Unveiling the Invisible Threat: A Review of Heavy Metal Exposure and its Devastating Health Consequences

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Abstract

The widespread of heavy metals in air, soil, and water is a grave concern that poses a significant global threat. The distribution of contaminants such as mercury, lead, and cadmium are widespread and are associated with serious health risks such as cancer, cardiovascular and respiratory diseases, and Alzheimer's disease. Exposure to these heavy metals is known to cause numerous adverse health and environmental consequences, including toxicity from mercury and arsenic, neurological impairments caused by lead, and acute and chronic effects on various ecosystems, including birds, fish, and other species.

This comprehensive review aims to highlight potential routes of exposure to the three most common heavy metal pollutants - mercury, cadmium, and lead - focusing on their uptake through drinking water, ambient air, and dietary sources. The review will delve into the mechanisms by which these metals enter the body and the various health implications associated with their exposure. Understanding how these metals enter the body and the negative effects they cause, emphasizes the need for effective mitigation strategies and stricter regulations to protect human health and safeguard the environment.

Keywords: Heavy metals, Cancer, Health effects, Exposure, Environment

Introduction

Heavy metals are metallic chemical elements that occur naturally in the earth's crust and possess a high density, which renders them potentially dangerous or poisonous, even in little amounts. Mercury, Cadmium, Arsenic, Chromium, Thallium, Lead, and other heavy metals are naturally present in the Earth's crust. These metals occur naturally in food, water, and air, and can enter the body in trace amounts through the consumption of food, water, or air. Furthermore, several metallic elements, like Copper, Selenium, and Zinc, are essential for the proper operation of the human body in minimal quantities, as they aid in metabolism. Bioaccumulation is the process by which heavy metals are rapidly absorbed and stored in the body, leading to their gradual accumulation over time.

Water supplies can also become contaminated with heavy metals. Contributors encompass industrial and domestic trash, including acid rain that corrodes soil and facilitates the seepage of toxic heavy metals into streams, lakes, rivers, and groundwater. Human exposure to three prevalent heavy metal contaminants, namely Mercury, Lead, and Cadmium, can have adverse effects on both human health and the surrounding environment. Mercury can negatively impact the emotional, physical, and neurological functioning of people of all ages, as well as their cardiovascular, renal, respiratory, and immunological systems. Specifically, infants and young children are very susceptible to the impacts
of mercury due to their limited cognitive processing abilities. The buildup of mercury in fish has been associated with several harmful consequences on fish and other aquatic organisms. These impacts include decreased fertility, impaired kidney function, delayed growth, aberrant behavior, and even death in birds and mammals that consume fish. Even minimal exposure to lead can result in neurological impacts in children and can negatively affect cardiovascular, renal, gastrointestinal, hematological, and reproductive functions. Lead undergoes bioaccumulation in the environment across a wide range of species, presenting a potential hazard to plants, animals, and microbes. Cadmium exposure has been associated with pulmonary irritation, kidney illness, bone fragility, and the possible development of lung, prostatic, and renal cancer. The primary factors responsible for the presence of cadmium in the general population are the intake of cigarettes and food.

Mercury
The United Nations Endowment for the Prevention of Pollution (UNEP) (2002b) has conducted substantial research on the environmental pollutant mercury. However, there is still a limited understanding of its routes and the impact it has on human and environmental health. Throughout the industrial revolution, there has been a substantial increase in mercury levels, resulting in its extensive distribution in the environment and worldwide food supply networks. Even areas with minimal mercury emissions, such as the Arctic, are nonetheless susceptible to its worldwide dispersion. Greenpeace (1998) said that an estimated 40,000 to 80,000 individuals globally are likely experiencing mercury poisoning due to the consumption of contaminated seafood. Recent research indicates that human activities have caused a three-fold increase in the overall amounts of mercury in the atmosphere in industrialised regions. Additionally, the rate at which mercury is being deposited has grown by a factor of two to ten during the previous two centuries. Approximately 70% of human-caused air emissions are believed to come from burning fossil fuels and incinerating garbage. According to a research by the United Nations Environment Programme (UNEP) (2002b), the use of fossil fuels is projected to lead to an increase in mercury emissions. In addition, the possible consequences of global climate change are especially worrisome, as there is evidence of a rise in methyl mercury levels in lakes and streams that have recently experienced flooding. Moreover, it is observed that numerous countries suffer from a deficiency of fundamental knowledge concerning the utilisation, discharge, and quantity of mercury existing in the surroundings. Recent research has uncovered increased concentrations of mercury in certain seafood items, including sharks, swordfish, and tunas. As a result, certain nations have recommended that pregnant women refrain from consuming these particular types of seafood.

Lead
Lead extraction takes place in over forty nations globally, resulting in a total production of 3.150 million tonnes in 2004, as reported by the United Nations Educational, Scientific and Economic Council (UNEP) (2008a). UNEP reports that lead exposure is prevalent in nearly all countries globally, with the most elevated concentrations detected in the blood of around 200 million individuals worldwide. Greenpeace (1998) reported that ice core drilling in Greenland has uncovered a significant increase in lead levels during the Industrial Revolution. Lead deposition over the period from the 1960s to the 1990s was found to be eight times higher than in the pre-industrial era. Nevertheless, the utilisation of leaded fuel has diminished and the implementation of emission limits since the 1970s has led to a decline in lead levels detected in ice cores. UNEP's (2008a) data shows that global lead use for petrol additives declined significantly from 310 million tonnes between 1970 and 2004 to 14,400 tonnes. According to the United Nations Endowment for the Prevention of Pollution (UNEP) (2008a), the discharge of human-caused lead into the water fell considerably from 1983 to the mid-1990s. The total amount of lead emissions during this period was 120,000 tonnes. Most developed nations have observed a decline in overall lead emissions as a result of enhanced wastewater treatment. However, in numerous developing countries, such as Latin America and Small Developing Island States (SIDS), lead-containing items are not adequately disposed of due to a lack
of public consciousness. Moreover, the act of burning openly and unlawfully disposing of waste items containing lead, together with the manufacturing of plastics and paints, are probable sources of lead emissions that have a notable impact on the local and regional levels. It is crucial to acknowledge that exposure to lead has a substantial health influence and can have an adverse impact on development.

**Cadmium**

Anthropogenic activities have led to an elevation in the concentration of cadmium in the environment. From 1950 to 1990, global cadmium production nearly doubled, although consumption has remained generally stable at roughly 20,000 metric tonnes per year (UNEP, 2008b). Examinations carried out on ice cores from Greenland have revealed a deposition rate that was eight times greater than what was recorded in the pre-industrial era. However, recent study indicates that the rate of deposition has decreased since the late 1970s. Furthermore, a study conducted between 1990 and 2003 reveals that the emissions of cadmium, induced by human activities, in developing countries have decreased by an average of 50%. In 2008, the United Nations Endowment for Pre-Earmarkment (UNEP) conducted research that estimated manmade atmospheric emissions to be 2,903 metric tonnes in the mid-1990s. The main contributors of cadmium emissions are the non-ferrous metal sector and the combustion of fossil fuels. The estimated amount of cadmium in the aquatic environment is between 900 and 3,600 metric tonnes, mostly due to human activities that result in the deposition of cadmium in the atmosphere. In certain developing nations, the usage of cadmium has either been upheld or escalated. However, the regulations and restrictions in this particular area are not as comprehensive as those in other places. Furthermore, hazardous waste disposal practices that are not safe, such as landfill incineration or landfill discharge into rivers and wetlands, have posed risks to both human health and the environment. Greenpeace (1998) reported that cadmium usage could result in renal damage in around 250,000–500,000 individuals. Cadmium accumulates in agricultural soils by atmospheric deposition, the application of phosphate fertilisers, and the utilisation of sewage plant waste. This can result in an increase in the concentrations of cadmium in dietary items.

**Heavy Metal Poisoning Causes and Risk Factors**

Exposure to heavy metals can lead to a type of poisoning known as heavy metal poisoning. There are several potential causes of heavy metal poisoning, such as being exposed to heavy metal dust while working in a factory, consuming seafood from regions with high mercury levels, taking herbal remedies that contain heavy metals, eating uncoated dinnerware, or drinking water contaminated with heavy metals. One must be alert to potential exposure sources and take appropriate measures to avoid heavy metal toxicity.

**Heavy Metal Poisoning Symptoms**

In cases of chemical accidents or when a youngster swallows a toy containing lead, for example, ingesting a high quantity of metal at once can cause acute poisoning. Acute poisoning symptoms might vary from a lack of consciousness and numbness to vomiting, nausea, and confusion. When a little amount of the metal is consumed over an extended period of time, however, chronic toxicity develops. Constant poisoning can cause a wide variety of symptoms, including numbness, tingling, dehydration, and diarrhoea. Lead poisoning causes a cascade of symptoms that manifest over time, including but not limited to: constipation, muscle and joint pain, weakness, and exhaustion. For children, especially those who drink formula mixed with tap water, lead contamination of drinking water can have a detrimental effect on cognitive functioning and growth and development. Even though lead has been out of circulation for quite some time, it is still able to get into the water system via antiquated pipes. Even while certain water filters can eliminate lead, it's still a good idea to get your water tested if you're worried about the level of lead in it.

**Heavy Metal Poisoning Diagnosis**

Numerous tests, including X-rays, analyses of blood or urine, and other specialised examinations, can identify different types of heavy metals. These tests can detect the specific heavy metals that may be
present and assess the degree of heavy metal intoxication. A complete blood count (CBC),
electrocardiogram, protein analysis, liver function, abdominal radiograph, and kidney function tests
are common. The doctor may also inquire as to the patient's occupation, interests, food, and any other
activities that could expose them to harmful substances. It is important to mention that these tests are
typically not performed frequently; they should only be administered if the patient has a history of
heavy metal exposure or if there is a reasonable suspicion that they may be present.

**Heavy Metal Poisoning Treatments and Home Care**
Staying away from the poison's origin is crucial for preventing the disease from getting worse.
Finding the right precautions to take is something your doctor can help you with. It may be required
to pump the stomach in order to extract the metals in certain instances. One possible treatment for
severe poisoning is chelation, which involves injecting the patient with medicines to bind the heavy
metals. The body eliminates these medications through the urinary system. Chelation is a viable
therapeutic option for heavy metal poisoning, but it should only be used in cases where the levels are
high and the symptoms are obvious, and it is not appropriate for all cases.

**Heavy Metal Poisoning Prevention**
If you're worried about heavy metal poisoning, your doctor can give you personalized advice.

**General tips include:**
Heavy metal workers must use masks or other protective gear. To guarantee safe fish consumption,
consult local fish advisories. If a home was built before 1978, a lead paint test and abatement should be
done by a professional. Finally, examine product labels for heavy metals.

**Table 1. Description of toxic heavy metals, their forms, sources, permissible limit and their effects.**

<table>
<thead>
<tr>
<th>Heavy Metals</th>
<th>Pollutants</th>
<th>Source</th>
<th>Permissible limit(mg/L)</th>
<th>Effects</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>Methyl Mercury (MeHg)</td>
<td>Fungicides, Insecticides, Bactericides</td>
<td>0.01</td>
<td>Neurotoxicity, Nephrotoxicity</td>
<td>Cope et al., 2004, Terziev et al., 2019</td>
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<td></td>
<td>Hg vapour</td>
<td>Dental Amalgam</td>
<td></td>
<td>Blood-Brain Barriers, Hypogastrium,</td>
<td>Beckers et al., 2017</td>
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<td></td>
<td>Hg⁰° (Elemental)</td>
<td>Cosmetics</td>
<td></td>
<td>Bronchopneumonia</td>
<td>Birsan et al., 2023, Nduka et al., 2019</td>
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<td></td>
<td>HgCl₂</td>
<td>Production of PVC</td>
<td></td>
<td>Kidney Disfunctioning</td>
<td>Park et al., 2012</td>
</tr>
<tr>
<td></td>
<td>Hg₂Cl₂</td>
<td>Purgative</td>
<td></td>
<td>Gastro-Intestinal Pain, Chest Pain</td>
<td>Langford et al., 1999</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cadmium oxide, cadmium sulphide</td>
<td>Tobacco</td>
<td>0.06</td>
<td>Cardiovascular Diseases</td>
<td>Fagerberg et al., 2021</td>
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<tr>
<td>Metal</td>
<td>Compound</td>
<td>Application</td>
<td>Effect</td>
<td>Reference</td>
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<tr>
<td>Cadmium</td>
<td>Cadmium carbonate (CdCO₃)</td>
<td>Coatings, plating on metals</td>
<td>Carcinogenesis</td>
<td>Fatima et al., 2019, Sharma et al., 2015</td>
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<td></td>
<td>Cadmium chloride, Nickel-cadmium</td>
<td>Used in electroplating and prevents corrosion</td>
<td>Osteotoxicity And Multiple Bone Fractures</td>
<td>Fatima et al., 2019, Salek Maghsoudi et al., 2021</td>
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<td>Cadmium-metallothionein (Cdmt)</td>
<td>Stabilizers for plastic and paint pigments</td>
<td>Renal Disorder, Kidney Damage, Diabetes</td>
<td>Fatima et al., 2019, Hayat et al., 2019</td>
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<td>Cadmium chloride (CdCl₂)</td>
<td>Vegetables, fishes</td>
<td>Reproductive Failure, Infertility</td>
<td>Dutta et al., 2022, Massányi et al., 2020</td>
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<td>Cadmium hydroxide (Cd(OH)₂)</td>
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<tr>
<td>Lead</td>
<td>Lead sulphate</td>
<td>Pigments—dyes—paints</td>
<td>Neurotoxicity, Carcinogenicity</td>
<td>Tagne-Fotso et al., 2016</td>
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<td>Tetra-ethyl lead</td>
<td>Waste incineration, dust</td>
<td>kidney</td>
<td>Gidlow et al., 2004, Papanikolaou et al., 2005</td>
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<td>Lead acetate, lead nitrate</td>
<td>Textile industry, Rubber industry</td>
<td>Nephritis, vomiting, pulmonary inflammation</td>
<td>Hoet et al., 2005</td>
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<td><em>Tetramethyl lead</em> (TML)</td>
<td>Tobacco consumption</td>
<td>Anaemia, Dementia, Cerebral palsy, Encephalopathy</td>
<td>Bandyopadhyay et al., 2014, Singh et al., 2018</td>
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<td></td>
<td>Pb tetrachloride and tetracetate</td>
<td>Alcoholic beverages</td>
<td>gastrointestinal (GI) tract infection, tubular necrosis</td>
<td>Boskabady et al., 2018, Grant et al., 2020</td>
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**Conclusion**

The toxic effects of heavy metals on human health and the environment are a global concern due to their transport via air, soil and water. Depending on the concentration and various major sources, the
potential routes of entry into the body through water, air and food are numerous. These metals are necessary for the functioning of cells, metabolism and hormones in humans, however, when the limit is exceeded, it can lead to serious and potentially life-threatening health effects. The toxic effects of these metals on the soil are particularly damaging, as they kill microorganisms that are essential for soil fertility and nutrition. The International Agency for Research on Cancer (IARC) has reported that arsenic toxic effects can lead to cancer of the prostate, liver and blood, as well as skin Mercury is the primary cause of carcinogenic damage to the brain, lungs, skin, and colon. Lead is responsible for the development of colorectal cancer, intestinal cancer, and central nervous system cancer. Cadmium has toxic effects on the stomach, breast, lungs, and kidneys in humans. Additionally, in China, lead toxicity in children was attributed to the consumption of a particularly attractive dish, and in women, the use of food storage cans resulted in high lead levels in their blood. Additionally, cadmium is the primary contributor to Alzheimer's disease. Furthermore, phosphate fertilizers, due to their high usage, are beginning to accumulate in soils and enter into food chains. The World Health Organization (WHO) has identified mercury as a hazardous toxic metal that has a severe impact on aquatic life, and the consumption of mercury-tainted foods by humans has been linked to a variety of malignant diseases, including Minamata, as well as a range of physiological effects.

References
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