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# Harmful Health Impacts of Heavy Metals and Behavioral Changes in Humans

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**ABSTRACT:** Heavy metal pollution not only affects the environment but also the behavior of people who are greatly dependent on their surrounding environment for their survival. There are both natural and anthropogenic sources of heavy metals but their pollution by manmade activities are quite faster than natural sources. A person gets exposed to heavy metals by four major exposure pathways i.e. inhalation, ingestion, dermal exposure and injection. After exposure to heavy metals, internal normal body functions of an individual gets disturbed. This in turn alters the human behavior from normal to an abnormal state. Various behavioral changes are associated with heavy metals exposure such as depression, anxiety, irregular heartbeats, stress, decrease in strength and power, lack of confidence, restlessness, lack of tolerance and aggressions among the individuals and the society as a whole. This review entails the information regarding sources of heavy metals, exposure pathways and health effects of heavy metals resulting in behavioral changes in humans.

**Keywords:** Heavy Metals, Harmful Effects, Behavior, Humans

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## INTRODUCTION

Environmental contamination by heavy metals is of momentous concern now-a-days. Heavy metals are defined as metals having a density greater than $5gmL^{-1}$ (Huton and Symon, 1986). Copper, chromium, lead, zinc, cadmium, mercury, arsenic, iron, manganese, nickel etc. are the examples of heavy metals. Heavy metal contamination is increasing day by day with subsequent increase in anthropogenic activities such as industrial and agricultural. Entering the environment, these heavy metals ultimately disturbs the natural processes of ecosystem. Although heavy metals do occur naturally but their release in the environment through anthropogenic activities is much faster than the natural ones. Eventually posing more risk to the environment, heavy metals, unlike organic materials do not biodegrade rather retains, and in the long run accumulates in the environment after their release from the source (Ali et al., 2013).

Accumulation of heavy metals in various compartments of ecosystem such as soil gives rise to many health problems among the human population. Soil contamination by heavy metals in turn not only contributes to the contamination of air but also water (both surface and ground water) which is necessary for the survival and well being of humans. Once they enter the body of living beings, they accumulate in various body parts of these organisms and biomagnifies up the food chain i.e., being less in concentration at the lower trophic level and more in concentration at the highest trophic level. Heavy metals in soil also affect the activities of soil microbes, thus disturbing the natural balance of soil ecosystem (Ullah et al., 2024).

Heavy metals are either essential or non essential and this is dependent upon their functions in the biological system. Essential heavy metals such as copper, iron, manganese, nickel and zinc are those which are required by the body in small concentration in order to carry out normal body functioning (Gohre and Paszkowski, 2006). While non essential heavy metals such as lead, arsenic, cadmium and mercury are not required by the body even in its lowest concentration to carry out the normal function of body (Mertz, 1981; Karenlampi et al., 2000; Sanchez-Chardi et al., 2009). Concentration of heavy metals in human body exceeding their set permissible limits pose a great risk by causing various physical, chemical, mental and behavioral alterations in individuals.

## LITERATURE REVIEW

### *Sources of Heavy Metals*

Both natural and anthropogenic sources are responsible for the release of heavy metals in environment. Natural processes of weathering, erosion and volcanic eruptions are some important natural sources while various industrial activities including discharge of industrial effluent, improper dumping of waste, atmospheric deposition, mining activities, application of pesticides and sewage sludge, are all manmade sources of heavy metals (Wuana and Okieimen, 2011). Table 1 shows the sources of some heavy metals by anthropogenic activities.

**Table 1. Sources of heavy metals by anthropogenic activities.**

| Heavy metals | Manmade sources | References |
|---|---|---|
| **Lead** | Leaded gasoline, lead based batteries, use of weed killers and insecticides. | Thangavel and Subbhuraam (2004), Wuana and Okieimen (2011) |
| **Cadmium** | Nickel - cadmium batteries, use of phosphate fertilizers, fungicides, electroplating , paints, plastic stabilizers, for the formation of different alloys and some kinds of pesticides. | Salem et al. (2000) |
| **Chromium** | Various industries such as textile, leather tanning and steel industries, pulverized fuel ash. | Khan et al. (2007) |
| **Mercury** | Coal power plants, mining activities, waste generated by health care facilities. | Memon et al. (2001), Wuana and Okieimen (2011) |
| **Zinc** | Industrial processes such as welding, smelting. | Plum et al. (2010) |
| **Nickel** | Stainless steel, effluent discharge from industries, scullery appliances and rechargeable batteries. | Tariq et al. (2006) |
| **Arsenic** | Substances used to preserve wood, use of pesticides. | Thangavel and Subbhuraam (2004) |

Note. Sources of heavy metals by anthropogenic activities. Adapted from "Phytoremediation of heavy metals—concepts and applications", by Ali, H., Khan, E., & Sajad, M. A. (2013), Chemosphere, 91, p.870. Copyright 2013 by Elsevier Ltd. Adapted with permission.

***Exposure Pathways***

Health risks of heavy metals are dependent upon their amount, toxicity and the route by which they enter human body. Inhalation, injection, ingestion and dermal contact are the common ways by which a contaminant enters the body of living organisms. Workers at workplace take in contaminants through inhalation mainly. Thus, they should avoid eating and drinking activities at their workplace where there is a risk of release of heavy metals into the environment from various processes. Transport of heavy metals in the body of an individual through injection is very rare (Fatima et al., 2024).

Generally people get exposed to lead contamination by drinking water and/or eating food contaminated with lead. Plumbing material that is used to convey water is one of the sources of lead in drinking water, while food packaging and food contained in improperly glazed bowls can contribute to the presence of lead in food materials. Various other sources by which humans are exposed to lead pollution are lead based paints, use of hair dyes and other beauty products such as surma. Exposure to cadmium occurs via inhalation and ingestion of contaminated food; dermal exposure being rare (Perveen et al.). Cigarette smoke is one of the main contributors of cadmium intake in humans. Cadmium exposure by eating contaminated vegetables also pose a great health risk to human health.

In case of chromium, general public are exposed to chromium through ingestion. Whereas, inhalation and skin contact are the two exposure pathways of chromium intake among job related people. Mercury of any form i.e. organic or inorganic is poisonous. Its poisoning occurs by all the four major routes of exposure i.e. vapor inhalation, injection, ingestion or its absorption by skin. The most common pathway by which zinc enters the body of general population is through ingestion of zinc contaminated food. Zinc is mostly found in food that is of animal origin. Zinc concentration is considered to be higher in meat products as compared to fruits and vegetables. Through air and water, humans are also at an increased risk of zinc toxicity (Waseem et al., 2023). Table 2 shows main exposure pathways of some selected heavy metals.

**Table 2. Main exposure pathways of some selected heavy metals.**

| Heavy metals | Major exposure pathways | References |
|---|---|---|
| **Lead** | Ingestion and inhalation | Hutton (1987) |
| **Cadmium** | Ingestion and inhalation | Hutton (1987) |
| **Chromium** | Ingestion (food) | Rowbotham et al.(2000) |
| **Mercury** | Ingestion | Hutton (1987) |
| **Arsenic** | Ingestion | Hutton (1987) |

Among the general public; air, water and food contamination by nickel contributes to its transfer in human body (Tehseen, Ghaffar, Mahmood, Younus, & Anam). Nickel is also used in coins, keys and jewelry. Hence, coming in contact with such things also make an individual vulnerable to nickel toxicity. Apart from this, inhaling tobacco smoke is also responsible for causing nickel contamination inside the human body. Nickel contamination by dietary intake differs from one individual to another depending upon the consumption habits and type of food since some nourishments are high in nickel such as

legumes, soybeans and nuts. Kitchen utensils that are made up of nickel also contribute to food contamination. An average daily intake of nickel in an individual by drinking nickel contaminated water and eating such contaminated food is 2ug/kg and 168 ug/kg respectively (Haidri, Qasim, et al., 2024).

Arsenic is released in the environment by both natural and man-made activities, thus, causing pollution of water, air, soil and food. Humans get exposed to arsenic either by inhaling it or ingestion it in the form of food and water. Arsenic can also contaminate ground water. High level of arsenic is found in certain geological formations from where it can leach down to ground water, ultimately contaminating the water of public use (Klaue and Blum, 1999).

## METHODOLOGY

### *Data Collection and Analysis Technique*

The data for this review were collected from various secondary sources, including peer-reviewed journals, government reports, and reputable databases. The selection criteria for the sources included relevance to the topic, the credibility of the publication, and the recency of the data. The gathered information was systematically reviewed and categorized based on the source of heavy metals, exposure pathways, and health and behavioral effects.

The analysis involved a thematic review, where the collected data were organized into key themes relevant to heavy metal exposure and behavioral changes. These themes included sources of heavy metals, exposure pathways, and specific health impacts leading to behavioral changes. Each theme was further analyzed to identify patterns, correlations, and significant findings. The analysis also involved comparing findings from different studies to ensure the consistency and reliability of the conclusions drawn.

## RESULTS AND DISCUSSION

### Health Effects of Heavy Metals Resulting in Behavioral Changes in Humans

Exposure to heavy metals by anthropogenic activities induce such changes in human body which affects its normal functioning thereby, causing it to behave differently than it would behave in normal circumstances. For example an infected liver could disrupt its natural ability of detoxification, affecting the body's internal enterohepatic circulation. Such disturbances in human body may lead to many psychological and visible behavioral changes in an individual (Haidri, Fatima, et al., 2024).

Heavy metal toxicity in humans affects their body and mental health adversely and is therefore gaining much attention by general public and scientific society (Tehseen, Mahmood, et al.). Most of the heavy metals are toxic and are responsible for causing toxicity in humans even in their minute concentrations (Memon and Schroder, 2009). Some of them are essential for normal body functioning while others are not. Lead, cadmium, mercury, copper, chromium and arsenic are some common examples of heavy metals. They are considered as problematic due to their persistant nature and bioaccumulation capacity in living things after getting exposed to them.

Oxidative stress in an individual may also be induced by heavy metal toxicity. Individuals suffering from oxidative stress feel pain in their muscles and joints, develop wrinkles and grayish hair at an early age. Eye sight of such people also gets weak. They feel tired all the time, become sensitive to noise and more vulnerable to other infections than healthy ones.

Various environmental factors including heavy metal exposure are responsible for triggering Parkinson's. People diagnosed with this particular kind of disease experience many changes in their normal behavior. They remain sad all the time, do not take care of their health and come across with many strange feelings such as of death. They think that they are a burden on their family. This makes them hopeless and helpless. Such patients become the victims of depression and anxiety. Their sleeping and eating habits also gets disturbed which makes them tired. So, they remain unable to perform and enjoy daily activities which make them further frustrated (Ummer et al., 2023).

Lead exposure makes a person vulnerable to cardiovascular diseases. An individual diagnosed with this disease becomes the victim of depression which further makes the situation worst (Van der kooy et al., 2007) causing more death rates than those patients who do not get depressed even after getting diagnosed with cardiovascular disease. This shows that depression and cardiovascular diseases share a direct proportional relationship. People suffering from heart diseases loses their physical abilities to achieve certain goals in life .This makes them irritable and they try to commit suicide. All of these behavioral changes caused by metal induced cardiovascular diseases in humans negatively affects their overall personality (Ummer et al.).

Arsenic interferes with oxidative phosphorylation. ATP normal functioning in human body also gets disturbed by the presence of metallic form of arsenic in body (Tripathi et al., 2007). Arsenic mimics phosphorous in ATP molecule as both of them have same valency i.e. +3 and +5. If in ATP, phosphorous is replaced by arsenic, then ATP would become unable to provide energy in the body where it is needed, ultimately locking the energy (Sulaiman et al., 2023). This is turn affects the physical abilities of an individual such as reduced capacity of exercise, diminished power, decrease in strength and endurance. Also, such people become readily exhaust and tired after doing a small piece of work (Abernethy et al., 2005). This depicts an overall dull personality of an individual exposed to arsenic toxicity. Victim of toxicity resulting from arsenic can even die as a result of energy lockup. Children are at a greater risk of exposure to arsenic than adults as they have a habit of putting their hands in mouth and they do not adopt protective measures like adults.

By getting exposed to cadmium, endocrinal system of an individual gets disturbed. This in turn is associated with depressive disorders. Hyperthyroidism is one of its example in which hormones are overproduced by thyroid. Several behavioral alterations are linked to it such as depression, anxiety, nervousness, loss of hair, development of breast in males, lack of confidence, diminished ability to concentrate on a particular work, disturbance in sleeping habits. Aggressive and brutal behavior is also associated with

endocrine disruption. All of this leads to poor lifestyle, making a person often violent (Zala and Penn, 2004).

Those individuals diagnosed with cancer by cadmium toxicity are at a greater risk of sadness and depression, making them aimless and hopeless (O'Connor et al., 1990). Anemia patients are unable to sleep properly; this adversely affects their mental health and ultimately the ability of thinking, making a person victim of depression. Kidney damage is also important with .regard to cadmium toxicity. If a person along with kidney disease is a victim of depression, makes his health status at a great risk as depression in kidney patients enhances inflammation inside the body which further aggravates the situation of kidney often leading to hospitalization and ultimately death of an individual.

Exhaustion, depression, diminished tolerance, anxiety, spontaneous body movements and aggression are all the behavioral changes associated with mercury toxicity in humans. Such people are never at ease and are always found in a state of restlessness which makes their personality suspicious. Nickel is a cause of skin diseases in humans. People with skin diseases may become the victims of stress and depression and face many psychological problems in return. They cannot intermingle with people openly, visible rashes on the skin takes away their confidence which in return reduces their social interaction and hence social contribution. More behavioral problems are found in children with skin diseases than the healthy ones (Beattie and Lewis-jones, 2006). Poor mental health is also associated with nickel toxicity. Greater amount of zinc intake in the body causes upper abdominal pain, nausea and vomiting due to which a person feels dizzy, tired and is unable to perform work passionately (Fosmire, 1990).

Anaemia, kidney damage, adverse impacts on brain, liver cirrhosis and gastrointestinal irritations are caused by copper toxicity (Salem et al., 2000). Gastrointestinal irritation makes an individual physically and mentally disturbed leading to a nervous state, damaging the well-being of an individual and often causing fatness which further induces various personality complexes.

Central fatigue, a result of copper toxicity is caused by disturbance of neurotransmitters within the nervous system. Anxiety and depression are among some other behavioral alterations in humans. In liver cirrhosis, normal functioning of liver gets impaired. Its capability to detoxify harmful toxins inside the body also gets adversely affected. This in turn affects the normal functioning of brain causing an element of confusion among such individuals and giving rise to disturbed sleep patterns which further instigate mood swings and irritable behavior (Faazal et al., 2023).

Hair loss caused by chromium toxicity often leads to baldness. Such people are often bullied so they avoid making new friends and going out at public places. They also keep themselves away from those discussions which are related to hair as they are embarrassed of their own hair. Sometimes such people also try to commit suicide as other people humiliate them. This overall damage their self confidence and they consider themselves degraded (Safdar et

al.). Table 3 shows harmful health impacts of heavy metals and the resulting behavioral changes from them in humans.

***Analytical Results of Heavy Metal Exposure***

This study reveals that exposure to heavy metals leads to a wide array of adverse health effects. Heavy metals such as lead, cadmium, and mercury are associated with serious health conditions including cardiovascular diseases, kidney damage, and neurological disorders. These health impacts are not only significant but also diverse, reflecting the various ways in which different metals affect bodily functions. The severity of these health issues often correlates with the level of exposure and the specific metal involved.

**Table 3. Harmful health impacts of heavy metals and the resulting behavioral changes in humans.**

| Heavy metals | Harmful health impacts | References | Behavioral changes | References |
|---|---|---|---|---|
| **Lead** | Heart diseases, kidney failure developmental abnormalities in children. | Salem et al.(2000), Wuana and Okieimen (2011) | Affects memory and intelligence of children, depression caused by cardiovascular diseases. | Van der kooy et al.(2007) |
| **Cadmium** | Disturbs the endocrine system, kidney failure, changes the genetic material, and causes cancer | Salem et al. (2000) | Depression in kidney patients, disturbance to endocrine system makes the one susceptible to depression, anxiety and aggression. | Zala and Penn (2004), Patel et al.(2010), O'Connor et al.(1990) |
| **Chromium** | Hair loss | Salem et al. (2000) | Such people avoid making friends and are ashamed of their personality. | Schmidt et al, (2001) |
| **Mercury** | Affects lungs, kidney and brain adversely. | Gulati et al. (2010) | Exhaustion, depression, convulsions, anxiety, and frequent loss of temper. | Gulati et al. (2010) |

| | | | | |
|---|---|---|---|---|
| **Zinc** | Vomiting,nau ea,upper abdominal pain. | Fosmire (1990) | Tiredness, feeling unbalanced, lack of enthusiasm. | Fosmire (1990) |
| **Copper** | Damage to brain and kidney, liver diseases, and reduction in red blood cells. | Salem et al. (2000), Wuana and Okieimen (2011) | Anxiety, depression and other psychological problems. | Aaronson et al. (1999) |
| **Arsenic** | Disturbs ATP synthesis and oxidative phosphorylatin. | Tripathi et al. (2007) | Unable to give physical performance properly | Abernethy et al.(2005) |

*Note*. Harmful health impacts of heavy metals and the resulting behavioral changes in humans. Adapted from "Phytoremediation of heavy metals—concepts and applications", by *Chemosphere*, *91*, p.870. Copyright 2013 by Elsevier Ltd. Adapted with permission.

In addition to health problems, heavy metal exposure is linked to notable behavioral changes. Individuals exposed to these metals often experience cognitive impairments, emotional disturbances, and social withdrawal. These behavioral effects highlight the broader implications of heavy metal contamination, extending beyond physical health to impact psychological well-being and social interactions. The findings underscore the need for comprehensive strategies to manage and mitigate the risks associated with heavy metal exposure, emphasizing both preventive and therapeutic approaches to protect public health.

Although many studies have discussed the harmful impacts and the resulting dreadful diseases by exposure to heavy metals in humans. Psycosocial factors are dicussed in terms of diseases only (O'Connor et al., 1990). No work has been done on heavy metal exposure and their direct relation to behavioral changes in humans such as aggression, depression, lack of tolerance e.t.c. This shows a gap lapse which is needed to be filled. Present review is an attempt to incorporate adverse health impacts caused by heavy metals and relating those harmful impacts to human behavioral changes from normal to abnormal state.

## CONCLUSIONS AND RECOMMENDATIONS

Heavy metals have various adverse health impacts on humans and are responsible for inducing negative behavioral changes in them. An individual being a unit, thus changes the society. We are living in the times of diminished tolerance. People nowadays are prone to violence like never before. Our surroundings are getting all the more dangerous not only for us but for our children also. People do not feel themselves responsible for their actions and are unaware of their personal responsibilities towards individuals and society. Etiquettes, courteous ways of life and respect for elders are an obsession of the

past. It's a scary world to pass on to our next generations. We are in dire need to reduce heavy metal contamination to save and revive our sanity by handing over a healthier environment to our offspring.

**FURTHER STUDY**

This study has some limitations. Firstly, the majority of the included studies focus on short-term exposure, with limited data on the long-term behavioral impacts of chronic heavy metal exposure. Secondly, there is a lack of consistency in the measurement of behavioral changes, making it difficult to compare findings across studies. Many studies did not account for potential confounding factors such as socioeconomic status, genetic predispositions, and concurrent exposure to other environmental toxins, which could influence the observed behavioral outcomes. Future research should aim to address these limitations by conducting longitudinal studies, standardizing behavioral assessment tools, considering a broader range of confounding variables, and employing objective measures of behavioral changes to enhance the validity and reliability of the findings.

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