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Heavy Metals Contamination and what are the Impacts on Living Organisms

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Review Article

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ABSTRACT

Heavy metals are toxic metals having density five times greater than water. They are toxic for all living organisms. In humans they enter into body through various ways like ingestion, absorption etc. They become harmful when their accumulation rate is more than their discharge. They accumulate gradually in body over a long time and are toxic. Heavy metal contamination is a major problem in environment and of medium sized cities due to anthropogenic activities. Human activities may contribute largely in their production such as burning of fossil fuel, mining and use of many chemical for crop growth etc. Waste water also contains heavy metal and when it is applied to crops it can cause threat to soil and plants growing in that soil. Waste water health risks can be determined by different indices. Generally, heavy metals cannot be removed from waste water and when they enter into the soil, interfere with the plant roots - these plants when eaten by animals or humans they enter into food chain. Plants along with other nutrients also uptake lead and cadmium; their accumulation may be effected by the concentration time of exposure and climatic factor. Heavy metals affect the quality and production of crop and influence atmospheric and water quality. These contamination are important and of concern because of increasing demand for food safety. There are different sources for heavy metal such as natural and manmade, as industries and air borne sources. These heavy metals have severe effects on plants, animals, humans and ultimately on environment.

Keywords: Concentration, density, man made, risks.

INTRODUCTION

Heavy or toxic metals are trace metals which are detrimental to human health and having a density at least five times that of water. Once liberated into the environment through the air, drinking water, food, or countless varieties of man-made chemicals and products, heavy metals are taken into the body via inhalation, ingestion and skin absorption. If heavy metals enter and accumulate in body tissues faster than the body's detoxification pathways can dispose of, then a gradual build-up of these toxins occurs. High concentration exposure is not a necessity to produce a state of toxicity in the body, as heavy metal accumulation occurs in body tissues gradually and, over time, can reach toxic concentration levels, much beyond the permissible limits. (Suruchi et al, 2012).

Human activities such as industrial production, mining, agriculture and transportation release a high amount of heavy metals to the bio sphere. The primary sources of metal pollution are the burning of fossil fuels, smelting of metal like ores, municipal wastes, fertilizers, pesticides and sewage (Nriagu, 1979, 1996; Pendias and Pendias, 1989; Rai, 2009). Heavy metal contamination and acid mine drainage are very important concerns where waste materials containing metal rich sulphides from mining activity have been stored or abandoned (Concas et al., 2006; Rai, 2008).

Wastewaters carry toxic heavy metals that get introduced into the soil and aquatic system through various processes, prominent among them being irrigation (Khan et al., 2008). Heavy metal pollution in the air increases through human activities. Smelting and burning of coal, oil and waste will bring heavy metal pollution into the atmosphere. In coal burning areas, the different contents of heavy metals (As and Cr) in the coal have affected the emission of heavy metals into the atmosphere (Chen et al., 1989).

Heavy metal contamination is a major problem of the environment especially of growing medium sized cities in developing countries primarily due to uncontrolled pollution levels driven by causative factors like industrial growth and heavy increase in traffic using petroleum fuels. Heavy metal contamination may occur due to factors including irrigation with contaminated water, the addition of fertilizers and metal based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale (Radwan and Salama, 2006; Tuzen and Soylak, 2007; Duran et al., 2007).

Heavy metals are generally not removable even after the treatment of wastewater at sewage treatment plants and thus, cause risk of heavy metal contamination of the soil and subsequently to the food chain (Fytianos et al., 2001).

Deposition of air pollutants is captured by the plant canopy and accumulated in or on the leaves. As the accumulation is roughly a function of the deposited amount of pollutants, the exposure time and the effects of climatic factors are of prime importance. As such, many plant species are useful for bio monitoring atmospheric deposition of pollutants. In the case of heavy metal containing aerosols, the elements are mainly accumulated on the leaf surface. However, there is no adequate method to completely remove all heavy metals originating from the dust deposition, as fine particulates can enter the leaves via stomata and moreover, fixation of particulates by epidermal cells may occur, other techniques are needed to show the contribution of airborne metals to the contamination status of the plants. Experimental work using labeled cadmium in the soil offered the opportunity to make a distinction between soil and airborne cadmium in several crops (Hovmand et al., 1983).

Heavy metal pollution not only affects the production and quality of crops, but also influences the quality of the atmosphere and water bodies, and threatens the health and life of animals and human beings by way of the food chain. Most severe is that this kind of pollution is covert, long term and non-reversible (Zhang, 1999). Heavy metals are also one of the major contaminating agents in our food supply (Zaidi et al., 2005; Khair, 2009).

Vegetables are vital to the human diet and in particular provide the well-known trace elements and heavy metals. Minor or trace elements are essential for good health if they come from an organic or plant source. In contrast, if they come from an inorganic or metallic source, they become toxic. The processes of plant growth depend on the cycle of nutrients including trace elements, from soil to plant (Mohamed et al., 2003). Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals because they absorb these metals in their leaves.

The geological background level of heavy metal is low (Wei et al., 1991). In soil, the average contents of Al, Cd, Cu, Mn, Pb and Zn are 66200, 0.097, 22.6, 583, 26.0 and 74.2 mg/kg, respectively.

Food safety is a major concern at present. The increasing demand of food safety has accelerated research regarding the risk associated with food consumption contaminated by heavy metals (Mansour et al., 2009). The rate at which heavy metals are accumulated in the soil depends on the physiochemical properties of the soil and the relative efficiency of crops to remove the metals from the soil. Heavy metals accumulated in cultivated soils can be transferred to humans through various exposure pathways causing adverse effects on human health (Qishlaqi et al., 2008).

Lead and cadmium are among the most abundant heavy metals and are particularly toxic. The excessive amount of these metals in food is associated with etiology of a number of diseases, especially with cardiovascular, kidney, nervous as well as bone diseases (Sanchez-Castillo et al., 1998; Steenland and Boffetta, 2000). Lead is well known for its toxicity and adverse effects on human health. Absorption of ingested lead may constitute a serious risk to public health. Some chronic effects of lead poisoning are colic, constipation and anaemia (Bolger et al., 2000).

Heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, intrauterine growth retardation, impaired psychosocial faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar and Nair, 2000; Türkdogan et al., 2003;Arora et al., 2008).

Serious systemic health hazards can develop as a result of extreme dietary accumulation of heavy metals such as Cr, Cd, Ni and Pb (Oliver, 1997). Heavy metals accumulated in cultivated soils can be transferred to humans through various exposure pathways causing adverse effects on human health (Qishlaqi et al., 2008).

The level of health risks posed by wastewater with heavy metals was determined using different indices, including the transfer factor (TF), daily intake of metals (DIM) and health risk index (HRI) or health quotient (HQ) (Liu et al., 2005; Khan et al., 2008).

Plants and animals take up metals from contaminated soil and water as well as from deposits on parts of the plants exposed to the air from polluted environment (Santos et al., 2006).

Sources of heavy metals:

Heavy metals exist naturally in the soil from the soil forming processes of disintegration of parent resources at rare levels (<1000 mg kg^{-1}) and infrequently poisonous (Kabata-Pendias and Pendias, 2001; Pierzynski et al., 2000). Heavy metals comes from manmade sources trying to be more moveable in the soil, hereafter biologically available than soil forming phenomena (Kuo et al., 1983; Kaasalainen and Yli-Halla, 2003). Metal-containing solids at polluted places can originate from an extensive variation of manmade sources in terms of metal mine stakeouts, leaded gasoline and paints that are lead based, application of fertilizer, discarding high metal wastes in inappropriately protected landfills, animal manures, bio solids (sewage sludge), coal combustion remainders, compost, petrochemicals, pesticides and deposition in atmosphere (Khan et al., 2008; Zhang et al., 2010; Basta et al., 2005) are discussed here.

Fertilizers:

Huge amounts of fertilizers are frequently applied to soils in concentrated farming systems to deliver suitable N, K and P for crop growth. The complexes used to offer these elements comprise rare quantity of heavy metals (for example Cadmium and Lead) as contaminations, that, after continual fertilizer application may meaningfully proliferate their quantity in the soil (Jones and Jarvis, 1981). Metals like Cadmium and Lead have no recognized physiological actions. Certain phosphatic fertilizer applications unintentionally add Cd and other possibly dangerous elements for the soil, including F, Pb and Hg (Raven et al., 1998).

Pesticides:

Numerous known insecticides used widely in agriculture in the past contained considerable amounts of metals. As in the recent past, near 10% of the chemicals have permitted for use as pesticides and in UK fungicides were based on complexes which comprise Cu, Hg, Pb, Mn or Zn. For Example, such pesticides that are fungicidal spray that contained copper like copper oxychloride and Bordeaux mixture that consists of copper sulphate (Jones and Jarvis, 1981). Lead arsenate was applied in fruit orchards for several years to regulate some parasitic pests. Compounds that consist of arsenic were applied widely to control livestock ticks and for the control of insects in banana in New Zealand and Australia, wood has been well-preserved with preparations of Copper, Chromium and Arsenic (CCA), and there are currently many neglected sites where soil amounts of these elements largely surpass background focuses. Such pollution has the capacity to result in problems, especially if sites are improved for other agricultural or non-agricultural purposes. Linked with fertilizers, the application of these ingredients has been more restricted, being localized to special sites or crops (McLaughlin et al., 2000).

Bio solids and Manures:

The supply of various bio solids for example., composts, cattle's manure and municipal sewage sludge (MSS) to land unconsciously points towards the build-up of heavy metals like Arsenic, Cadmium, Chromium, Copper, Lead as well as Hg, Se, Ni, Mo, Zn, Sb, in the soil (Basta et al., 2005). Some animal wastes like livestock, poultry and pig manures created in agriculture are usually supplied to crops and meadows either in the form of solids or semi solids (Sumner, 2000). Though most compost can be seen as valued fertilizers, in the poultry and pig industry, the Copper and Zinc are included in foods as growth enhancers and Arsenic presence in poultry fitness products may have the ability to cause metal pollution of the soil (Sumner, 2000; Chaney and Oliver, 1996). The manures that are created from animals as a result of these diets possess greater amounts of Cu, As and Zn and, if continually supplied to prohibited areas of land, can result in reasonable accumulation of these metals in the longer period of time in these soils.

Bio solids (including sewage sludge) are basically solid products organic in nature, formed by treatment processes of wastewater that can be usefully recycled (USEPA, 1994). Heavy metals most usually established in bio solids include Ni, Pb, Cd, Cu, Cr and Zn, and the metal amounts are ruled by nature and the strength of the industrial processes, as well as the sort of activity worked during the treatment of bio solids (Mattigod and Page, 1983). Under specific situations, metals supplied to soils by applying bio solids can be percolated downwards by the soil horizons and may have the ability to pollute groundwater (McLaren et al., 2005). Latest researches on some soils of New Zealand applied with bio solids have resulted in increased amounts of Ni, Cd and Zn in drainage percolates (Keller et al., 2002; McLaren et al., 2004).

Waste water:

The supply of wastewater coming from industrial land municipal sources and associated wastes to soil dates back 400 years and is a usual practice now in different parts of the globe (Reed et al., 1995). Internationally, it is projected that 20 million (20m) hectares (ha) of arable land are watered with some sort of waste water. In various African and Asian cities, studies propose that agriculture relied on watering with wastewater contributes for 50 % of the vegetable source to urban areas (Bjuhr, 2007). Farmers usually are not worried about environmental welfares or dangers and are principally concerned with maximizing their productions and profits. Though the metal amounts in wastewater discharges are comparatively low, long-term watering of land with such wastewater can finally cause heavy metal build-up in the soil.

Industrial wastes and metal mining processes:

Withdrawal and milling of metal minerals joined with industries have bequeathed various countries, the bequest of extensive circulation of metal pollutants in soil. Through withdrawal, tailings (larger particles settled at the end of the flotation cell while mining) are straight discharged in naturally occurring depressions, as well as onsite wetlands resulting in high amounts (DeVolder, 2003). Widely, Lead (Pb) and zinc (Zn) mineral withdrawal and smelting have resulted in pollution of soil that causes danger to human and environmental health. Many retrieval methods that are used for these places are prolonged and costly and may not result in restoration of soil efficiency. Soil heavy metal's ecological threats to humans are connected to bioavailability. Assimilation routes encompass the incorporation of plant material that is grown in contaminated soils (food chain), or the ingestion of contaminated soils directly (Basta and Gradwohl, 1998).

Extra materials are produced by a variation of industries such as tanning, textile, petrochemicals from unintentional oil spills or consumption of petroleum-based products, insecticides and pharmaceutical industries and are extremely variable in configuration. Although certain products are disposed of on soil, some have assistances for agriculture and forestry. In addition, various are possibly dangerous due to their constituents of heavy metals like Cr, Pb and Zn or poisonous organic mixtures and are sometimes, if ever, supplied to land. Some others are actually little in plant nutrients or have no soil conditioning effects (Sumner, 2000).

Air borne sources:

Aerial resource of metals that include chimney or duct releases of air, vapor streams or gas and brief discharge like dust from storage places and waste piles. Metals that are from airborne sources are usually discharged as particulates consist on the gas stream. Some metals like Cd, As and Pb can similarly volatilize by high-temperature activities. These metals will change to oxides and shrink as smaller particulates until a reducing air is upheld (Smith et al., 1995). Emissions from chimney may be circulated over an extensive area by natural air flow still dry and/ or wet precipitation actions eliminate them from the gas tributary. Another chief source of soil pollution is the floating release of Pb from the burning of petrol having tetraethyl lead; this enhances considerably the part of Pb in soils of urban areas and in those next to main roads. Zinc and Cadmium can also be applied to soils next to roads, the sources include tyres and lubricant oils (USEPA, 1996).

Effects on humans:

Heavy Metals are reported to encourage tumor and mutations at greater amounts in animals (Degraeve, 1981). They have capacity of producing genetic harm to germ cells of both male and female animals. (Hayes, 1984; Groten and Vanbladeren, 1994; Wagner, 1993). They are observed as growing toxins which through biomagnifications in plants affect the health of humans (Groten and Vanbladeren, 1994).

In animals (including human being), heavy metals are extremely poisonous at comparatively smaller amount. Ingesting food or drinking water with very greater degree of heavy metals relentlessly infuriates the stomach results in diarrhea and vomiting. Correspondingly greater degree of Lead (Pb) might be minimizing response period, and result in anemia, a disease of blood in humans (ATSDR, 1993).

Reported ways for the connection of heavy metals to the human body comprises direct breathing of polluted air, drinking of polluted water and direct contact with soil and ingestion of food comprising of plants developed in metal-polluted soil (Dudka and Miller, 1999 and Bhagure and Mirgane, 2011).

Heavy metal-polluted food can severely reduce some vital nutrients in the body that are accountable for declining immunological defenses, growth delay, reduced psychosocial abilities, incapacities related with malnutrition and greater occurrence of upper gastrointestinal cancer degrees (Iyengar and Nair, 2000; Türkdogan et al., 2003; Arora et al., 2008).

Metals are non-decomposable and are recognized as main environmental contaminants causing cytotoxic, mutagenic and cancerous (carcinogenic) effects in animals (More et al., 2003 and AL-Othman et al., 2011).

Long contact to heavy metals like cadmium, copper, lead, nickel and zinc can result in lethal health problems in humans (Reilly, 1991). The biotic half-lives of these heavy metals are lengthy and furthermore these have capacity to store in various organs of the body and therefore results in annoying side effects (Jarup, 2003; Sathawara et al., 2004; Ata et al., 2009).

Continuous exposure of Cadmium (Cd) in edibles and water results in accumulation of Cadmium in kidneys cause kidney diseases (ATSDR, 1993). Nickel (Ni) confirms deadly if it surpasses the allowed amount in edibles.(Nriagu and Pacyna, 1988). Higher contact with Cd may result in lung disorders like bronchiolitis, emphysema and alveolitis. Renal effects (kidney related) may also be caused by sub chronic breathing of Cadmium (Young, 2005; Ogwuegbu and Muhanga, 2005).

Lead and cadmium are included in the most plentiful heavy metals and are principally poisonous. The unnecessary quantity of these metals in edible things is linked with etiology of various disorders, particularly with cardiovascular, nervous, kidney as well as bone disorders (Sanchez-Castillo et al., 1998; Steenland and Boffetta, 2000).

Lead is known for its toxicity and negative impacts on human health. Absorption of swallowed Lead may have a severe danger to public health. Some long lasting negative impacts of Lead toxicity includes colic, constipation and anemia (blood related disorder) (Bolger et al., 2000). Zinc is a constituent of various enzymes that are the ribonucleic polymerases, carbonic anhydrase, alcohol dehydrogenase and alkaline phosphatase in humans (Goldhaber, 2003).

Children show weakness towards Lead (Pb) noxiousness and that Pb results in harm to the central nervous system, in severe chances death may occur (Nicklow et al., 1983). However, metabolism of both Pb and Ca are alike in both their storage in and movement from bone. (Forstner and Wittmann, 1983). Under usual circumstances, more than 90 % of the lead (Pb) reserved in the body exists in the skeleton. Moreover, during lactation and pregnancy, lead moves from mother's bones to breastfed infants and fetuses (Suruchi and Khanna, 2011). Lead (Pb) is noxious and there are doubts that body weights under those at which clinical signs of Lead Pb noxiousness shows, may result in cerebral injury in young children (Davies, 1995) and increase blood pressure (BP) in adults (Suruchi and Khanna, 2011). Furthermore, the carcinogenic (cancerous) and mutagenic properties of lead have been frequently proved (Michalak and Wierzbicka, 1998).

Lead (Pb) toxicity results in decrease of hemoglobin production, disorder in the working of kidney, reproductive system, joints and cardiovascular systems and causes long-lasting injury to the central and peripheral nervous systems (Nolan, 2003).

Existence of poisonous heavy metals in lakes, reservoir and river water disturbs the lives of native people that rely on these water bodies for their regular supply of water (Rai et al., 2002). Fish is reported as one of the chief protein sources for humans that plays role in lowering the blood cholesterol level and offers omega-3 fatty acids that minimize the danger of stroke and heart related disorders (Al-Busaidi et al., 2011). They are metals that can be stored by fish through the food chain as well as water (Hadson, 1988).

Deficiency of nickel have been linked with hyperglycemia, depression, sinus congestion, fatigue, reproductive failures and growth problems in humans, while excess intake leads to hypoglycemia, asthma, nausea, headache and epidemiological symptoms like cancer of nasal cavity and lungs. Higher concentration of Zn can cause impairment of growth and reproduction (Rattan et al., 2005).

Lack of zinc may result from insufficient nutritional consumption, reduced absorption, unnecessary excretion or hereditary disorders in zinc metabolism (Colak et al., 2005) while copper shortage resulted in neutropenia, anemia and skeletal disorders (Radwan and Salama, 2006).

Effects on plants

Greater quantity of Heavy Metals in soils has been testified to prevent plant's progress in growth, uptake of nutrients, physiological as well as metabolic processes. This also affects chlorosis, harm to root tips, minimized water and uptake of nutrients and impairment to enzymes (Baisberg-Påhlsson, 1989; Sanità di Toppi and Gabbrielli, 1999). Heavy metals, similar to other ecological stressors, also encourage amplified antioxidant enzyme processes in plants (Iannelli et al., 2002).

In plants, heavy metals such as cadmium (Cd), lead (Pb) and nickel (Ni) are greatly toxic at comparatively low amount. Heavy metal poisonoussness is the product of multifaceted interaction of chief noxious ions with other vital or non-essential ions. The metals can be a source of decrease in the hydrolysis products viz., α-amylase, Phosphatase, RNAs and proteins. They disturb the enzyme activities by substituting metal ions from the metalo-enzymes and prevent various physiological developments of plants (Agarwal, 1999).

Different rare metals are crucial for plants, showing main roles in plant anabolism, catabolism and biosynthesis, together as cofactors for enzymes and as metabolic yields (Rattan et al., 2005). For example, Zn, Fe, Cu, Cr, and Co is critical nutrients but conversion to toxic elements at greater amounts. Comparatively, lead (Pb) and cadmium Cd have no recognized favourable effects in plants and are solely lethal (Radojevic and Bashkin, 1999; Mohamed and Ahmed, 2006).

The threshold lead level allowed for fruits and small fruits are 0.10 and 0.20 mg/kg, respectively (EC, 2006). Plants grown in the Zn and Cu-polluted soils store abundant portion of metals in roots (Stalikaset al., 1997). Copper (Cu) is known to be important and poisonous for numerous biological systems.

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