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Review Article

HEAVY METALS IN ENVIRONMENT, LIVING SYSTEMS AND HERBAL PREPARATION: AN OVERVIEW

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ABSTRACT
Heavy metals occur as a natural constituent of earth's crust. Due to the indiscriminate human activities there is drastic change in geochemical and biochemical balance which results in accumulation of metals in plant parts having secondary metabolites with particular pharmacological activity. All over the world the concentration of essential and non-essential heavy metals such as Cadmium, Copper, Lead, Nickel and Zinc beyond permissible limit is a matter of great concern for public wellbeing. Molecular understanding of plant metal accumulation is essential as it has many biotechnological implications.

Key words: Ayurveda, herbal preparation, hyper-accumulation, phytoremediation.

INTRODUCTION

Heavy metals have a density of 6.0 g/cm^3 or more which is much higher than the average particle density of soils which is 2.65 g/cm^3 and occur naturally. Irrespective of their atomic mass or density any toxic metal may be called heavy metal.[1] Common transition metals such as Copper, Lead and Zinc cause environmental pollution from sources such as leaded petrol, industrial effluents and leaching of metal ions from soil into lakes and rivers by acid rain.[2] In India three principal systems of medicine like Ayurveda, Siddha and Unani Tibb are practised which utilizes drugs of natural origin containing plants, animals and mineral preparations. In medicine "heavy metal poisoning" can possibly include excessive amounts of iron, manganese, aluminium, mercury, cadmium, or beryllium (the fourth lightest element) or semimetal as arsenic.[3]

HISTORY

Ayurvedic medicines which depend largely on herbal medicinal products (HMPs) originated in India long back 2000 years ago. Approximately 80% of India's 1 billion populations use Ayurveda.[4] Safety concerns have been raised about Ayurveda, when two U.S. studies found that about 20% of Ayurvedic treatments contained toxic levels of heavy metals such as lead, mercury and arsenic. The use of herbs containing toxic compounds and the lack of quality control in Ayurvedic facilities also comes under other concerns.[5]

HEAVY METALS AFFECTING LIVING ORGANISMS

Varying amounts of heavy metals are required by living organisms. Iron Cobalt, Manganese, Molybdenum and Zinc are required by humans. All metals produce toxic effects at higher concentrations. Excessive levels of these can cause severe damage to the organism. Heavy metals disrupt metabolic function in two ways:

1. They accumulate and thus disturb function in vital organs and glands of our body such as heart, brain, kidneys, bone, liver etc.
2. They dislocate vital nutritional minerals from their original place and thus hinder their biological function. There are many ways by which these toxins can be introduced into the body such as by consumption of different food products, exposure to household products, personal products and varying numbers of industrial products and chemicals.[6]

Types of Heavy metals and their effect on human health with their permissible limits are listed in Table 1.[7-12]

When plants are exposed to heavy metals they experience oxidative stress which leads to cellular damage and also disturbs cellular ionic homeostasis. Plants have evolved a detoxification mechanism based on chelation in order to reduce the effects of heavy metal exposure. In transpeptidation reaction phytochelations (PCs) are synthesized from reduced glutathione (GSH) which is catalysed by the enzyme phytochelation synthase (PCS). Therefore during the exposure of plants to heavy metals glutathione is important for PCS synthesis in.[13]

HEAVY METALS POLLUTING ENVIRONMENT

Soil is a crucial component of rural and urban environments. Metal concentration in soil ranges from less than one to as high as 1,00,000 mg/kg. Mining, manufacturing, and the use of synthetic products (e.g. pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Extreme levels of many metals in soil can degrade its quality, reduce its crop and may result in poor quality of agricultural products, affecting to human, animal and ecosystem health.[14] Therefore it becomes important to remove accumulated metals. Various processes for removal of heavy metals are shown in Table 2.[7]

The permissible limits for heavy metals in plant species as per Indian Pharmacopoeia 2007 guidelines are given in Table 3.[7] Nitric Oxide [NO] plays important roles in diverse physiological processes in plants. Research shows that Nitric Oxide [NO] controls plant responses to a variety of abiotic and biotic stresses. It scavenges heavy metal induced Reactive Oxygen Species (ROS) and increases antioxidant content in plants thus reducing heavy metal stress in plants. It also affects root cell wall components so as to increase heavy metals accumulation in root cell walls and decrease heavy metals accumulation in soluble fraction of leaves in plants. So it can function as a signalling molecule under heavy metal stresses.[15]

HEAVY METALS AND CONTAMINATION OF VEGETABLES

Dietary exposure to heavy metals, namely Cadmium (Cd), Lead (Pb), Zinc (Zn), Copper (Cu) has been identified as a risk to human health through the consumption of vegetable

crops. Heavy metals have toxic and mutagenic effects even at very low concentration. Several cases of human disease, disorders, malfunction and malformation of organs due to metal toxicity have been reported. Along with the human beings, animals and plants are also affected by toxic levels of heavy metals.[16] Heavy metals may be present either as a deposit on the surface of vegetables, or may be taken up by the crop roots and enter into the edible part of plant tissues. Heavy metals deposited on the surface can be eliminated simply by washing prior to consumption, whereas bio-accumulated metals are difficult to remove and are of major concern.[17]

HEAVY METALS USE IN POLYMERS

In hydrometallurgical applications metal chelating and ion exchange polymers were used such as retrieval of rare metal ions from sea water and removal of traces of radioactive metal ions from wastes. Uranium is a potential environmental pollutant in mining industries wastewater. Adsorbents containing amidoxime group have proven to be most effective for recovery of Uranium from seawater and aqueous media at very low concentration levels more efficiently.[18] Uranium not only cause nephrotoxicity but also neurotoxicity (targeting the brain), it is genotoxic (causing DNA damage related to cancer), immunotoxic (weaken the immune system) and also disturbs hormone balances.[19] Heat stabilizers are mainly used for construction products made of polyvinyl chloride, for example window profiles, pipes and cable ducts. Light stabilizers which are especially needed for polypropylene and polyethylene. The environmental impact of stabilizers for polymers can cause serious problems because of heavy metal content.[20]

HEAVY METALS INFLUENCE ON ECOSYSTEM

Heavy metals such as lead, arsenic, mercury, cadmium and aluminium constitute the most dangerous toxins in our ecosystem. Contaminations of land resources by heavy metals are the focus of many environmental studies. Due to the high amount of heavy metals content Municipal solid waste (MSW) fly ash is considered as a hazardous material. For the decontamination of MSW fly ash, it is first mixed with alkali or alkaline earth metal chlorides (e.g. Calcium chloride) and water. The resulting mixture is then pelletized and treated in a rotary reactor at about 1000^0C. More than 90% of cadmium and lead and about 60% of copper and 80% of zinc could be removed by this process.[21]

The sewage sludge contains useful concentrations of elements like nitrogen, phosphorus, organic matter and heavy metals. Sewage sludge should be exposed to biological, chemical or thermal treatment, long-term storage or other suitable process which can reduce its ferment ability and health related dangers resulting from its use before applying it in agriculture. This increases the utilization of sewage sludge for fertilization and re-cultivation of ruined soils in agriculture.[22]

EVIDENCE TO SUPPORT USE OF HEAVY METALS

1. **Effective against microbes**
   i. Zinc - Zinc chloride is found in some mouthwashes and it is often used as an antifungal in paint. Zinc lozenges are sold as treatment for colds.
   ii. Copper - Copper sulphate is useful algaecide in bodies of water or aquariums. Copper compounds may also be used in paints to prevent mildew.
   iii. Forms of silver - Cream containing silver combined with a sulfa drug, catheters impregnated with silver, a silver-containing product for surfaces (Surfacine).[23]
2. **In Herbal preparations**
   Heavy metals are toxic, but their oxides are non-toxic.
   i. Food and drug Administration has approved Arsenic Trioxide to be used in Acute Promyelocytic Leukemia (APL).[24]
   ii. Navbal Rasayan [NR], a metal based Ayurvedic formulation is used for treatment of multiple sclerosis. No toxic effects have been seen with study of Navbal Rasayan in animal. Histamine, Acetyl choline and Serotonin shows increase or decrease in agonistic activity which needs further research.[25]
   iii. Two gold preparations; Ayurvedic Swarna Bhasma and Unani Kushta Tila Kalan are claimed to possess general tonic, hepatotonic, and nervous tonic cardio-stimulant, anti-infective and antiaging properties.[26] For more than sixty years with potential documented effects on immune function gold compounds (e.g. Gold Disodium Thiomalate and Auranofin) have been used in treatment of rheumatoid arthritis.[27]
   iv. Studies have shown that Tamra Bhasma, a metallic Ayurvedic preparation, inhibits lipid peroxidation (LPO) and also the rate of airborne oxidation of reduced glutathione (GSH) content, thus the activity of superoxide dismutase (SOD) in rat liver is induced.[28] This preparation is useful for treating liver disorders, gastrointestinal (GIT) disorders, old age diseases, leucoderma and free radical- mediated disorders, either alone or as herbo-mineral preparation.[29]
3. **Industrial applications**:
   i. Nickel- Component in manufacture of stainless steel, other corrosion-resistant alloys, coins, nickel steel for armour plates, burglar-proof vaults.
   ii. Copper- Component in metal alloys; electrical wiring; some water pipes; preservatives for wood, leather and fabrics.
   iii. Arsenic- Component in manufacture of bronze materials, fireworks, shot, agricultural chemicals, laser materials.[30]

CONCLUSION

In the last decade there has been a steady increase in the use of herbal medicine globally. Worldwide there is discussion going on for the use of Ayurvedic metallic preparations. Since 12th century, Bhasma preparation is in clinical use and one cannot just simply prohibit its use by presuming that heavy metals are toxic. Proper scientific documentation pertaining to these is required to validate the claims about the metallic preparations. As the use of herbal medicines by the world population is increasing day by day, quality controls to ensure that toxic elements are within the maximum allowable regulation limits is required. WHO has made it compulsory that before exporting, herbal products should be tested for their heavy metal content so that heavy metals remain within permissible limits.

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TABLE1. TYPES OF HEAVY METALS WITH THEIR EFFECT ON HUMAN HEALTH ALONG WITH THEIR PERMISSIBLE LIMITS[7,8,9,10,11,12]

Pollutants	Major Sources	Effect on human health	Permissible level (mg/l)
Cadmium	Welding, electroplating Cd and Ni batteries, Nuclear Fission plants	Reproduction problem because it affects sperm and reduces birth weight, Renal dysfunction, Lung disease, Lung cancer, bronchitis	0.06
Silver	Jewellery, silverware, electronic equipment, and dental Fillings	Arthralgia, allergy, breathing problems, stomach pail	0.00010
Lead	Pint, pesticide, automobile, burning of coal	Damage to the brain, cardiotoxic, congenital paralysis, damage to liver, anaemia, high blood pressure, infertility, reduced learning abilities and kidney damage.	0.1
Barium	Barium-nickel alloys, diagnostic medicine	Large amounts of barium intake can cause, high blood pressure, changes in heart rhythm or paralysis and possibly death.	2.0 in drinking water
Zinc	Brass manufacture metal plating plumbing	Zinc fumes have corrosive effect on skin, cause damage to nervous membrane	15.0
Copper	Mining, pesticide production, metal piping	Anaemia, hypertension, sporadic fever, uraemia, coma, liver and kidney damage.	0.1

TABLE 2. VARIOUS PROCESSES FOR REMOVAL OF HEAVY METALS[7]

Metal	Removing agent	Major method	Other methods
Heavy metals in water	Natural zeolites Polymers [Polypyrrole and Polyaniline] Calcium alginate microparticles	Ion exchange	Biosorption Complexation
Chromium ions [mainly from industrial waste]	Activated carbon, Rice hull	Ion-Exchange Adsorbents on solid sorbents	Chemical precipitation, Chemical oxidation, surface absorption, reverse osmosis
Mercury	Activated carbon, Bentonite	Ion Exchangers	Reduction Precipitation
Arsenic	Polypyrrole and its Composites, Ultrafiltration Membrane Assisted Process , Coagulation technology, bentonite, Activated charcoal	Oxidation, adsorption	Oxidation by adsorbents and surfactants

TABLE 3. PERMISSIBLE LIMITS FOR PLANT SPECIES[7]

Name of Herbs	Botanical Name	Family	Medicinal properties	Permissible limits (in ppm)
Ashwagandha	*Withania somnifera*	Solanaceae	Anti-metastatic activity	20
Brahmi, Thyme-leafed gratiola, Water hyssop	*Bacopa monnieri*	Plantaginaceae	Treatment for epilepsy and asthma, enhance immune function	20
Pippali, Long pepper	*Piper longum*	Piperaceae	longevity enhancer, for throat irritation	20
Sunthi	*Zingiber officinale rose*	Zingiberaceae	Influence gastrointestinal function	20
Tulsi	*Ocimum sanctum*	Lamiaceae	Hypoglycemic, antioxidant	20
Vasaka	*Adhatoda vasica*	Acanthaceae	Expectorants	20