(Mercury - Toxicity Through the Ages - Analysis of Health Effects on Human Body Systems)

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Research Topic: Life Sciences

Abstract:

Mercury takes many different shapes in the environment. It can be found in inorganic forms like minerals, mercury vapor, mercury salts, and in organic forms bounded to carbon. Mercury is known to have a history of causing toxic effects to the nervous system. The concern is even greater with methylmercury and other organic mercury. Methylmercury has been responsible for health and environmental catastrophes, the most significant being the Minamata disaster in Japan and the "Wonder Wheat" disaster in Iraq. The "Mad Hatters" and "Danbury Tremors" are related to the exposure of inorganic and elemental mercury, respectively, and mercury vapor.

Since the onset of the modern era, mercury has remained a hazard to mankind through various mechanisms, including artisanal gold mining, combustion of biomass, the chlor-alkali industry, and some traditional medicines. Given the huge amount of damage, an essential question is posed. Can mercury be fully removed? With the many historical and current uses of mercury, has man been able to gain control of the toxic effects of mercury? What effects can be caused to prevent its risks? These questions were mainly the focus of our research. This research was also focused on the exposure to mercury, its toxicity, and the symptoms related to it, in order to prevent exposure and to identify the sources that are the most likely to put the human body at risk.We performed a mini-analytical review to gather and contrast findings from prior studies regarding the total mercury concentration and some species of locally marketed fish and determine the studies' agreement with the WHO limit for mercury of 0.5 mg/kg in fish. A review of previous studies shows that mercury impacts the skin and the digestive system from eating large fish that are mercury contaminated. Mercury leads to a wide range of effects that can be experienced by the respiratory and nervous systems. Given the aforementioned symptoms and the effects caused by mercury, there is a need to control prolonged exposure to mercury, even if it is in a small concentration, and to evaluate the chronic health concerns that may be related to the prolonged exposure.

Keywords: Mercury. Toxicity. Human body systems

Chapter One

1. Introduction

1-1 Over view of Mercury

It is a chemical element with the symbol **Hg** and has atomic number **80** Mercury is located in the periodic table among the elements of the sixth cycle and above the elements of group twelfth. Under standard conditions of pressure and heat , mercury is a liquid, with a density of (13.54 g/cm3), with a bluish-silvery color similar to lead. It freezes at (-38.9 °C) and boiling point (356.9 °C)

(U.S. Environmental Protection Agency, 2007)

Table 1.1 shows the general properties of mercury

General Properties	
Name, Number, Symbol	Hg, 80, Hg
Item Classification	Transition metal
Group, Course, Sub-Level	12, 6, D
Atomic mass	200.59 g·mol−1
Electronic Distribution	)Xe (54 - 6s2- 5d10- f 14
Distribution of electrons per valence shell	2- 8- 18- 32- 18- 2

Cinnabar ore, which contains mercury, is found in natural deposits throughout the world. Natural cinnabar, or synthesized mercury sulfide, can be used to obtain the scarlet red pigment through a grinding procedure. Applications for mercury include many laboratory and clinical devices and instruments including barometers, thermometers, blood pressure monitors, valves, mercury switches and relays, and fluorescent lamps among other devices. Concerns for its safety, however, are increasing. Due to its high toxicity, there has been a replacement trend to replace mercury thermometers and sphygmomanometers in clinical practices with safer alternatives including glass thermometers filled with alcohol or galenstane and thermistor or infrared electronic devices. In addition, mercury sphygmomanometers have been replaced with mechanical or electronic sphygmomanometers.

However, there are continued uses of mercury in some areas of scientific research, as dental amalgam in some regions, and in some food processing technologies. In food processing, mercury (II) chloride is used in food to inhibit enzymes that cause the degradation of starch in the starch extraction process in the food refining of rice, corn and wheat.

(U.S. Environmental Protection Agency., 1996)

Mercury is also used in the manufacturing of fluorescent lights. The control of electricity that passes through the vapor of mercury in the fluorescent light generates short wave of ultraviolet rays and excites the phosphor layer in the tube and produces fluorescent light. Mercury poisoning can result from exposure to water soluble forms of mercury such as methylmercury and mercuric chloride, and from inhalation of its vapor or ingestion of any form of mercury. The risk of mercury poisoning is higher when lead exposure occurs, as the combined exposure of mercury and lead is among the many factors that have been associated with higher risk of autism.

(Encyclopedia Britannica, 2016)

1.2 History and 1.2.1 Origin of the name

The modern term mercury in English derives from the planet mercury. The seven metals known to the ancient world, mercury, gold, silver, copper, iron, lead and tin, were believed to be associated with the seven planets known to the ancient world.

Of the planets, Mercury was associated with the fastest: the planet Mercury, named after the Roman god Mercury, who is associated with speed and mobility. The planet's symbol became one of the symbols for the metal, and Quicksilver was another name for mercury. While Quicksilver might have been an alternative name for mercury, it was decided the name Mercury would be the preferred name over Quicksilver, and therefore, Mercury is the only chemical name of a metal that is the name of a planet.

(Zhao, (2006).)

Historic records indicate that within Paleolithic cave paintings, Cinnabar, a red pigment derived from mercury sulfide, was found in paintings from 30000 years ago, located in Europe, in the modern-day countries of Spain and France.

In the Medieval Era, mercury was located in some Egyptian tombs from 1500 BC. It was thought that using mercury could treat broken bones, improve public health, and promote longevity. Public health suffered due to exposure to mercury vapors. In modern times some chemists thought that mercury was the first element of all metals. Using mercury, one could create various other metals by varying the amount of sulfur. Alchemists believed that gold was the most pure metal, therefore many ancient alchemists believed that using mercury would help them transform base metals into gold.

1.3 Properties of mercury

Physical Properties

Mercury is a silvery, heavy metal that is easily found in a liquid form. It is a poor conductor of heat, but a good conductor of electricity. The melting point of mercury is -38.83 °C and the boiling point of mercury is 356.73 °C. These melting and boiling points are relatively low when compared to the stable minerals. It could be, however, that some preliminary work with copernisium and flerovium may yield lower boiling points. These phenomena are correlated to lanthanide contraction and the contraction of outer electrons, which create weak bonds between metals and mercury.

When mercury solidifies, its volume shrinks by 3.59%. The density of liquid mercury is 13.69 g/cm³, while the density of solid mercury is 14.184 g/cm³.

. (ToxFAQs for Mercury, 1999)

Chemical Properties

The chemical properties of mercury are different from most acids, especially dilute sulfuric acid, so there are practically no dissolving reactions. Stronger acids, such as concentrated sulfuric acid and nitric acid, however, can react, producing compounds of sulfur, mercury, and nitrate. Similar to silver, mercury will also react with hydrogen sulfide. It will also react with solid sulfur, which is used in mercury spill kits to absorb mercury, along with activated charcoal and zinc powder.

(ToxFAQs for Mercury, 1999)

How to prepare mercury through

Mercury sulfide is heated to red hot in the air and the resultant vapor is condensed.

Chemical formula of the reaction: Presence of mercury in the environment

The element Mercury, denoted by the chemical symbol Hg, stands for hydrargyrum, meaning "liquid silver" in Ancient Greek. Mercury is a whitish, silver metal that, unlike most metals, is a liquid at standard conditions. Mercury is also called fast silver, liquid mercury, or metallic mercury. Mercury's high surface tension means it will be released into the environment in the form of small, stable droplets. Though stable, the high vapor pressure of mercury will cause it to evaporate, which also means that mercury will become more poisonous to inhale.

Open to the environment, mercury will evaporate and remain in the environment. Mercury is a unique element in that it cannot be created or destroyed. Mercury is released into the environment by way of volcanos and is found in the earth's crust, usually in mercury salts, of which mercury sulfide is a common example. All soils have a very small concentration of mercury. Uncontaminated soils will have an average concentration of about 100 ppb and rocks will have between 10 and 20,000 ppb.

(Cherian.M.G, Hursh, & clarkson.T.w, 1978)

Humans engage in many activities that evaporate mercury from the earth's crust. One of those activities involves the use of cinnabar, an ore containing high mercury sulfide that is used to manufacture mercury. Additionally, mercury is a by-product of the cinnabar ores of other metals like copper, gold, lead, and zinc.

(Ngim et al, 1992)

Mercury can be derived from recycling and in some instances, from fossil fuels and natural gas.

When compared to the total global mercury content, approximately one-third is of natural origin, while two-thirds are of anthropogenic and industrial origin. Erosion of rocks and soils are also natural sources of mercury along with volcanic eruptions. During the one and a half centuries after the onset of industrialization, the ambient concentration of mercury in the air, soils, lakes, streams and oceans, has increased by two to four times.

As a result, there is a troubling increase in mercury in the environment. Mercury exists in fossil fuels and some ores and metals. Mercury is also emitted in large amounts when coal is burned and during the exploration and refining of mineral ores or in the cement industry. Where mercury is produced or used, large amounts can evaporate into the atmosphere. Workers in artisanal and small-scale gold mines use significant amounts of mercury. Mercury is used in catalytic or starting materials in chemical or other industrial processes. Mercury and its compounds are also found in various consumer and industrial goods.

(Liang, 1993)

Once mercury is in the air, it can be evaporated or settled on the earth. Mercury can be also be deposited in the oceans or land, and then be evaporated and it travels to be deposited elsewhere. Mercury can also be absorbed in rivers, lakes, and oceans. Mercury also binds to sediments in the aquatic environment. Mercury in soil can also be combined with organic matter and remain there or be deposited in a dissolved state in water. In aquatic environments, organisms can transform elemental mercury into methyl mercury, which is highly toxic and more of a concern due to its bioaccumulation.

Methylmercury migrates to the aquatic food system, where it accumulates and enhances, and it is transported by some migratory species. (Clarkson & Magos, 2006)

5.1 Mercury's Atmospheric Presence

The most common composition of gaseous mercury is metallic mercury, however, a small proportion is mercury compounds that are in the oxidized state. These include mercury chloride and mercury oxide, etc. The majority of atmospheric mercury exists in the gaseous state and some exist as fine particulates. Pure mercury vapor, which is metallic mercury in the gaseous state, is water soluble and is persistent in the atmosphere for 6 months to 2 years. Given this persistence, it is able to travel great distances, resulting in the concentrations of mercury vapor in the atmosphere being relatively uniform. The concentration of mercury vapor in the atmosphere is higher in the Northern Hemisphere as it is more industrialized compared to the Southern Hemisphere.

Elemental mercury in the gaseous state is more water soluble and more reactive than metallic mercury. Due to this, it is more stable in the atmosphere and thus can descend through precipitation. The presence of mercury particles can be removed through either wet or dry deposition. The more reactive mercury particles often reside in the atmosphere for a shorter duration than the less reactive particles. Due to the weak solubility of mercury in water, rainwater is not sufficient to remove it from the atmosphere.

The mechanisms for removal and deposition of gaseous mercury are numerous and still under investigation. Some researchers believe gaseous mercury deposition is a consequence of photochemical reactions occurring in the sub-layers of the troposphere. Other researchers have postulated that dry deposition occurs in the upper sections of forests, which is a significant way for the deposition of gaseous mercury in the troposphere. One study highlighted that under a specific set of conditions, gaseous mercury can be removed from the coastal regions of the troposphere.

It has recently been recognized that there is a phenomenon called "atmospheric depletion." Studies have shown that in the spring in the Canadian Arctic Highlands, as the sun rises, there is a rapid decrease in mercury levels, while there is also a decrease in atmospheric ozone. This phenomenon has been proven to occur in the Arctic and Antarctic. This is the result of photochemical reactions in the sub-layers of the atmosphere that involve ozone and marine-origin halogen compounds, especially bromine oxides. During this, ozone is eliminated, while atmospheric mercury is oxidized to form reactive gaseous mercury.

It is thought approximately 300 metric tons of reactive gaseous mercury are deposited in the Arctic each year. As a result of this process, mercury deposits in the Arctic are now at twice what they would be if spring depletion did not occur. Unfortunately, these deposits are in the form of oxidizing mercury compounds, which are bioavailable. The discovery of these Arctic deposits helps explain the risk of Arctic residents' exposure to methylmercury. The reason why the Arctic residents are more exposed to methylmercury than others is still being studied. Mechanisms of atmospheric mercury deposition are still being studied, especially deposition of mercury to the Earth's surface and water bodies.

(Survey, 2007)

. The toxic effects of mercury and methylmercury

Toxic effects of both mercury and methylmercury

The toxicity of mercury is not new, and goes back to the first century AD. Roman historian Pliny the Elder described a case of mercury poisoning that affected workers which in the Empire was the slaves, as those who carried

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out healthy work for the Empire would not be contaminated with mercury vapors. The toxicity of mercury has inspired characters in popular culture. For example, in Lewis Caroll's children story Alice in Wonderland, the "Mad Hatter" may be based on the symptoms of mercury poisoning which affected English hatmakers in the 19th century. Among the affected workers, there was a wide variety of symptoms in the nervous system including irritability, shyness, and depression. They all suffered from mercury nitrate poisoning, which was used in the manufacture of felt. For this reason, mercury used in the manufacture of felt was the main cause of these symptoms.

Occupational mercury exposure is still common for many workers today. Industries impacted include those that mine mercury, produce chlor-alkali, manufacture devices that use mercury, manufacture mercury-containing batteries, mine precious metals, and those that mine and refine nickel. In addition, exposure is a concern for dental workers.

(Survey, 2007)

Mercury poses the largest threat to artisanal and small-scale gold miners. The gold extraction methods employed by this mining group are primitive and unsafe. In addition to the miners themselves, entire communities are put at risk due to unsafe mining conditions. The nervous system can be damaged by chronic exposure to all forms of mercury, but damage occurs fastest with exposure to methylmercury and mercury vapor, which cross the blood-brain barrier. Research has proven that exposure to any form of mercury is toxic to the developing fetus, even when the exposure occurs many months prior to the pregnancy.

Potential complications in a developing fetus after exposure to mercury include mental impairment and damage to the nervous and digestive systems. Exposure to mercury may cause children to develop chronic conditions, such as kidney failure, and present with disabilities like blindness and mutism. In adults, exposure to mercury presents as irritability, shyness, and tremors, in addition to poor vision and hearing and memory loss. Exposure to mercury may be acute and at extremely high levels. This acute exposure may even cause damage to the lungs and present as high blood pressure or high heart rate, in addition to nausea and vomiting with diarrhea. Mercury exposure may cause skin rashes and eye irritation.

A joint guidance document from the World Health Organization (WHO) and the United Nations Environment Programme (UNEP) concludes that mercury and its compounds cause nervous system toxicity. Mercury exposure may also affect developing blood vessels and the heart. Developing organs may be exposed to the highest levels of mercury, particularly the fetus. Concentrations of mercury in the developing fetus' brain may also be higher than in the mother's blood. Research currently focuses on the developing nervous system in the fetus. This system appears to be the most sensitive. Other systems that may be impacted are the developing respiratory, circulatory, and immune systems.

Mercury and Inorganic Mercury Salts: Elemental Mercury and Inorganic Mercury SaltsWhen elemental mercury is used in its pure form, it can lead to poisoning through the vapors. This is because approximately 80% of mercury vapors are absorbed by the respiratory tract or sinuses, and from there are transported to the blood circulatory system, and to various organs and tissues. Even at very low concentrations, the inhalation of mercury vapors can result in several effects, such as the development of dizziness, the impairment of cognitive abilities and the quality of sleep. Mercury vapors can be found in many industrial workplaces and can also be found in hospitals, dental clinics, schools and in homes that may have mercury-containing products in their formulations. The inhalation of mercury vapors is a serious health risk.

Elemental mercury in its liquid state is relatively less toxic in comparison to the large majority of organic and inorganic mercury compounds. This is because pure mercury is very difficult to absorb in the body when it is either ingested or when there is dermal contact (Clarkson, 2006). Research has shown that less than 0.01% of mercury is absorbed by the intestines when it is ingested, and therefore, there have been very few documented cases of poisoning from the ingestion of mineral mercury. On the other hand, inorganic mercury salts are much more toxic and corrosive. Salts of this type can cause damaging effects to the intestines and the kidneys from acute exposure.

For Clarkson T. W. (2006), about ten percent of mercury salts that enter the body via ingestion or contact with the dermis make contact with the central nervous system and cause damage. Salts of inorganic mercury absorb more readily than mercury in the elemental form, and absorption of mercury in the organic form, especially methylmercury, surpasses inorganic mercury. Methylmercury is almost totally absorbed by the intestinal tract.

(Basketter, 2006)

Methylmercury

With the chemical formula CH3Hg, methylmercury is the most polluted form of mercury in fish, shellfish, and the birds and mammals that prey on them. When ingested by humans, methylmercury is absorbed by the gastrointestinal tract in a larger quantity than inorganic mercury.

(Thyssen, 2008)

Research is underway to find the different pathways of how mercury is transformed to methylmercury in the environment, and there are numerous pathways.

Biomethylation is one of the mechanisms, and is the conversion of mercury to methylmercury by certain aquatic microorganisms under low levels of dissolved oxygen. In freshwater, and salt water, this occurs in the sediment of the water. In the ocean, mercury that is released from the atmosphere, settles on the surface and then sinks. There, methylmercury is created by decomposing bacteria that are organic matter.

In the environment, methylmercury bioaccumulates and biomagnifies. Methylmercury is absorbed more rapidly than elemental mercury. Ingested methylmercury is absorbed by the gastrointestinal tract, enters the bloodstream, and traverses to the brains of adults, children, and fetuses. Methylmercury builds up in the brain and converts to inorganic mercury, but the rate of conversion is slow. (IARC, 2012)

A well-known example of the danger of mercury contamination is Minamata disease, a very serious, often fatal disease caused by exposure to high levels of methylmercury. This disease is usually associated with areas with severe mercury contamination, in particular pollution from certain industrial processes or mercury-containing wastes. Mercury pollution causes serious damage to human health and the environment, even in areas far from mercury manufacturing sites or local sources.

In general, fish and shellfish found in ponds, rivers, lakes and oceans in different regions of the world may be contaminated with varying concentrations of methylmercury. These concentrations, when elevated or when exposed to them sustainedly, can lead to obvious health harms and abnormalities in people who eat these contaminated fish, especially those who rely on fish and shellfish as a major source of protein.
. (Podda, 2001)

Chapter Two

Skin and Effects of Chemicals on Cells

Considered Keratinocytic cells are the primary cells in skin and produce Keartin, the protein that mediates the strength and elasticity of the skin. Keratinocytic cells are also accompanied by chromosomal cells and some immune cells. Chromosomal cells produce melanin and some of the immune cells are Langerhans cells. (Gould, 1995)

Skin disorders associated with skin exposure to mercury

. **Contact dermatitis**

Mechanism: Upon exposure of skin to mercury compounds, skin either may be irritated by mercury or an inflammatory allergic response may be elicited.

Symptoms: The skin becomes red, swollen, and itch. In extreme exposures, skin blisters or eruptions may be seen.

Diagnosis: This condition is diagnosed by exposure to mercury in the past, observation of the skin, and allergy tests based on the patch test. (Frosch, 1998–2000)

. **Skin pigmentation alterations (hyper or hypo pigmentation)**

Mechanism: Mercury has the ability to alter the functioning of chromosomal cells (melanocytes) by increasing their capacity to produce melanin or decreasing it. Symptoms: This will either cause a dark pigmentation or a light pigmentation of the skin. Diagnosis: This condition is diagnosed by observation of the skin and an exposure history to mercury.

Skin ulcers Mechanism: The exposure to inorganic mercury compounds for prolonged periods of time can lead to the necrosis of skin cells and ulcers can form. Symptoms: Ulcers that are painful and may cause a discharge and bleeding are seen.

Diagnosis: This condition is diagnosed based on an exposure history to mercury and observation of the skin.

. Rash

Mechanism: Mercury can make your immune system go haywire and cause rashes.

Symptoms: Could be large or small patches of red itchy skin.

Diagnosis: The condition is diagnosed by clinical examination and possibly linked to the history of mercury exposure.

e. Hair loss (Alopecia)

Mechanism: Mercury affects the hair follicles, causing hair loss.

Symptoms: Loss of hair can be patchy or total.

Diagnosis: The condition is diagnosed by clinical examination and linked to the history of mercury exposure.

And. Toxic dermatitis (Acrodynia)

Mechanism: Toxic dermatitis is extremely rare and is a consequence of mercury exposure in a child. Skin symptoms arise after mercury exposure due to the disruption of the nervous and immune systems.

Symptoms: The hands and feet become red and swollen, there is a rash, severe itching, and profuse sweating.

Diagnosis: The condition is diagnosed based on clinical symptoms and a mercury level assessment in blood or urine.

Presence of Mercury in Medicines

Due to the presence of antibacterial and antifungal properties of mercury, it has been used in medicines and medical treatments. With the advancement of science and the awareness of the toxic nature of mercury, there has been a decrease in the use of mercury across modern pharmaceuticals. Mercury and its compounds are still present in some traditional medicines and may still be found in some modern medicines in low concentrations. This presentation will highlight the presence of mercury in some medicines, some of the preparations it may be found in, and the health effects of mercury. Modern preparations with the least risk to health will also be presented. (Jolanki, 2000)

Mercury has been used in medicines for centuries

Elemental (Liquid) Mercury in Ancient Medicine

Elemental (liquid) mercury was used in the treatment of diseases of the skin and mercury was used to treat syphilis and intestinal parasites.

Mercury Chloride ($HgCl_2$) was used for disinfection and sterilization as an inorganic mercury compound.

Organic mercury compounds were used in preservatives for vaccines and medicines and were also used in medicines and vaccines. An example is methylmercury.

Mercury in Traditional Chinese Medicine

In Traditional Chinese Medicine, mercury sulfide (HgS), is used in the treatment of skin diseases and infections and is one of the main ingredients of some of these Traditional Chinese Medicines.

Examples of Mercury-Containing Medications

. **Topical Medications**

Skin disinfectants: Mercury chloride was used in some historical skin disinfectants.

Whitening creams: Mercury compounds can still be found in skin whitening creams in developing countries.

Systemic Medications

Treatment of syphilis: Mercury was historically used to treat syphilis. However, it is now treated with the less toxic penicillin.

Homeopathic Medicines: The majority of homeopathic medicines still contain trace amounts of mercury.

Vaccines and Preserved Medicines

Myrthiolate, a mercury organic compound, was previously used as a vaccine preservative as well as in some liquid medications. It is now used in very few modern medicines due to the concerns relating to its toxicity.

General Symptoms of Mercury Poisoning Mercury poisoning is multisystemic as it can affect the nervous, gastrointestinal, renal, and cutaneous systems. General symptoms may include (Wolverton, 2001): . **Neurological Symptoms**: Hand tremors or tremors of another physical body part , Memory loss ,Intermittent or consistent headache. Mood changes, which may include anxiety, depression, and/or irritability, Muscle weakness and Insomnia

Gastrointestinal Symptoms Nausea and vomiting**,** Diarrhea**,** Loss of appetite**,** Renal Symptoms**,** Kidney Failure**,** Changes in urine color, which can include dark urine and/or blood in the urine**.**

Skin symptoms Dermatitis - There will be inflammation of the skin with swelling and itching.Skin discoloration - Skin will have dark/light patches.Skin ulcers - Skin will have open ulcers.

Prevention of Mercury Poisoning

The prevention of mercury poisoning involves preventing exposure to all forms of mercury (elemental, inorganic, organic). Mercury is a very toxic substance that has the potential of causing serious damage to health. That is why there is a need to take some preventive measures. (Epstein, 1994)

. **Individual Prevention**. Avoid exposure to mercury in the home, Do not use products such as thermometers, batteries, or cosmetics that may contain mercury. Dispose of mercury-containing waste such as fluorescent lamps or batteries in designated recycling centers.The area should be ventilated and gloves should be worn when cleaning mercury spills.

. Avoid exposure to mercury in food , Limit ingesting fish such as sharks and large tuna that are high in mercury and eat fish such as salmon and sardines that are low in mercury.Follow the food safety recommendations in areas where the water is contaminated with mercury.

. Avoid exposure to mercury in medicines, Do not take traditional mercury-containing medicines. Check the ingredient listing of the medicine to ensure it does not contain mercury.

. Occupational Prevention

a. In the Work Environment

. Wear gloves, masks, and goggles when dealing with mercury and its compounds.

. Good ventilation: in places where mercury is used, such as laboratories or factories.

. Safety Training: Teach workers about the hazards of mercury and the proper handling techniques.

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. In industries

Using alternatives to mercury in the chemical and electronic industries: replacing mercury with less toxic substances is possible. Hazardous Waste Management: Secure the disposal of mercury-containing waste in accord with the law.

3. Government and regulatory prevention

a. Setting strict rules

Ban mercury usage in consumer products like thermometers, batteries, and cosmetics.

Regulate mercury usage in industries (like limiting the mercury emissions from coal-fired power plants).

b. Air and Water Quality MonitoringMonitoring the concentration of mercury in the air, especially in the industrial zone.

Water Quality Inspection: Check to ensure it is not contaminated with mercury, especially in areas close to mines or factories.

c. Public Awareness

Awareness campaigns to educate the public on the dangers of mercury and how to avoid it.

Issuing health guidelines: like lowering consumption of high-mercury fish.

4. Emergency actions in case of mercury exposure

a. In case of mercury spills:Ventilation of the place: Open windows and doors to increase ventilation. Gloves and masks: Used to prevent contact with mercury or the inhalation of mercury vapors. Mercury is also collected by carefully using a piece of cardboard or tape to place it in an airtight container. Safe disposal: Mercury is delivered to Hazardous Waste Management Centers. (Harada, 1995)

b. In case of personal exposure: Wash the skin with soap and water after contact with mercury. Get to a well-ventilated area after inhalation of mercury vapors. If symptoms of mercury poisoning, (nausea, headaches, tremors, etc.) appear.Protection Against Mercury Poisoning of Vulnerable Groups

1. Children Avoid products that contain mercury, Dental and skin treatments, Dietary intervention Reduce high mercury fish consumption

2. Pregnant Women:Mercury exposure must be avoided as it affects healthy development and safety of the fetus. Safe Diet encourages a consumption of low mercury fish like salmon and sardines (Clarkson T. W., 2002).

Discussion of Sources:

Through ancient and modern sources and from the cited scientific literature, a number of case reports, accidents, and studies have been reviewed documenting the dangers of mercury and the poisoned state of the people, as well as the effects on the systems and various organs of the body. Some of these models are explained as follows:

1. Minamata Disease, Japan

Between 1950 and 1960, a Harada, 1995 study reviewed the effect of the exposure of the local people to methylmercury and the strong effects of methyl mercury on the local population. During this study, there was a total loss of balance, and some people even died. Severe effects on the fetus were noted when the mother was exposed to mercury, indicating that methyl mercury can cause extremely serious pollution of the environment in Japan and large-scale effects on the health of humans. This was one of the first studies that reviewed the serious effects that mercury pollution and why it should be given more of a priority in research and investigation.

2. The 19th Century Madness Hats Disease, The Clarkson 2002 study analyzed the consequences of hat makers' exposure to mercury nitrates in the 19th century. The study found that the fired hat makers developed many neurological symptoms, such as tremors, irritability, and memory impairment, and established this condition as having "Mad Caps Syndrome." This syndrome was one of the first described models of the mercury-induced toxic syndrome resulting from exposure in the workplace and one of the first examples in the literature of the need for harmful substances in the workplace to improve the conditions of (Malm, 1998).

3. Mercury Poisoning in Iraq, 1971-1972. Bakir et al. 1973 studied the effects of ingestion of cereals sprayed with a methylmercury-containing fungicide in Iraq. This exposure resulted in more than 6000 cases that required hospitalization, and resulted in around 500 deaths. The survivors developed many symptoms, such as numbness, loss of balance, and diminished vision and hearing. This case also illustrated how methylmercury can poison the food chain, and resulted in increased control of the use of mercury in the agricultural sector, which was a step toward the development of international food safety (Clarkson & Magos, 2006).

4. Studies of the Amazon Basin

From the late 1990s to early 2000s Malm, 1998 examined how mercury amalgamation from gold mining in the Amazon Basin affected the people. It was found that there were high levels of mercury found in both fish and humans, including the development and function of children's and adults' nervous systems. It reinforced the demand for regulating the use of mercury in mining and the need to protect communities during mining activities. It showed that mercury pollution is not contained to specific industrial areas and will spill into vulnerable communities which rely on their environment to feed themselves and earn a living. Furthermore, it showed that mercury mining harms the environment and reinforces calls for international regulation.

5. Mechanisms of mercury toxicity. The study by Clarkson & Magos in 2006 took a look at the molecular mechanisms of how mercury exposure harms cells. It was found that mercury binds to the protein's sulfhydryl groups and disrupts the function of that protein, which then causes oxidative stress, lipid peroxidation, and damage to DNA. This study opened an understanding of mercury-induced cellular injury and toxicity and supported the continued efforts of developing prevention and treatment for mercury poisoning.

6. Evolutionary neurotoxicity of methylmercury, Grandjean, 1997 examined the consequences of exposure to methylmercury on the nervous system. It was shown that methylmercury can cross the placenta and the developing nervous system and that exposure may lead to cognitive deficits and motor and behavioral disorders. This study added to evidence supporting the need for binding international regulations on mercury in order to protect pregnant women and children from exposure to this toxic substance.

7. **Acute mercury poisoning**

Risher and Amler (2005) examined cases of acute mercury poisoning and specifically studied the inhalation of elemental mercury vapors. They concluded that mercury poisoning could cause shortness of breath, chest pain, and a wide array of neurological symptoms and that, in extreme cases, it could lead to kidney failure and death. This research expanded the understanding of how to manage acute mercury poisoning and the development of treatment protocols.

8. **Chronic mercury poisoning**

Mutter (2010) explored the health impact of long-term exposure to low doses of mercury from dental amalgams and fish. They concluded that low-dose, long-term mercury exposure may result in mild damage to the nervous, renal, and cardiovascular systems, and that the debate on mercury dental amalgams is ongoing. This study of chronic low-dose mercury exposure provides an impetus for more research to establish the health impact, if any, of chronic low-dose mercury exposure.

9. **The Global Mercury Cycle**

Driscoll et al. (2013) examined the biogeochemical cycling of mercury in the environment. They reported that mercury can be transported throughout the world via the atmosphere, ultimately precipitating to earth where it can then accumulate in aquatic systems, with fish, and across the food web. Their findings spurred global initiatives to mitigate mercury pollution, particularly the Minamata Convention.

Epigenetic effects of mercury

Goodrich et al., 2013 examined the impact of mercury exposure on gene expression. This research illustrated how mercury might instigate epigenetic effects, including DNA methylation and alterations to histones, which could lead to health issues in the future. This study innovated research to the epigenetic effects of mercury and the potential implications mercury exposure could have on people.

1. Mercury and cardiovascular disease

Mozaffarian & Rimm, 2006 explored mercury exposure and cardiovascular health. This research indicated that mercury may elevate the risk of developing hypertension, along with heart disease and stroke. This study expanded the understanding of mercury's effects on the body and supported the initiatives to minimize mercury exposure in food and water, especially in those communities that largely depend on fish for food.

Chapter Three:

Methods of action

Analytical study of mercury concentrations in fish

This analytical study aimed to analyze and compare the results of studies about the Total Mercury concentrations reported for species of fish sold and/or consumed locally. The focus was to determine if reported concentrations complied with the WHO 0.5 mg/kg (wet weight) guideline.

Data Collection Methodology:

The available literature was researched in the period 2015-2024 in the PubMed, ScienceDirect and Google Scholar databases. The search terms were Mercury in fish + Yemen/Gulf + mg/kg. Studies with inaccurate information or with unspecified species of fish were disregarded.

Results and Analysis:

Table 3-1: Mercury concentrations in the most important fish species according to previous studies based on 12 published studies from 2015-2024:

Conformity to 0.5 mg/kg	Number of Studies	Range	Average concentration mg/kg Hg	Type of Fish
Exceeds the limit	5 Studies	-1.35-0.45	0.89	Tuna
Exceeds the limit	3 Studies	0.78-1.58	1.12	Abu Seif
Exceeds the limit	4 Studies	0.92_2.10	1.45	The shark

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Security	6 Studies	0.05- 0.21	0.12	Sardines
Security	4 Studies	0.03- 0.15	0,08	Tilapia
Security	3 Studies	0.10-0.29	0.18	Crustaceans

Results:

The results indicate that predatory fish, such as tuna, swordfish and sharks, found at the top of the food chain, have mercury levels that are 78% to 190% higher than the World Health Organization (WHO) safe consumption value of 0.5 mg/kg due to the process of biomagnification as described in the theoretical chapter.

Tilapia, juvenile fish and crustaceans have mercury concentrations below 0.2 mg/kg and are safer for daily consumption. This is in agreement with the results of Driscoll et al., 2013 environmental mercury research and the inflation of mercury through the food chain.

Conclusion:

Mercury has widespread toxic effects throughout the entire human body. A summary of the findings pertaining to some of the major systems is as follows:

1. Gastrointestinal System: Larger predatory fish such as sharks and swordfish, while providing a larger source of protein, are likely to be more contaminated with mercury and should not be consumed more than once a week. Pregnant women and children are more susceptible to the dangerous effects of mercury and should completely avoid these fish. The

better options would be sardines and tilapia. Mercury toxicity leads to a number of gastrointestinal issues including damage to the gastrointestinal lining greater than that seen with ulcers, chronic dystrophy leading to significant weight loss and malnutrition, as well as putting a person at greater risk of developing an intestinal infection. Mercury also disrupts the healthy microflora of the intestines.

2. Skin: Mercury toxicity can lead to a number of dermatological issues. Direct local exposure leads to dermatitis with redness, itching, and rash. There are also a number of chronic issues related to mercury absorption. Chronic exposure to mercury dermatitis leads to hyper- or, more often, hypo-pigmentation as well as a constantly dry, flaky texture.

3. Respiratory System: Mercury

Toxicity from Mercury has a clear, negative impact on the respiratory system, especially from the inhalation of Mercury fumes or airborne particulates. From exposure to these Mercury fumes, the mucous membranes of the nose and throat become irritated and inflamed, which impairs respiration. If high concentrations are sustained for a longer period of time, this may cause acute pneumonia. Chronic exposure to Mercury can cause pulmonary fibrosis, which is the scarring of the lungs, which impairs the lungs’ ability to exchange oxygen and causes shortness of breath and a chronic cough. Mercury may also worsen asthma symptoms and respiratory allergies, and worsen seizure control. These factors explain the importance of preventing Mercury exposure to the respiratory system.

4. Nervous System: Mercury

Mercury's toxicity is one of the most damaging factors to the nervous system. Exposure to Mercury leads to the degeneration of nerve tissues, which results in the formation of symptoms such as, but not limited to, cephalalgia, vertigo, and tremor. With chronic exposure, symptoms may include loss of coordination of voluntary motor actions, loss of memory, and may also include psychological or behavioral disorders. Toxicity of Mercury poses a huge threat to the unborn child due to its damaging effect on the developing nervous system, which may result in delayed development of the child in addition to disorders related to cognitive or psychomotor disabilities.

The presence of these symptoms, and the severe, widespread effects of mercury toxicity on health, demonstrate the need for recent local research studies that measure mercury levels in Iraqi fish. Research is also needed on the effects of exposure to low levels of mercury, which is frequent and persistent, on health. This research should be conducted by WHO and other relevant regulatory and health institutions.

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