

A Small Dose of Mercury
Or
An Introduction to the Health Effects of Mercury
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Dossier

Name: Mercury (Hg) (inorganic)
Use: consumer products, industry, dental amalgams, switches, thermometers
Source: mining, environment, workplace
Recommended daily intake: none (not essential)
Absorption: inhalation, intestine poor
Sensitive individuals: fetus, children, women of childbearing age
Toxicity/symptoms: nervous system, irritability tremor, drowsiness, depression, incoordination, and tremors, (mad as a hatter)
Regulatory facts: ATSDR – MRL – Inhalation $0.2 \mu\text{g}/\text{m}^3$
General facts: long history of use, liquid silver evaporates at room temperature, bacteria convert to organic methyl mercury
Environmental: global environmental contaminate
Recommendations: avoid, recycle mercury-containing devices

Name: Mercury (organic) (methyl mercury - Hg-CH_3)
Use: limited laboratory use
Source: contaminates some fish (e.g. tuna, shark, pike)
Recommended daily intake: none (not essential)
Absorption: intestine (90%)
Sensitive individuals: fetus, children, women of child bearing age
Toxicity/symptoms: nervous system, developmental effects include cerebral palsy-like symptoms with involvement of the visual, sensory, and auditory systems, tingling around lips & mouth, tingling in fingers & toes, vision, hearing loss
Regulatory facts: EPA – RfD – $0.1 \mu\text{g}/\text{kg}/\text{day}$
later – EPA 0.3 ppm advised MeHg fish tissue level for human health based upon water quality standards
FDA – 1 ppm in commercial fish
ATSDR – MRL – $0.30 \mu\text{g}/\text{kg}/\text{day}$
Canada - 0.5 ppm Hg for retail fish and seafood
General facts: bacteria convert inorganic mercury to methyl mercury then in to food supply (bioaccumulation)

Case Studies

“Well, Mr. Baldwin this is a pretty kettle of fish.”
Queen Mary of England

Minamata, Japan – Mercury and Fish

In the late 1950s the subtle and serious consequences of methyl mercury exposure became evident in Minamata, Japan. Initially, early signs of uncoordinated movement and numbness around the lips and extremities followed by constriction in visual fields in fishermen and their families baffled health experts. Developmental effects were clearly evident in infants that exhibited subtle to severe disabilities. This spectrum of adverse effects was finally related to methyl mercury exposure from consumption of contaminated fish. Minamata Bay was contaminated with mercury and methyl mercury from a factory manufacturing the chemical acetaldehyde. Mercury was used in the manufacturing process, which also resulted both mercury and methyl mercury being discharged into Minamata Bay. The fish in the bay accumulated increasing amounts of methyl mercury, which was subsequently passed to the fish consuming residents of the area. This was one of the first modern lessons of the consequences of the bioaccumulation of methyl mercury.

Mercury and Gold mining

Environmental contamination from the use of mercury in gold mining started centuries ago and continues today. The Peruvian Incas first used elemental mercury in gold mining in the 1500s. The gold binds to the mercury and when the mercury is removed the gold is left behind. Imagine heating a pan of a silvery substance (mercury-gold amalgam) and watching it turn to gold, a trick worthy of any alchemist. The mercury literally evaporates into the atmosphere leaving the gold behind. This practice continues today in Central and South America, Africa and the Philippines. It is estimated that it takes approximately 3 to 5 kg of mercury to extract 1 kg of gold. A large portion of this mercury contaminates the local environment and by moving into the atmosphere can be rained down to earth many miles and even counties away contributing to the global mercury contamination. The elemental mercury is converted to methyl mercury by bacteria after which it moves up the food chain, often in fish that are consumed by a range of animals and humans. Local miners, their families and particularly children suffer from mercury exposure.

Mercury coated seed grain in Iraq

The toxic anti-fungal properties of organic mercury compounds were beneficial when applied to seed grain, but when humans consumed these seeds there were tragic consequences. During much of the twentieth century, seeds were coated with organo-mercury compounds to reduce their destruction by fungus in the soil. Often these seeds were pink colored to indicate they were coated with an anti-fungal agent and were for planting only, not consumption. During the early 70s, a severe drought in Iraq resulted in a loss of seed grain as people struggled with malnutrition. Pink-colored mercury-coated seed grain was shipped to Iraq to for planting. Unfortunately, the local population could not read the foreign language on the seed bags nor recognize the pink seeds as hazardous. Bread made from these seeds was pink, tasty and toxic, particularly to the developing child. Many people died or were tragically disabled for life, giving the world another lesson in communication and mercury toxicity.

Mercury in Paint

Prior to the 1990s mercury compounds were routinely added to interior and exterior paint to prevent bacterial and fungal growth. The practice of adding mercury to paint was halted after the adverse effects of inhaled mercury were seen in a 4-year-old boy. The child's unventilated bedroom was painted with mercury containing interior latex paint. The boy was diagnosed with acrodynia; a rare disease caused by mercury exposure and characterized by flushed cheeks, pink, scaling palms and toes, profuse sweating, insomnia and irritability. Manufacturers agreed to discontinue the use of mercury in paint in 1991 but because people often store paint for long periods of time this existing paint could still cause health problems.

Mercury under floorboards

Mercury is commonly used in many industrial applications and is a source of a nasty surprise when not adequately removed. In 1996 it was reported 6 children and a number of adults were exposed to mercury vapor while living in condominiums in a converted manufacturing building. Prior to being converted, this building had been used to manufacture mercury vapor lamps. Pools of mercury were discovered beneath the floorboards of the condominiums.

Introduction and History

Mercury exists in different forms with very different properties; thus each section of this chapter is divided into inorganic mercury – the common silvery liquid – and organic mercury (usually methyl mercury – Hg-CH₃) that is generated from mercury and accumulates in some commonly consumed species of fish.

Mercury's dual nature of being both industrially useful and potentially harmful was recognized historically, but only in the last 20 years have we begun to appreciate its more subtle qualities and effects. The contradictory nature of mercury was recognized in Roman mythology, in which the winged messenger Mercury, who was noted for his cleverness, cunning and eloquence, was both the god of merchants and commerce as well as of thieves and vagabonds. The history of mercury's use by humans shows our struggle to balance and understand the usefulness of this compound and its harmful effects to humans and the environment. We now grapple with mercury as a global pollutant as we recognize its potential risks to children.

“For then she bare a son, of many shifts, blandly cunning, a robber, a cattle driver, a bringer of dreams, a watcher by night, a thief at the gates, one who was soon to show forth wonderful deeds among the deathless gods...”

Description of the birth of the Greek god Mercury

Inorganic Mercury

Elemental mercury, also known as quicksilver or metallic mercury, is a silvery liquid at room temperature, with a low boiling point, a high vapor pressure (e.g. evaporates) at room temperature, and a high density, weighing 13.6 times as much as water. Stone, iron, lead, and even humans can float on its surface (see Putman, 1972). Its toxicity has been recognized since Roman times when slaves mined it in Almaden, Spain; this mine remains active today as a major mercury source. While all rock types contain some mercury, cinnabar contains the greatest concentration of inorganic mercury (>80%). Elemental mercury is produced from cinnabar by condensing the vapor of heated ore. In the United States elemental mercury is produced primarily as a byproduct of mining.

Hg

Mercury

Atomic Number: 80

Atomic Mass 200

Elemental mercury is used industrially in electric lamps and switches, gauges and controls (e.g., thermometers, barometers, thermostats), battery production, nuclear weapons production, and the specialty chemical industry, including the production of caustic soda. Because elemental mercury has a high affinity for gold and silver, it has

been, and continues to be used, in precious metal extraction from ore. Elemental mercury has been used for over one hundred years in mercury-silver amalgam preparations to repair dental caries. Mercury continues to be used in folk remedies and in certain cultural practices, with unknown public health implications.

The Chinese used cinnabar to make in red ink before 1000 BC, and in cosmetics, soaps and laxatives. Inorganic mercury (as an acid of mercury nitrate) was used in the felting industry to aid in matting felt; felting was a leading source of occupational mercury exposure in the United States into the 1940s. A 1937 Census of Manufacture of the U.S. Census Bureau reported 5.2 million pounds of hatter's fur used in the production of over 30 million felt-hat bodies among 140 factories in the United States, and a study of 25 Connecticut hat factories demonstrated evidence of chronic mercurialism among 59 of 534 hatters.

Peruvian Incas used elemental mercury to wash gold-bearing gravel as early as 1557. The original extraction process, which took place over 20 to 30 days, underwent subsequent modification, leading to the ability to extract gold in a pan over a fire in less than 6 hours by the 1830s. With some modifications this process continues to be used to this day, especially in Central and South America, Africa, and the Philippines, where it requires approximately 3 to 5 kg of mercury to extract 1 kg of gold,

Dental amalgams were used as early as the 7th century, and the first commercial mercury dental amalgam was used in the 1830's in New York. Chronic mercury exposure among dentists and dental assistants is a well-

Wipe off this glass three times.
There is arsenic in it.
I hear messages from God
through the fillings in my teeth.

Anne Sexton (1928–1974)

recognized occupational hazard. Concerns over the public health risks of mercury amalgam fillings have also been raised in the scientific literature, though this is an area of significant controversy. Recent studies indicate that amount of mercury in the urine is related to the number of dental amalgams and that a similar relationship exists for mercury excretion in human breast milk. Some countries are advising women of child bearing and children not to use mercury based dental amalgams. The U.S. FDA while taking no position on this

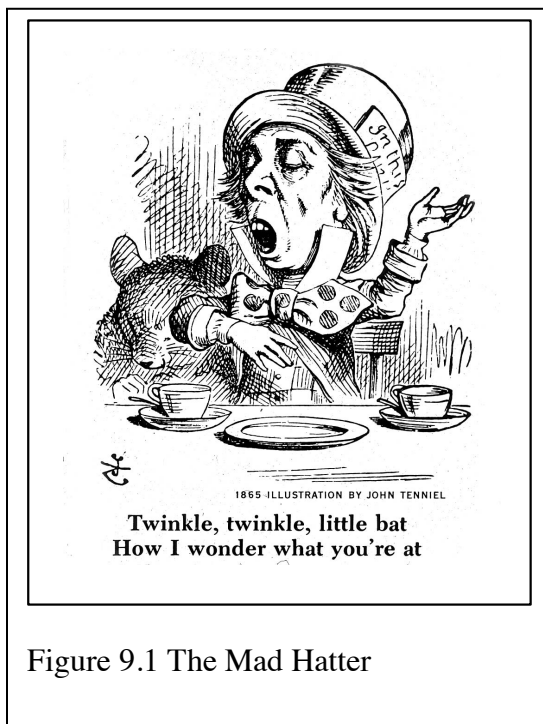


Figure 9.1 The Mad Hatter

issue is requesting additional information and is reviewing its advisory. Perhaps the most important aspect is that there is a very acceptable alternative to mercury amalgams, which from a precautionary principle perspective would suggest that mercury amalgams should be avoided. Sweden, prohibits the use of dental amalgam in ordinary dental care and bans its use in children and youth.

Mercury thermometers have been used for decades. In some instances their use has been discontinued, such as in infant incubators where it was found that significant mercury vapor concentrations could be achieved if the thermometers were broken in this enclosed environment. Disposal of thermometers and thermostats continues to add significantly to the toxicity of municipal waste. In 1995, discarded thermometers contributed 16.9 tons of mercury to municipal solid waste stream.

Organic Mercury

The first reported use of organic mercury compounds in chemical research occurred in 1863. Their synthesis immediately led to the recognition of their extremely high toxicity relative to inorganic mercury forms, and by 1866 two chemists had died from organic mercury poisoning. Therapeutic applications of organic mercurials in the treatment of CNS syphilis, which began in 1887, led to non-occupational poisoning; the use of organic mercury-based medicines ceased soon after because of their extremely high toxicity. The use of synthetic organic mercurials as antifungal dressings for agricultural seeds began in 1914. Their use in this industry has resulted in scattered case reports of acute poisoning associated with the chemical manufacture, application, and inadvertent consumption of either the treated grain or of animals fed with the treated grain. The use of organic mercurials in agriculture has resulted in large scale poisoning episodes worldwide, such as occurred in Iraq.

Both elemental mercury and inorganic mercury are used in chemical manufacture, including vinyl chloride and acetaldehyde synthesis (inorganic mercury), and chlor-alkali production (elemental mercury). For example, the Minamata Factory used mercuric oxide dissolved into sulfuric acid as a catalyst for the hydration of acetylene to acetaldehyde. In addition, vinyl chloride production at Minamata Factory used mercuric chloride absorbed onto activated carbon for the production of vinyl chloride from acetylene and hydrogen chloride. It is these processes that directly led to the contamination of Minamata Bay and the Agano River, and Niigata by mercury effluent. This discharge resulted in the large-scale human methyl mercury exposure and toxicity during the 1950s and 1960s and led to our present-day appreciation of mercury's environmental cycling, biomethylation and food chain transfer

Organic mercury compounds have also been used in latex paint to extend the shelf life, though such uses are currently restricted in the United States following the recognition of this potential hazard to children. Subsequent evaluation of interior rooms of homes painted with mercury-containing latex paint found that mercury vapor concentrations

were elevated and in several cases were above the 0.5 microgram per m³ concentration recommended by the Agency for Toxic Substances and Disease Registry.

Biological Properties

Inorganic Mercury

Inorganic mercury can also be in the form of salts as either monovalent (Hg⁺, mercuric) or divalent (Hg²⁺, mercurous). Two major mercury chloride salts, calomel (mercurous chloride) and sublimate (mercuric chloride) were first produced in the Middle Ages. Inorganic mercury-based skin creams were first used during this period for the treatment of syphilis, and inorganic mercury was used as a clinical diuretic during the early 1900s.

When mercury vapor from elemental mercury is inhaled, it is readily and rapidly absorbed into the blood stream, easily crosses the blood-brain barrier, and the placenta. Ingestion of elemental mercury is far less hazardous than inhalation of mercury vapor due to its poor absorption in the gut. After entering the brain, mercury is oxidized and will not transfer back across the blood-brain barrier, thus continued exposure to mercury vapor, will result in mercury accumulation in the nervous system.

Organic Mercury

While there are many synthetic organic mercury compounds, the most important organic mercury is the naturally occurring form methyl mercury (MeHg). In the environment, inorganic mercury is biotransformed to MeHg primarily through microbial methylation in sediments of fresh and ocean waters. Once produced, MeHg readily enters the aquatic food chain and bioaccumulates in tissues of aquatic organisms. Because MeHg is stored throughout the life of aquatic organisms, it is transferred up the food chain and results in the highest concentrations in larger, long-lived, predatory species such as swordfish, pike, and ocean tuna. The bulk of mercury in fish is stored in muscle, and almost all of the mercury in muscle is MeHg. The concentration of MeHg in fish depends on the age and trophic level of the particular fish, and can be quite substantial (> 1000 µg/kg (ppm)). For example, the total mercury in the edible tissues of shark and swordfish can average as high as 1200 µg/kg. Organomercurials have been used as fungicides, as paint preservatives, and in medicinal applications, though these uses have ceased as a result of their recognized neurotoxicity. Therefore, fish and marine mammal consumption are the primary sources of human MeHg exposure, and to a lesser degree research applications of MeHg and other organomercurials.

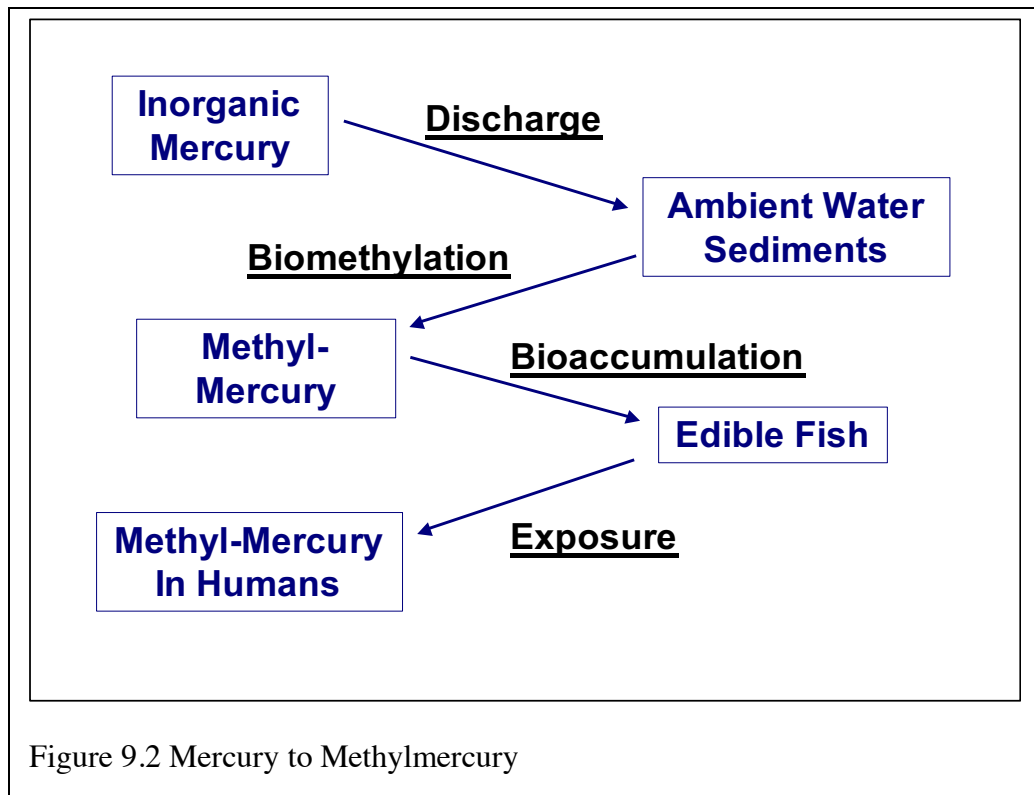


Figure 9.2 Mercury to Methylmercury

Health Effects

Inorganic Mercury

Elemental mercury in the form of mercury vapor is readily and rapidly absorbed into the blood stream when inhaled and easily crosses the blood-brain barrier and the placenta. Oral ingestion of elemental mercury is far less hazardous than inhalation of mercury vapor due to its poor absorption in the gut. Acute, high level exposure to mercury vapor can result in respiratory, cardiovascular, neurological, and gastrointestinal effects, and even death.

Either acute, high dose or chronic, low dose exposure to mercury vapor can result in increasing and irreversible neurological effects. Symptoms include tremors and loss of feeling in the hands (paresthesia or stocking-glove sensory loss), emotional instability, insomnia, memory loss, and neuromuscular weakness. Exposure to mercury vapor may precipitate tremor, drowsiness, depression, and irritability; such symptoms form the basis for the expression “mad as a hatter” and the Mad Hatter in Lewis Carol’s, “Alice’s Adventures in Wonderland.” Decreased performance on memory tests and verbal concept formation has also been documented in industry workers exposed to mercury vapor.

Neurotoxic effects such as dizziness, weakness, insomnia, numbness and tremor were observed in a 12-year-old girl exposed to spilled mercury.

Organic Mercury

The devastating health consequences of methyl mercury (MeHg) exposure were well documented from several tragic incidents (see the case studies section). Historically, MeHg exposure played a very important role in drawing worldwide attention to the consequences of industrial pollution not just for workers but also for the general public. In the 1950's, the consequences of MeHg exposure to the people of Minamata and Niigata, Japan were recognized. In both cases MeHg exposure resulted from consumption of fish from waters receiving industrial effluent discharge containing mercurials, which demonstrated conclusively that MeHg poisoning could occur through food-chain transfer of MeHg. By 1974 over 2150 cases of, what was then called Minamata disease, had been established in the Minamata region alone. Observations of an abnormally high incidence of cerebral palsy-like symptoms with involvement of the visual, sensory, and auditory systems among children from the Minamata region also heralded a new concern over the potential developmental toxicity of industrially derived MeHg. However, as with the adult cases of MeHg-poisoning, establishing a causal relationship between environmental MeHg and cases of observed infantile developmental toxicity was difficult to establish. Difficulties in making an association arose because the affected children had not eaten fish and there were no identified neurological effects in their mothers based on evaluations at that time. The susceptibility and the sensitivity of the fetus, relative to adults, to MeHg-induced neurotoxicity were later documented in other studies.

A tragic incident in Iraq clearly documented the fetal effects of maternal methyl mercury exposure (see case study section). During the winter of 1971 some 73,000 tons of wheat and 22,000 tons of barley was imported into Iraq. This grain, intended for planting, was treated with various organic mercurials. Unfortunately, this grain was made into flour and consumed throughout the country, resulting in the hospitalization of some 6,530 people and death of 459 at the time of the study (Table 9.1).

The accumulated evidence leaves no doubt that MeHg is serious developmental toxicant in humans, especially to the nervous system. While the toxicological, and behavioral outcomes resulting from high concentration *in utero* MeHg exposures are not in debate, questions regarding risks and mechanisms of action following low-concentration, chronic *in utero* exposures remain.

A U.S. National Research Council report states "over 60,000 newborns annually might be at risk for adverse neurodevelopmental effects from in utero exposure to MeHg (methyl mercury)." This report clearly makes the point that many infants are exposed to mercury above levels considered safe.

Table 9.1 Major Mercury Poisoning Incidents

Place	Year	Cases
Minamata	1953-60	1000
Nigata	1964-65	646
Guatemala	1963-65	45
Ghana	1967	144
Pakistan	1969	100
Iraq	1956	100
Iraq	1960	1,002
Iraq	1971	40,000
On-going	2001	???

One of the complications with diagnosing MeHg exposure is that presentation of symptoms appears to occur after a latency period during which no effects are observed. The period of latency appears to be related to the level of exposure, with higher exposure concentrations resulting in a shorter latency period. The exact biological mechanisms underlying this latency period are unclear. Some researchers have suggested that latency not only reflects the time to reach accumulation of MeHg in the brain, but also reflects achievement of a threshold wherein enough tissue is destroyed that the capacity of the CNS to compensate for the damage is overwhelmed. Observation of long latencies following cessation of MeHg administration in animals and humans, however, may also derive from long-term demethylation of MeHg to inorganic mercury in the brain

Reducing Exposure

Inorganic Mercury

There are numerous sources of metallic mercury in the home and workplace. The best advice is to properly dispose of any product with mercury and above all avoid exposure, especially inhalation, particularly for young children. In the past few years, many industries have worked to reduce the use of mercury in products. In addition, some states have also restricted the use of mercury or have developed programs to aid in the recycling and recovery of mercury. The average household fever thermometer contains about 3 grams of mercury, which is does not seem like much until it is multiplied by the 105 million house holds in the United States. Even if only half of the households had a mercury thermometer, the total amount of mercury is very large. Additional sources of atmospheric mercury include coal fueled electric generation facilities, hospital waste, fluorescent light bulbs, dental offices, and even crematoriums. Efforts are being made on

a number of fronts to mandate reduction in mercury released into the atmosphere and in general reduce the use of mercury. As individuals, we must also work to insure mercury products are properly recycled and take action to reduce atmospheric mercury.

If a mercury spill occurs it is very important to ventilate the area and do NOT use a vacuum cleaner to clean up the mercury. A vacuum cleaner will only warm and disperse the mercury in the room. Collect all the mercury and place in a sealed container and take to an appropriate disposal site. If it is large spill professionals must be called.

Table 9.2 Common Sources of Metallic Mercury

Switches in gas furnaces, heaters, etc.
Major household appliances (tilt switches in freezers, dryers, etc.)
Irons (tilt switches)
Automobile switches
Bilge pumps, sump pumps, etc. (float switches)
Dental amalgam
Measuring devices and lab equipment, such as barometers, manometers, etc.
Medical equipment and supplies
Fluorescent lights
Batteries
Computers
Novelty items
Film pack batteries

Organic Mercury

The primary concern with organic mercury is methyl mercury in fish. Children and women of child bearing age should be cautious about consuming fish know to accumulate mercury such as tuna, shark, swordfish, and pike. Local fish consumption advisories should be followed

Regulatory Standards

Inorganic –Mercury

The liquid silver inorganic mercury evaporates into the atmosphere. When inhaled, mercury cross move easily into the blood and then to the brain, thus the primary hazard concern is from inhalation. Metallic mercury is poorly absorbed after oral ingestion, thus much less hazardous than inhalation. Below are some of the advisories on mercury vapor inhalation.

- ATSDR – Minimal Risk Level (MRL) – 0.2 $\mu\text{g}/\text{m}^3$
- OSHA – Permissible Exposure Limits (PEL)-TWA – 0.05 mg/m^3

- ACGIH – Threshold Limit Value (TLV)-TWA – 0.05 mg/m³

Organic – Methyl Mercury

The primary human exposure to methyl mercury is from consumption of contaminated fish. The most sensitive population is the developing fetus or infant due to the effects of methyl mercury on the nervous system (neurotoxic) and developmental effects. Exposure limits and fish consumption advisory are directed at pregnant women, women of childbearing age and children. All agencies also recognize the fish consumption has many nutritional benefits and is an important part of many peoples diet. Nevertheless, the widespread distribution of mercury and subsequent bioaccumulation of methyl mercury requires that many agencies have developed recommendation for levels of mercury in fish. Below is a list of some of these recommendations but it is very important to consult the local fish consumption advisories.

- FDA – 1 ppm in commercially harvested fish (i.e. tuna fish)
- FDA – Action level – 0.47 $\mu\text{g}/\text{kg}/\text{day}$
- ATSDR – Minimal Risk Levels (MRLs) – 0.30 $\mu\text{g}/\text{kg}/\text{day}$
- Washington State – Total Daily Intake – 0.035-0.08 $\mu\text{g}/\text{kg}/\text{day}$
- EPA – Reference Dose (RfD) – 0.1 $\mu\text{g}/\text{kg}/\text{day}$
- (In 1997 the EPA estimated the 7% of the women of child bearing age in the United States exceed the established RfD of 0.1 $\mu\text{g}/\text{kg}/\text{day}$.)
- 41 states have issued over 2,000 fish consumption advisories related to mercury

Recommendation from the State of Washington (U.S.)

- Women of childbearing age should limit the amount of canned tuna they eat to about one can per week (six ounces.) A woman who weighs less than 135 pounds should eat less than one can of tuna per week.
- Children under six should eat less than one half a can of tuna (three ounces) per week. Specific weekly limits for children under six range from one ounce for a twenty pound child, to three ounces for a child weighing about sixty pounds.

See: <http://www.doh.wa.gov/fish/FishAdvMercury.htm>

Recommendation and Conclusions

Mercury is a potent toxicant and a global environmental pollutant. There is overwhelming data demonstrating that low levels of exposure to methyl mercury or mercury vapor damage the nervous system, particularly the sensitive developing nervous system. Mercury vapor travels around the globe in the atmosphere. Once on the ground or

in the water, it is converted to methyl mercury and accumulates in the food supply, contaminating fish, a main source of protein for many people. There needs to be a global effort to reduce human release of mercury into the environment. The production, sale and use of mercury must be restricted in recognition of the health effects mercury. Mercury use in consumer products, such as thermostats, thermometers and jewelry should be eliminated and replaced with already well-established and cost effective alternatives. Coal contains low levels of mercury that are released as the coal is burned. The discharge from coal fired electric generating facilities can be greatly reduced with current technology. Finally there must be on going monitoring of mercury contamination in fish and appropriate advisories issued to protect sensitive populations. This will involve education of the consumer about limiting the consumption of fish that accumulate mercury.

Summary of Recommendations on Mercury

- Reduce global environmental release
- Restrict global production and sale and use
- Clean up contaminated sites
- Reduce mercury emission from coal fired electric power facilities
- Reduce or eliminate use in consumer products (cars, thermometers, thermostats, jewelry)
- Advise women of childbearing age on fish consumption
- Monitor mercury levels in fish

More Information and References

Slide Presentation

- A Small Dose of Mercury presentation material and references online: www.asmalldoseoftoxicology.org
Web site contains presentation material related to the health effects of mercury.

European, Asian, and International Agencies

- United Nations Environment Program's Global Mercury Assessment 2018.
Online: <<https://www.unenvironment.org/resources/publication/global-mercury-assessment-2018>> (accessed: 08 September 2020).

This program aims to develop a global assessment of mercury and its compounds, including an outline of options for addressing any significant global adverse impacts of mercury.

- World Health Organization – Elemental Mercury and Inorganic Mercury: Human Health Aspects. Online: <http://www.inchem.org/documents/cicads/cicads/cicad50.htm> (accessed: 08 September 2020).
Document on human health aspects of inorganic and organic mercury.

North American Agencies

- Health Canada - Mercury. Online: < <https://www.canada.ca/en/health-canada/services/healthy-living/your-health/environment/mercury-human-health.html> > (accessed: 08 September 2020).
Health Canada provides information on the health effects and environmental distribution of mercury.
- Health Canada - Mercury - information sheet < <https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/chemicals-glance/mercury-compounds-public-summary.html> > (accessed: 08 September 2020).
Health Canada provides information on the health effects of mercury..
- U.S. Food and Drug Administration (FDA) – Mercury and Methylmercury. Online: <https://www.fda.gov/food/metals-and-your-food/mercury-and-methylmercury> (accessed: 08 September 2020).
Site has recent FDA consumer information on Mercury and Methylmercury.
- U.S. Environmental Protection Agency (EPA)
 1. EPA – Main site on Mercury. Online: <<http://www.epa.gov/mercury/>> (accessed: 08 September 2020).
 2. EPA Advisories and Technical Resources for Fish and Shellfish Consumption. Online: <https://www.epa.gov/fish-tech> (accessed: 08 September 2020).
 3. EPA (1997). Mercury Study Report to Congress. Office of Air Quality Planning and Standards and Office of Research and Development. EPA-452-R-97 –003 through –010 (Volumes I-VIII). Online: <<https://www.epa.gov/mercury/mercury-study-report-congress>> (accessed: 08 September 2020).

4. EPA Integrated Risk Information System. Online: <<https://www.epa.gov/iris>> (accessed: 08 September 2020)
- U.S. Agency for Toxic Substance Disease Registry (ATSDR) – Toxicology Profile Series on Mercury. Online: <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=24> (accessed: 08 September 2020).
ATSDR produces toxicology profile documents on many compounds including mercury.
- U.S. Department of Labor - Occupational Safety & Health Administration (OSHA). Online: <<http://www.osha.gov/>> (accessed: 08 September 2020).
- U.S. Geological Survey (USGS). Online: <https://www.usgs.gov/science-explorer-results?es=mercury> (accessed: 08 September 2020).
Site has maps and supply information on mercury.
- U.S. National Research Council (NRC) – EPA's Methylmercury Guideline Is Scientifically Justifiable For Protecting Most Americans But Some May Be at Risk. Online: <<http://www.nationalacademies.org/publications/>> (accessed: 08 September 2020).
The full NRC report on mercury can be read on the web, search on methylmercury.
- Washington State Department of Health – Fish Facts for Health Nutrition. Online: <<http://www.doh.wa.gov/fish/>> (accessed: 08 September 2020).
Site has information on Washington State's advisory of fish consumption and mercury.
- Washington State Department of Ecology – Mercury Reduction in Washington – Including the Mercury Chemical Action Plan. Online: <http://www.ecy.wa.gov/mercury/> (accessed: 08 September 2020).
Comprehensive information on uses and release of mercury in Washington and efforts to reduce mercury use and release. .

Non-Government Organizations

- The Mercury Policy Project (MPP). Online: <<http://www.mercurypolicy.org/>> (accessed: 13 September 2020).
“MPP works to raise awareness about the threat of mercury contamination and promote policies to eliminate mercury uses, reduce the export and trafficking of mercury, and significantly reduce mercury exposures at the local, national, and

international levels.” While material seems accurate the last addition to the web site was March 20, 2016.

- Got Mercury. Online: www.gotmercury.org (accessed: 13 September 2020). A calculator that estimates mercury intake from fish and shellfish. Managed by Turtle Island Restoration. Network
- American Conference of Governmental Industrial Hygienists (ACGIH®). Online: www.acgih.org (accessed: 13 September 2020). “ACGIH is a member-based organization and community of professionals that advances worker health and safety through education and the development and dissemination of scientific and technical knowledge.” “This original goal is reflected in both our current mission – the advancement of occupational and environmental health – and in our tagline: Defining the Science of Occupational and Environmental Health.

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Newer References

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