

Impacts of Heavy Metals and Behavioral Changes in Humans

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Abstract

Heavy metal pollution not only affects the environment but if absorbed into the body, common heavy metals include lead, mercury, cadmium and arsenic can accumulate in leading to a range of adverse health effects. Chronic exposure to heavy metals can result in long term health problem. 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.*

1. Introduction

Heavy metals are defined as metals having a density greater than 5gmL^{-1} (Hutton & Symon, 1986); (Nriagu & Pacyna , 1988). Their persistence in the environment and bioaccumulation in living organism raise serious health concerns (Duruibe , Ogwuegbu , & Egwurugwu, 2007). Heavy metal contamination is increasing day by day with subsequent increase in anthropogenic activities such as industrial and agricultural. Although heavy metals do occur naturally but their release in the environment through anthropogenic activities is much faster than the natural ones. Common heavy metals such as lead, mercury, and cadmium can enter the human body through various pathways like soil, water, air and food (Ali, Khan, & Sajad , 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. Heavy metals in soil may increase the activities of soil

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microbes, thus disturbing the natural balance of soil ecosystem (Khan, Hesham, Qiao, Rehman, & He, 2010).

2. Sources of heavy metals

Both natural and anthropogenic sources are responsible for the release of heavy metals in environment. Industrial activities like mining, metal processing and manufacturing contribute significantly so heavy metals release into air, soil and water. The burning of fossils fuels and the combustion of waste water can release these heavy metals. (Modaihsh , Al-Swailem , & Mahjoub , 2004); (Chehregani & Malayeri, 2007); (Fulekar, Singh, & Bahaduri, 2009); (Mehmood , Chaudhary, Tufail, & Irfan , 2009); (Wuana & Okieimen, 2011). Table 1 is showing the sources of some heavy metals by anthropogenic activities.

3. Exposure pathways

Heavy metals can enter the environment through various anthropogenic activities such as industrial processing. Once released, the metals can follow a complex exposure pathway, posing potential risk to human health and environment.

Generally, people get exposed to lead contamination by drinking water and/or eating food contaminated with lead. Soil is a primary reservation where heavy metals accumulate, either through direct deposition or by reaching from contaminated water. From the soil metals can be taken up plants and subsequently enter the food chain, leading to the human exposure through the consumption of contaminated crops (Wang, Sato, Xing, & Tao, 2005).

Airborne transport is another pathway, as heavy metals can be released into the atmosphere and eventually settle onto the soil and water surface, 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 (Blanusa, Varnia , Piasek, & Kostial , 2005).

4. Health effects of heavy metals resulting in behavioral changes in humans

Heavy metals exposure has associated with a range of adverse effects on human behaviour, potentially leading to change in cognitive function and psychological wellbeing (Bao, et al., 2009).

The neurotoxic properties of certain heavy metal, such as lead, mercury and cadmium can impact the central nervous system, disrupting neurotransmitter function and synaptic transmission (Kara, 2005); (Tchounwou, Wilson , & Ishaque, 1099); (Memon & 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 persistent nature and bioaccumulation capacity in living things after getting exposed to them.

Chronic exposure of these metals has been believed to cognitive impairments, leaving difficulties and memory deficits, particularly uncivilized (Mudipalli , 2008). 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 disease (Seidler , et al., 1996). 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.

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, Van Hout, Marwijk, Stehouwer, & Beekman, 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 proportion 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.

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. This in 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 exhausted and tired after doing a small piece of work (Abernethy, Hanrahan, Kippers, Mackinnon, & Pandey, 2004). This depicts an overall dull personality of an individual exposed to arsenic toxicity. Victims 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 their mouths and they do not adopt protective measures like adults (Bearer, 1995). Table 3 shows harmful health impacts of heavy metals and the resulting behavioral changes from them in humans.

The levels of heavy metal may contribute to increase irritability, anxiety and depression (O'Connor, Wicker, & Germino, 1990). Anemia patients are unable to sleep properly; this adversely affects their mental health and ultimately the ability of thinking, making a person a victim of depression. Kidney damage is also important with regard to cadmium toxicity (Cukor, Peterson, Cohen, & Kimmel, 2006).

Exhaustion, depression, diminished tolerance, anxiety, spontaneous body movements and aggression are all the behavioral changes associated with mercury toxicity in humans (Neustadt & Pieczenik, 2007); (Ainza, Trevors, & Saier, 2010); (Gulati, Banerjee, Lall, & Ray, 2010). 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 (Thomas, 2024). They cannot intermingle with people openly, visible rashes on the skin take away their confidence which in return reduces their social interaction and hence social contribution (Beattie & 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).

Anemia, kidney damage, adverse impacts on brain, liver cirrhosis and gastrointestinal irritations are caused by copper toxicity (Salem, Eweida, & Farag, 2000). Gastrointestinal irritation makes an individual physically and mentally disturbed leading to a nervous state, damaging the well-being.

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 (Manu, Lane, & Matthewa, 1998); (Lloyd, 1998); (Lee, Hicks, & Nino-Murcia, 1991); (Aaronson, et al., 1999). In liver cirrhosis, normal functioning of liver gets impaired.

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 (Schmidt , Fischer , Chren , Strauss , & Elsner, 2001).

Psychosocial factors are discussed in terms of diseases only (Swain, 2000). 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 etc. 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.

5. Conclusion

Impact of heavy metals on human behavioral changes are a cause for significant concern, highlighting between the environmental contaminants and mental health. The nontoxic effects of heavy metals particularly on the central nervous system, contribute to cognitive impairments, learning difficulties and memory deficits with children being particularly vulnerable. Moreover, the levels and the induction of oxidative stress can lead to alterations in mood, manifesting as increased irritability, anxiety and depression.

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, Eweida & Farag, (2000); Pulford and Watson (2003)
Chromium	Various industries such as textile, leather tanning and steel industries, pulverized fuel ash.	Khan, Ahmad & Rahman, (2007)
Mercury	Coal power plants, mining activities, waste generated by health care facilities.	Memon, Aktoprakligil, Özdemir & Vertii (2001), Wuana and Okieimen (2011), and Rodrigues, Henriques, Reis, Duarte, Pereira & Römken (2012)
Zinc	Industrial processes such as welding, smelting.	Plum, Rink & Haase, (2010)
Nickel	Stainless steel, effluent discharge from industries, scullery appliances and rechargeable batteries.	Tariq, Ali & Shah, (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.

Table 2: Main exposure pathways of some selected heavy metals in humans.

Heavy metals	Major exposure pathways	References
Lead	Ingestion and inhalation	Hutton (1987)
Cadmium	Ingestion and inhalation	Hutton (1987)
Chromium	Ingestion (food)	Rowbotham, Levy & Shuker (2000)
Mercury	Ingestion	Hutton (1987)
Arsenic	Ingestion	Hutton (1987)

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 and other developmental abnormalities in children.	Salem, Eweida & Farag, (2000), Padmavathiamma and Li (2007), Wuana and Okieimen (2011) and Iqbal (2012)	Unable to concentrate properly, affects memory and intelligence of children, depression caused by cardiovascular diseases.	Bellinger, Stiles & Needleman (1992), Lanphear et al. (2005), Van der Kooy, van Hout, Marwijk, Marten, Stehouwer, & Beekman, (2007)
Chromium	Hair loss	Salem, Eweida & Farag, (2000)	Such people avoid making friends and are ashamed of their personality as they are often humiliated by	Schmidt, Fischer, Chren, Strauss & Elsner, (2001)

			others. This ruins their self-confidence.	
Mercury	Affects lungs, kidney and brain adversely.	Neustadt and Pieczenik (2007), Ainza, Trevors & Saier (2010), Gulati, Banerjee, Lall & Ray (2010)	Exhaustion, depression, convulsions, anxiety, frequent loss of temper leading to aggression. People with mercury toxicity are found never at rest leading to disturbed personality	Neustadt and Pieczenik (2007), Ainza, Trevors & Saier (2010) and Gulati, Banerjee, Lall & Ray (2010)
Zinc Nickel	Vomiting, nausea, upper abdominal pain. Skin diseases, cancer of throat and stomach, affects DNA and CNS, damage to kidney.	Fosmire (1990) Salem, Eweida & Farag, (2000), Duda-Chodak and Baszczyk (2008), Das, Das & Dhundasi, (2008)	Tiredness, feeling unbalanced, lack of enthusiasm. Children with skin diseases avoid making new friends and are unable to intermingle with people easily.	Hess and Schmid (2002), Fosmire (1990) Beattie and Lewis - jones (2006), Thomas (2004)
Copper	Damage to brain and kidney, gastrointestinal irritations, liver diseases, reduction in red blood cells.	Salem, Eweida & Farag, (2000), Wuana and Okieimen (2011)	Central fatigue resulting from disturbance of neurotransmitters within the central nervous system,	Lee, Hicks & Nino-Murcia (1991), Manu, Lane & Matthews (1988),

			anxiety, depression and other psychological problems.	Lloyd (1998), Aaronson et al. (1999)
Arsenic	Disturbs ATP synthesis and oxidative phosphorylation.	Tripathi et al. (2007)	Unable to give physical performance properly due to lack of energy which in turn decreases strength and power.	Abernethy, Hanrahan, Kippers, Mackinnon & Pandy (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 Ali, H., Khan, E., & Sajad, M. A. (2013), *Chemosphere*, 91, p.870. Copyright 2013 by Elsevier Ltd. Adapted with permission.

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