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Uses and Effects of Mercury: A Review Article

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Abstract

Mercury, in a natural and highly toxic element that is used in medicine, dentistry and traditional healthcare practices in many cultures over millennia. Due to its unique properties a number of applications have been made including dental amalgam and medical instruments; and traditional medicines such as Cinnabar in Chinese, Tibetan, Mongolian systems. Mercury's therapeutic benefits however, has been dulled by the its environmental persistence, high toxicity and health risk (acutely to chronically) typically resulting in increasing restriction and calls for safer alternatives. This review explores mercury's historical and contemporary uses, chemistry, pharmacology, toxicology and the environment in which it takes place, and addresses global efforts led by WHO (World Health Organization) and UNEP (United Nations Environment Programme) to minimize its dangers. The importance placed on education, policy innovation and sustainable practices in order to find a balance of mercury's utility versus the possibility of harm is stressed.

***Index Terms*: Mercury, Medicine, Dentistry, Traditional Healthcare Practices, Dental Amalgam, Cinnabar, Environmental Persistence, Pharmacology, Toxicology**.

1. Introduction

Mercury (Hg) is a unique and versatile element that continues to entice humanity owing to its liquid condition at room temperature, and a wide range of applications. Mercury, historically known as hydrargyrum or quicksilver, is a central part of medicine, alchemy and industrial use, across cultures including ancient Greece and China, medieval Europe and in contemporary society. One of its long history of use in traditional Chinese, Tibetan, Mongolian, and Indian, as well as Western, medicine in treating diseases and furthering scientific advancements.

Mercury is an element occurring mostly in the form of cinnabar (mercuric sulfide). Producers are China and Kyrgyzstan. An application exists for its use in gold and silver extraction, chlor-alkali production, manometers, thermometers, and dental amalgams. Mercury compounds are used in the antiseptics, reagents catalyst and batteries in healthcare. Common mercury salts include: Mercuric chloride, Mercurous chloride Mercuric sulfide. There are three forms that Mercury can be found in— elemental, inorganic, and organic—and they behave differently. Its biochemical affinity for sulfur and sulfhydryl groups has played a critical role in its therapeutic applications for treating syphilis and inflammation, but also subserves its toxicity. -Risk to Mercury on the nervous, cardiovascular, renal, hepatic, and immune system because Mercury is able to interrupt proteins, enzymes, and cellular membranes. In addition, its volatility and atmospheric persistence increases global deposition and bioaccumulation in aquatic ecosystems, where it undergoes transformation to highly toxic methylmercury.

Its historical significance and industrial importance notwithstanding, mercury has drawn toxicological and environmental concern. Despite the decline, human activities, including the production of industrial products and coal burning, continue to be major sources of mercury emissions, greatly increasing health and ecological risks. This review describes: historical, medical and industrial uses of mercury, pharmacological and toxicological aspects, and changing perceptions of its impacts on public health and the environment. It is a critical task to balance its utility with its challenges to address mercury's complex legacy.

2. Sources of Mercury

Mercury is released into the environment through natural processes and human activities. Key sources include:

2.1 Natural Sources: Volcanic activity and rock weathering.

2.2 Anthropogenic Sources: Coal-fired power plants, industrial processes, waste incineration, and mining activities.

Once released, mercury transforms into methylmercury through bacterial action, bioaccumulating in aquatic life. Predatory fish, such as tuna and swordfish, often contain high levels of mercury, posing health risks to humans.

3. Forms of Mercury

3.1 Elemental (Metallic) Mercury

Historically, the term for elemental mercury is "quicksilver," and this is a shiny, silver white metal. At room temperature it is a liquid; it was used widely in older thermometers, fluorescent light bulbs and some electrical switches. If left is exposed to the air at room temperatures, mercury will evaporate into an invisible, odorless, toxic vapor that is a health risk if inhaled.

Elemental mercury will transform into inorganic or organic mercury compounds when reacting with other substances. The environmental and health implications of this transformation are very important.

3.2 Inorganic Mercury Compounds

The term for elemental mercury has historically been 'quicksilver' and is a shiny, silver white metal. It is a liquid at room temperature and has been used in older thermometers, fluorescent light bulbs and some electrical switches. Mercury will evaporate into an invisible, odorless, toxic vapor if left is exposed to air at room temperatures, a vapor that is a risk of health if inhaled.

Elemental mercury reacts with other substances and will adjust to become inorganic or organic mercury compound. These transformations are very important from the environmental and health stand point.

Mercury (I) chloride: Used in medicine and electrochemistry.

Mercury (II) chloride: A corrosive, poisonous compound.

Mercury fulminate: A detonator in explosives.

3.3 Organic Mercury

Among the organic mercury compounds are methylmercury and the antiseptic and cosmetic thimerosal. Although they are antibacterial, these pose great neurotoxic risks, especially to developing fetuses and infants.

Methylmercury

Methylmercury is an organic compound that is formed as organic mercury is produced from inorganic mercury by microscopic organisms. Mercury's cycle through the atmosphere, land, and water is this process.

Methylmercury accumulates biochemically in the aquatic system, and in the case of fish and shellfish, particularly in top predators.

Most exposure to methylmercury comes from eating contaminated seafood. It poses severe health risks — particularly to developing fetuses and young children — because of its neurotoxic effects.

4. Therapeutic Applications of Mercury

The four medicines of mercury are used as diuretics, as antiseptics and for ointments for skin diseases. Mercury is a main component of amalgam fillings because they are durable and easy to work with in dentistry. But efforts to curb its use in modern practice are stymied by safety issues.

4.1 Uses of mercury in Medicine – Ancient

Mercury has been used in medicine since the times that passed. In 2nd century China mercury was the focus of alchemical studies in hopes of finding an elixir of life. It's no surprise that cinnabar (mercury sulfide) was experimented with by one of the more famous alchemists of the time, Ge Hong, who believed it possessed transformative powers. Versatile as it was, cinnabar was used for things such as turning people into walking miracles or serve as a fertility aid when mixed with raspberry juice. Mercury is also a contraceptive used by ancient Chinese women over 4,000 years ago, and cinnabar remains a sedative in Chinese traditional medicine.

The earliest known academic reference to mercury is made by Aristotle in the 4th century BCE, who referred to it as 'fluid silver' -- or 'quicksilver'. As Mercury's perceived 'metal-ness' in all metals made it the focus of ceremonial and therapeutic practice. Around 500 BCE mercury was used as an aphrodisiac and was used in various medical treatments by Indian and Chinese cultures.

4.2 Mercury in Indian Medicine

In Ayurveda mercury (Rasa) was held as the most effective doctor of rejuvenation and curation, especially in syphilis cure. Even Unani and Siddha systems employed mercury in formulations for ulcers, paralysis, and skin diseases and purifications of mercury were emphasized to make formulations safer and more effective. "Kushta" preparation of mercury detoxified, it and rendered suitable for therapeutic use.

4.3 Mercury in European Medicine

The use of mercury in alchemical and medicinal applications gained prominence in Europe during the Middle Ages. It's dosage dependent toxicity and Paracelsus was a proponent of it. Traces of mercury compounds such as calomel (Hg_2Cl_2) and corrosive sublimate ($HgCl_2$) were used to cure syphilis, ulcers, and liver diseases. Being concerned regarding health and environmental issues, industrial and agricultural applications of mercury in the 20th century resulted in the emergence of a problem.

4.4 Mercury in Dental Practice

In the 1830s mercury amalgam became a revolutionary dental restorative material. Amalgam fillings were initially met with resistance that consisted of silver, tin, copper, zinc, and mercury. They were banned by the American Society of Dental Surgeons in the 1840s, and labeled malpractice. But by 1859, the creation of the American Dental Association brought greater acceptance of amalgam fillings, with a few people still worrying about being exposed to mercury.

Dental amalgam still constitutes a major source of mercury exposure in developing countries. Mastication and oral hygiene practices cause mercury release and we need safer alternatives and better regulatory oversight. Some of the safety thresholds are exceeded when amalgam fillings release up to 27 μg of mercury vapor daily, according to studies.

5. Pharmacology

Pharmacological Applications Mercury-containing preparations exhibit diverse pharmacological effects:

a. Cinnabar (HgS): Tranquilizes the mind, relieves convulsions, and detoxifies.

b. Zuotai (Tibetan medicine): Anti-inflammatory, anti-convulsive, and immunity-enhancing effects.

c. Mengen Wusu (Mongolian medicine): Astringent and muscle growth-promoting properties.

d. Mercury in Ayurveda and Unani: Effective in treating syphilis, ulcers, and convulsions.

6. Modern Perspectives and Challenges

Stringent restrictions on use of mercury arise out of environmental concerns and the risk to human health. Speciation analyses of mercury in pharmaceuticals are mandated by the European Union, while Chinese patent medicines containing mercury suffer export limitations.

Research in the field of Nanomedicine has shown the rise in nano formulations, namely nano realgar and nano calomel, which open new opportunities to improve bioavailability and reduce toxicity. Is these innovations a sustainable way of integrating conventional mercury based therapeutics within conventional medicine.

Today, medical use of mercury is controlled, but increasingly difficult. Though the risks from mercury containing products like skin lightening creams, soaps and thimerosal preserved vaccines have been reduced in developed countries, they still exist in developing counties. The EU's historical production and export of goods containing mercury used to be a case in point of double standards in manufacturing and exporting, if we are to efforts to eliminate mercury exposure globally.

7. Mercury Toxicity

Volcanic eruptions and the operation of plants and factories both release mercury into the environment. About 50% of the mercury in the atmosphere is anthropogenic, with the largest contribution originating from coal combustion and gold production as well as from waste incineration. There is mercury contamination in medical products, thermometers and any dentals amalgams and once discarded it further contaminates the ecosystem.

Chemical Mercury and its exposure routes influence toxicity. The largest source of mercury uptake is inhalation of elemental mercury vapor; methylmercury from contaminated foods are bioaccumulated and cause neurological and developmental damage. The enzyme is made inactive by chronic exposure and the cell is damaged. Severe human health impacts of mercury poisoning are illustrated by history, for example, about Minamata disease.

7.1 Toxic Effects of Mercury

Mercury toxicity depends on the form of mercury and the exposure route. The following summarizes its health impacts:

a. Acute Toxicity

High levels of exposure can cause respiratory distress, gastrointestinal irritation, and acute kidney injury. Symptoms are observed at blood mercury levels exceeding 50 μg/L.

b. Chronic Toxicity

Long-term exposure, even at low levels, may result in neurological symptoms such as tremors, insomnia, and cognitive impairment. Chronic exposure can also affect the immune and renal systems.

c. Dimethylmercury

This highly toxic compound poses a significant hazard due to its ability to penetrate the skin and cause fatal neurotoxicity even in small amounts. Stringent precautions are essential when handling it.

7.2 Health Impacts

Mercury is toxic because it affects the nervous, respiratory and immune systems. Mercury vapor causes cognitive impairments, tremors and mood disturbances after chronic exposure. Severe respiratory distress and pulmonary damage will result from acute exposure. The Minamata disease in Japan is just one of many symptomatic incidences of industrial mercury pollution to produce devastating effects.

7.3 Healthcare Sector Contributions

The pollution of mercury comes from healthcare facilities. Mercury that is released by dental practices goes into sewage systems, and mercury containing devices like sphygmomanometers and thermometers represent risks of spillage or exposure. The US EPA reported in 1997 that each medical waste incinerator was responsible for 10 percent of mercury emissions. Nonindustrial mercury vapor exposure is primarily from dental amalgams containing 45–55% mercury.

7.4 Global Statistics

In India, dental practices in cities like Delhi contribute around 51 kg of mercury yearly.

In the **UK,** 7.41 tons of mercury from dental amalgams are discharged annually into various environmental pathways.

7.5 Vulnerable Populations

Pregnant women and children are particularly at risk. Methylmercury exposure can impair cognitive development in utero. Chronic exposure may lead to:

Neurological symptoms (tremors, memory loss, cognitive dysfunction).

a. Kidney damage and failure.

b. Skin and eye irritation.

8. Safety Standards and Regulatory Measures

Guidelines about mercury exposure have set by US Environmental Protection Agency (EPA) and Food and Drug Administration (FDA). But many countries like Pakistan have not drafted comprehensive regulations. Without mitigating mercury related health risks, setting safety standards is important.

9. Prevention and Control

9.1 Reducing Environmental Releases

a. Phasing Out Mercury Mining: Mercury handling, eliminating the need for new mining.

b. Promoting Clean Energy: Moving toward non coal sources of energy in order to reduce emissions.

c. Artisanal Gold Mining: Using non-mercury extraction techniques.

9.2 Alternatives to Mercury-Containing Products

a. Medical Devices: Replacing mercury thermometers and sphygmomanometers with safer alternatives.

b. Consumer Products: Phasing out mercury in batteries, fluorescent lamps, and skin-lightening products.

9.3 Safe Handling and Disposal

Proper management of mercury-containing waste is essential. This includes:

a. Controlled disposal of products like thermometers, barometers, and dental amalgams.

b. Education on the hazards of mercury in cosmetics and light bulbs.

10. International Efforts

10.1 Minamata Convention on Mercury

In 2013, the Convention adopted to reduce mercury emissions and phase out mercury-containing products. Effective from 2025, the 2023 amendment does not allow the production or trade of any of the several mercuries added products.

10.2 WHO's Role

The World Health Organization (WHO) supports global mercury reduction efforts through:

a. From health impact evidence, publishing.

b. In training healthcare professionals.

c. Managing healthcare waste as well as promoting non mercury medical devices.

WHO and UNEP recognize mercury as a hazard and encourage healthcare practices to be free of it. UNEP's Mercury Partnerships bring governments, industries and other stakeholders together to find ways to mitigate mercury impacts on the environment and human health. Phasing out of mercury-based devices and ones with safer alternatives are the strategies in place.

11. Mitigation and Reduction of Mercury Emissions

Recent decades have seen huge progress in mercury emission reductions in particular from waste incineration. The following measures have proven effective:

a. State and federal regulations banning mercury use and emissions adopted

b. Consumer products and industrial processes transitioning away from mercury

c. Better methods of recycling and disposal for mercury containing items

12. Conclusion

One of the key roles that mercury played throughout history as a base of medicinal, industrial, and scientific practice again emphasizes its vast contribution to human progress, but also poses tremendous problems for human and environmental health. The dual nature of health care underscores the need for rapid transformation toward safer alternatives and sustainable, mercury free technologies throughout health care and society. In the case of mercury – as is in the case of so many technological advances – promising pathways to preserve mercury's medicinal value while stemming its risks are based on rigorous scientific validation, innovative detoxification methods, and progress in the field of nanotechnology.

It is essential that we work together across global borders to combat mercury's adverse effects and create a safer future, and that we continue to invest in robust policies and technological advancements. Vigilance, innovation and commitment to continuing protecting human health and the environment perform the balancing with a legacy of history whilst maintaining modern safety standards.

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