharmacokinetic and pharmacodynamic properties, and the person exposed to these products.

Still we may conclude from data available that fetuses and children are most susceptible, because of the influence on their development by mercury product. For several reasons children may receive larger doses of mercury vapor than adults, among them the greater lung surface: body weight ratios, the increased minute volumes: weight ratios and the higher levels of mercury vapor nearer to the ground, because mercury vapor has a higher density than air.

In fishing populations and in other populations consuming fish contaminated with mercury children showed also impairment of the CNS functions. Other effects observed after accumulation are on the nervous system and kidneys.

In addition, not only will mercury pass through the blood-brain barrier and the placenta, but it will also transfer to breast milk. Baby's growing brain and nervous system may also be affected. Consequently, impaired neurological development may result involving cognitive thinking, memory, attention, language, fine motor and visual spatial skills.

Significant health risk from MeHg exists in population with high consumption of fish and other water species. Depending on the amount of MeHg there could be neurological damage,

paresthesia and more severe effects to adults and ultimately coma and death.

The effect of MeHg is probably determined by the peak value of mercury in the body, not the length of the exposure. Long-term exposure of adults to low dose MeHg can lead to accumulation of MeHg and the mercuric ion that is produced may cause adverse effects in the central nervous system.

The MeHg- glutathione complex that is formed in the liver is of great concern, because numerous therapeutics and other substances are metabolized in the liver whereby reactive metabolites are captured by glutathione. Without this protection from glutathione serious damage to the liver may develop.

Conclusion

From what has been mentioned so far it must be emphasized that almost anyone must be involved in the outcome of the effects of mercury and mercury compounds with regard to the environment and human health; particularly those who are exposed to mercury in any form because of their occupation, and people consuming MeHg contaminated foodstuff.

Objective information must be given as well to people who may be exposed directly to liquid mercury. Medical practitioners and other health care assistants must be aware of the effects that mercury products may produce, especially on children and pregnant women, and be cautious that diseases may be related to these products and that careful investigation is a necessity.

Governmental and non-governmental agencies must inform the general public of the existence of mercury compounds in foodstuff and other products such as fishmeal and insist to label the amount of methyl mercury in these products.

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Acknowledgment: Gratitude to dr. Albertus Gerrit (Bert) de Boer for his comments to the manuscript of this paper !