

The Effect of Different Heavy Metals on Human Health

Jiaqi Teng^{1,*}, Xiyao Yu²

¹ Beijing Royal School, Beijing, China

² Tianjin Yaohua High School, Tianjin, China

* Corresponding Author Email: 1911441121@mail.sit.edu.cn

Abstract. The effects of heavy metals on the human body have been extensively studied due to their potential to cause serious health issues. This research aims to provide a comprehensive overview of the adverse effects of these metals on various organ systems and highlight the importance of understanding their toxicological mechanisms. Mercury can disrupt neuronal function, leading to neurological symptoms and cardiovascular complications. Lead can impair cognitive function, causes behavioral disorders, and decreases IQ levels in children. Lead exposure is also associated with an increased risk of cardiovascular diseases. Cadmium disrupts cellular homeostasis, induces oxidative stress, and interferes with calcium signaling. Understanding the mechanisms underlying the toxic effects of these heavy metals is essential for developing effective strategies to protect human health. Further research is needed to explore emerging issues, such as the combined effects of multiple heavy metals and the long-term consequences of exposure. By raising awareness of the detrimental effects of mercury, lead, chromium, and cadmium, this paper aims to emphasize the importance of minimizing exposure and implementing preventive interventions to safeguard human health.

Keywords: Heavy metals, Human health, Effect.

1. Introduction

Heavy metals are present in the environment naturally, but they can also be added through industrial processes, pollution, and poor waste disposal. Heavy metals pose a serious risk to both human health and the environment because of their poisonous nature [1]. The consequences of heavy metals on the human body have been the focus of much investigation over the years. Being around heavy metals can cause a variety of harmful health outcomes, from acute poisoning to chronic disorders. The research status on heavy metals and their impact on the body can be summarized as follows.

Research has focused on identifying the different sources of heavy metal exposure, including contaminated water, air pollution, occupational hazards, and food contamination. Understanding these sources helps in developing strategies to minimize exposure and prevent health risks. Studies have investigated how heavy metals are absorbed into the body and how they accumulate in various tissues and organs. It has been found that different heavy metals have varying absorption rates and target specific organs.

For mechanisms of toxicity, researchers have explored the mechanisms by which heavy metals exert their toxic effects [2]. This includes oxidative stress, DNA damage, disruption of cellular processes, and interference with essential trace elements. Understanding these mechanisms helps in developing targeted interventions and treatments. Regarding implications for health, to comprehend the negative impact of heavy metal exposure on health, extensive study has been done. Exposure to lead can cause neurological abnormalities in children, whereas exposure to mercury is linked to delayed cognitive development and developmental delays. Cadmium exposure has been linked to kidney damage, and arsenic exposure is known to increase the risk of cancer. The research on heavy metals and their impact on the body has made significant progress in understanding the sources of exposure, absorption and accumulation patterns, health effects, mechanisms of toxicity, and risk assessment. This knowledge is crucial for developing effective strategies to mitigate heavy metal

exposure and protect human health. New challenges, like the combined effects of several heavy metals and the long-term impacts of exposure, require further study.

Although they are substances that are naturally present in the environment, heavy metals can also be released into the air, water, and soil through a variety of industrial operations. Due to their potential to result in serious health issues, research on the effects of heavy metals on the body has received a lot of attention lately. Heavy metal exposure has been associated to a wide range of unfavorable health impacts, including neurological disorders, renal damage, cardiovascular diseases, and even cancer. Heavy metals include lead, mercury, cadmium, and arsenic. Research into the mechanisms by which heavy metals cause harm to the body has been done in a number of researches. These investigations have shown that heavy metals can interfere with crucial biological processes, which can lead to the disruption of normal cellular functions. Heavy metals have been linked by researchers to a wide range of health issues, from neurological abnormalities to organ damage. Lead, for instance, has been proven to interfere with nervous system growth and function, while mercury can build up in the brain and affect cognitive ability. Concerns regarding heavy metal contamination of food, water, and the environment have grown over the past few decades. Governments and regulatory organizations have created standards and laws to restrict exposure to heavy metals as a result of this. Additionally, research has concentrated on developing treatments for disorders linked to heavy metal toxicity and finding efficient ways to reduce heavy metal toxicity. Better detection and quantification have been made possible by the development of improved analytical techniques. A fuller understanding of the impacts of heavy metals has resulted from the development of enhanced analytical techniques that have improved the detection and quantification of these substances in the body. For the purpose of creating efficient techniques to lessen the negative effects of heavy metals on the body, it is essential to understand the background of study on those effects. Researchers can identify knowledge gaps and conduct studies to further explore the processes of toxicity, create biomarkers for early identification, and assess the efficacy of preventive interventions by reviewing the body of existing literature.

2. The Impact of Heavy Metals on Human Health

2.1. Lead

The central nervous system (CNS) is known to be significantly impacted by lead. Several studies have suggested that lead exposure might cause behavioral problems, IQ decline, and mental retardation in children. Additionally, adult neurodegenerative illnesses including schizophrenia and dementia have been related to lead exposure.

By producing reactive oxygen species (ROS) and weakening antioxidant defense mechanisms, lead causes oxidative stress. ROS can harm DNA, proteins, lipids, and other biological building blocks, which can result in cellular collapse and inflammation. Lead can bind to sulfhydryl groups in enzymes, disrupting their structure and function. This interference can inhibit essential enzymatic processes involved in neurotransmitter synthesis, heme synthesis, and energy metabolism, leading to neurological and hematological abnormalities [1]. Lead can replace calcium ions in proteins, affecting their function and leading to impaired neuronal development, cognitive deficits, and skeletal abnormalities.

Lead is absorbed primarily through the gastrointestinal tract and respiratory system. Once absorbed, it enters the bloodstream and is distributed throughout the body, accumulating in various tissues, including bones, teeth, liver, and kidneys. Lead metabolism involves both endogenous and exogenous processes. Endogenous mechanisms include lead sequestration into bone and its subsequent release, leading to chronic exposure. Exogenous pathways involve the transformation of lead into various metabolites, such as lead sulfide and lead phosphate, which can be excreted via urine and feces.

Several factors influence lead metabolism, including age, nutritional status, genetic predisposition, and co-exposure to other metals. These factors can affect lead absorption, distribution, and elimination rates, thereby modulating the overall toxicological impact. Heart disease and stroke have

been linked to a higher likelihood of taking in lead. According to studies, lead can interfere with the cardiovascular system's regular operation, which can result in elevated blood pressure, coronary artery disease, and stroke. Lead is thought to encourage oxidative stress, swelling and damaged endothelial cells, all of which are associated with cardiovascular harm [2].

Lead exposure during pregnancy and in the early years of life can have significant implications on a child's ability to develop. There is evidence connecting preterm delivery, low birth weight, with intellectual disabilities to lead exposure during pregnancy. Additionally, learning disorders, ADHD, and stunted growth are more prevalent in children who have been exposed to lead [3].

2.2. Mercury

Mercury (Hg) is a naturally occurring hazardous metal that can be found everywhere. Hg concentrations in ecosystems have increased during the past 200 years as a result of human activities. When exposed to, the heavy metal mercury, people may experience negative health impacts. It can enter the body through a number of different channels, including cutaneous contact, ingestion, and inhalation. The brain, kidneys, and liver are just a few of the organs and tissues where mercury can build up after entering the body.

Mercury toxicity can disrupt the normal operation of neurons and neurotransmitters, making the central nervous system especially susceptible. Neurological symptoms like tremors, memory loss, and cognitive deficits may result from this. Mercury can also have an impact on the cardiovascular system by raising the risk of hypertension and heart disease. It may impede the blood vessels' regular operation and the control of blood pressure. Recent research suggests that exposure to methylmercury may raise the risk of cardiovascular disease, one of the world's leading causes of mortality [4]. Hu et al. conducted a thorough analysis of 29 studies on Hg and adult blood pressure levels. Their meta-analysis revealed a favorable connection between Hg from any marker and blood pressure as an ongoing factor or chances for elevated blood pressure [5].

The etiology of many neurological disorders, including Autism, Dyslexia, ADHD, etc. in adults, may be influenced by early exposure to toxic chemicals, either directly or through interactions with the genome. According to the National Research Council, 3% of behavioural neurological problems are caused by exposure to toxic environments, while another 25% are caused by a combination of environmental reasons and genetic problems [6].

Young children and pregnant women are fragile to the negative reaction of mercury. Prenatal contact with mercury can cause cognitive and motor deficits, among other developmental problems, in the developing fetus. Studies have shown that prenatal mercury exposure is associated with cognitive impairments, behavioral problems, and developmental delays in children. Pregnant women should take precautions to minimize their exposure to mercury, such as avoiding certain types of fish that are known to be high in mercury content. Exposure to mercury in youngsters can also cause behavioral issues and learning impairments [7].

Mercury exposure can come from a variety of places in our daily lives. Mercury tends to build in the aquatic food chain, thus one typical source is eating tainted fish and seafood. Mining and coal combustion are two industrial processes that emit mercury into the environment and increase its concentration in the air, water, and soil [8].

2.3. Cadmium

Cadmium is a widespread environmental pollutant that enters the human body through various routes such as inhalation, ingestion, and dermal contact. It accumulates primarily in the liver and kidneys but can also affect other organs, including the lungs, bones, and reproductive organs. Understanding the mechanisms underlying cadmium toxicity is crucial for developing effective strategies to protect human health. Cadmium is absorbed mainly through the respiratory and gastrointestinal tracts. Once absorbed, it binds to metallothionein and albumin, which act as transport proteins, facilitating its distribution throughout the body. However, it can also accumulate in other tissues, leading to widespread systemic effects [9].

Cadmium exerts its toxic effects through multiple molecular pathways and cellular processes. It disrupts cellular homeostasis by inducing oxidative stress, impairing DNA repair mechanisms, and interfering with calcium signaling. Furthermore, cadmium can disrupt mitochondrial function, leading to energy depletion and cellular dysfunction. It also activates inflammatory pathways and alters gene expression, contributing to tissue damage and disease development [10].

Risks to wellness associated with cadmium exposure include kidney damage, lung conditions, bone problems, and toxicity to fertility. A particularly well-known cause of dialysis and the onset of chronic kidney disease is cadmium-induced nephrotoxicity. In addition, the intake of cadmium over a long period of time has been research tied to a higher risk of lung cancer and osteoporosis.

To mitigate the adverse effects of cadmium, preventive measures are crucial. These include reducing environmental cadmium contamination, implementing occupational safety regulations, and promoting dietary strategies to minimize cadmium intake. Additionally, chelation therapy and antioxidant supplementation have shown promise in reducing cadmium toxicity in experimental studies.

Cadmium is a toxic heavy metal that poses significant risks to human health. Understanding the mechanisms through which cadmium affects the human body is essential for developing effective preventive and therapeutic strategies. Further research is needed to explore the molecular pathways and cellular processes involved in cadmium toxicity, as well as to identify novel interventions to protect individuals from its harmful effects.

2.4. Chromium

When the body has an excessive amount of chromium, which is sometimes referred to as chromium toxicity, chromium poisoning takes place. Trivalent chromium (Cr(III)) and hexavalent chromium (Cr(VI)) are two different types of chromium, a mineral that occurs naturally in many different combinations. Hexavalent chromium is extremely poisonous and can result in serious health problems, but trivalent chromium is a necessary nutrient for human health. Once inside the body, it can cause various adverse effects on different organ systems.

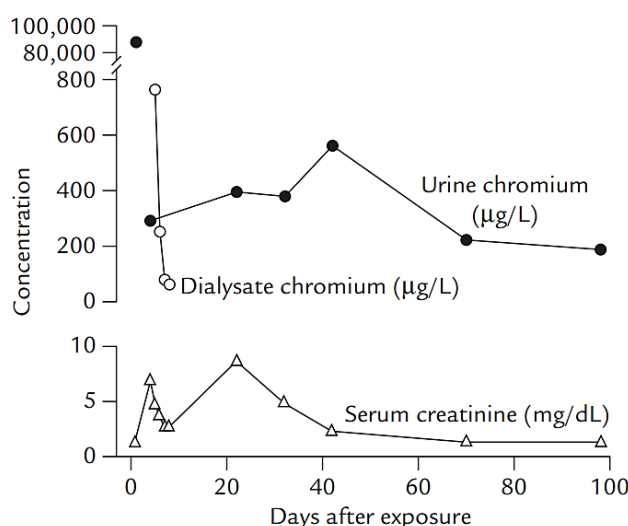


Figure 1. Analysis of chromium and creatinine levels [11, [https://doi.org/10.1016/S1726-4901\(09\)70059-0](https://doi.org/10.1016/S1726-4901(09)70059-0)]

Hexavalent chromium salts are highly corrosive and oxidizing substances that, when ingested through the skin, have local dermal effects as well as systemic toxicity. In cases of occupational exposure, local cutaneous symptoms such chemical burns, contact dermatitis, and chrome holes are frequently observed. As shown in Fig. 1, hexavalent chromium's systemic toxicity, which is typically brought on by purposeful exposure, causes severe internal bleeding, kidney failure, hemolysis in the vascular system, harm to the liver, and possibly death [11]. Hexavalent chromium transdermal exposure can cause systemic toxicity. Patients with chromic burn > 10% TBSA showed considerable

morbidity and mortality [12]. Chromic acid external burns of 10% and 40% in two cases resulted in death, while a 20% TBSA burn in another patient caused hepatic damage, severe renal failure, and anemia. Even a minor 1% TBSA burn has the potential to cause serious sickness [13]. Hexavalent chromic ions are thought to be absorbed via the skin very quickly. Generally speaking, 5 hours after skin exposure is when peak blood levels are reached. Organ damage may then occur [14].

Another form of chromium poisoning is oral. The powerful oxidizing properties of hexavalent chromium compounds make acute oral intoxication with them unusual, but frequently lethal. Three hours after consuming roughly 1 g of ammonium dichromate crystals, a 22-month-old infant was taken to the medical center [15]. When chromium VI is consumed, about 10% of it is absorbed, but only about 0.5% of chromium III [16]. Chromium VI is converted to chromium III in the plasma, where it forms non-toxic chromium III-protein complexes that are eliminated in the urine. Hexavalent chromium easily passes cell membranes after the plasma-reducing capability has been reached. When tiny particles and enzymes reduce chromium VI inside of cells, free oxygen radicals are produced. These radicals damage DNA and affect enzyme inhibition. Anasarca, shock, and noncardiogenic pulmonary edema all result from severe cellular failure [17]. The patient continued to deteriorate despite intense supportive treatment, and 48 hours after the intake, the patient passed away. An autopsy revealed many symptoms, including necrosis of most of the kidneys and intestinal ulcers [15].

3. Conclusion

Heavy metals' detrimental consequences on how we function are extensively understood and provide a serious public health risk. For the longevity of wellness, heavy metal exposure must be kept to a minimum. It is possible to lessen heavy metal contamination by putting strict limits on industrial emissions, ensuring the security of water supplies, and implementing sustainable farming methods. Additionally, regular monitoring of heavy metal levels in food and consumer products is essential. Public awareness campaigns and education about the potential sources and health risks associated with heavy metals can empower individuals to make informed choices and take necessary precautions. By following these steps, we can lessen the detrimental relate to heavy metals have on the body and encourage a healthy environment for the entire population.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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