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Heavy Metal Contamination: A Serious Hazard to Food-Chain

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ABSTRACT

Heavy metal contamination of the food chain because of urbanization and industrialization is of great concern because of potential health hazard due to dietary intake of contaminated products. Crop plants, especially vegetables, are vital to the human diet and in particular, provide the nutrients to maintain normal health. The prolonged application of fertilizers, pesticides have resulted in the accumulation of heavy metals, especially in vegetables. In this article The prolonged application of fertilizers, pesticides have resulted in the accumulation of heavy metals, especially in vegetables are described.

The rapid development and urbanization is incorporating a considerable amount of hazardous and toxic heavy metals in all the components of the environment, including soil, water, air and crop plants (Gupta *et al*., 2019; Shrivastava *et al*., 2019). The toxic heavy metals from different sources enter into the food chain and *via* foodgrains and vegetable consumption, biomagnified into living beings and originate potentially health-threatening effects (Kumar *et al*., 2019). The worldwide scenario depict that >10 million sites (>20 million ha area) are considered soil polluted sites. Out of that, more than 50% of sites are contaminated with heavy metals and metalloids (He *et al*., 2015). In India, 42 rivers have at least two heavy metals beyond the permissible limit (Central Water Commission, 2018). As per Central Ground Water Board (CGWB), India, groundwater of more than 718 districts is affected by heavy metal toxicity with cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb) and iron (Fe). The heavy metals in contaminated soils impair the natural ecosystem services and eventually damage the health of soil, plant and human via the food chain (Maurya *et al*., 2019).

Heavy metals, found in agricultural soils, are omnipresent in the ecosystem due to both geogenic as well as anthropogenic reason (Rahimi *et al*., 2017). Soil pollution by heavy metals is a universal problem for food production and the health of living beings. The most important natural sources for heavy metal in the soils are weathering of natural rocks, erosion and volcanic activity and the human-made sources of several ore mining activities, smelting, electroplating, industries' effluents, unsanitary landfills sites, military training, agricultural pesticides and phosphate fertilizer, application of biosolids and atmospheric deposition (Fig. 1).

Bioaccumulation of heavy metals through the food chain

The contamination of the food chain is the primary pathway of heavy metals exposure for living beings. The metal contamination of agricultural soil mainly occurs through irrigation with polluted water of industries and sewage waste treatment plants. Long-term application of wastewater results in the build-up of heavy metals in soil and crops that can limit soil functioning, reduce the nutritional quality of vegetables, toxicity to crops and contamination of the food chain (Fig. 2.) (Chen *et al*., 2010).

Due to continuous intake, the bioaccumulation of heavy metals takes place in vegetables, crops and humans. Crop species differ in their ability to absorb heavy metals from soil and water.

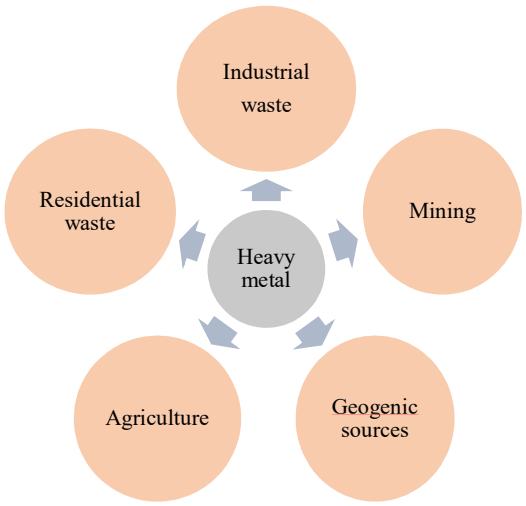

Fig. 1. Sources of hazardous heavy metal

Vegetables are an essential part of the human diet due to the richness of beneficial and essential minerals and nutrients. Unfortunately, vegetables can uptake and accumulate heavy metals beyond recommended limits in their entire body, including both edible and inedible parts (Tasrina *et al*., 2015). In the last few years, the concentration of heavy metals in vegetables has been observed at high levels. Eventually, the build-up of heavy metals in vegetables and edible plant parts in highly contaminated soils is a matter of great concern due to the harmful and irreversible effects of metals impacting both humans as well as animal's overall health.

Once these toxic metals enter into the food chain, they cannot be removed easily from the top of the food chain and thereby circulate into the whole food web. Many hyper accumulated plants serve as food for human beings and animals. Hence, the cycle from soil to humans *via* plants and again into the soil after the death of top consumers, provide a path for heavy metals to remain sustained within the environment for long periods inducing many harmful effects. The cycle of heavy metals in the food chain begins with various sources. For example, Cadmium (Cd) is taken up from soil via roots to the plant body. In the case of Lead (Pb), the heave metal is absorbed from the air dust into plants, and Arsenic (As) and Mercury (Hg) may be obtained from sewage water. During the transfer from one section to another in the food chain, some heavy metals have a tendency of accumulation in the tissues (liver, feathers, muscles, kidney and other organs) of top consumers.

The prolonged application of fertilizers, pesticides have resulted in the accumulation of heavy metals, especially in vegetables.Generally, the lower concentration of these contaminants also affects the several activities in living beings (Table 1). The heavy metals that quickly present in soil solution or solubilized by plant exudates are available for plant uptake (Blaylock *et al.,* 2000). Although plants require certain heavy metals for their growth and support, the excessive amounts of these heavy metals can become toxic to plants and cause a reduction in growth, performance, and yield. Whenever concentrations of these metals exceed optimal levels in the plant parts, they adversely affect the plant growth both directly and indirectly.

Some of the direct toxic effects caused by high metal concentration include inhibition of enzymes present in the cell sap and damage to cell structures due to oxidative stress (Chibuike and Obiora, 2014).

Toxic effects of metals are due to the interruption of cellular biochemical pathways (Onakpa *et al*., 2018). When poisonous metals are ingested in the stomach *via* contaminated foods, they are converted to their stable oxidation states in the acid medium and fuse with specific proteins and enzymes. The stabilized metallic compounds react with the sulphydryl groups (-SH) of cysteine and sulphur atoms of methionine ($-SCH_3$) in amino acids, thereby promoting the degeneration of protein molecules. The different forms of trace metals presented in the solid phase of soil and bonded by adsorption, complexed or occluded pools. Trace elements that are externally adsorbed or complexed with solid-phase such as clay minerals, hydrated oxides of iron and manganese, or soil organic matter are more or less exchangeable with the soil solution phase. The physical, chemical and biological properties of soil are also affected by trace metals contamination in the soil solution.

Conclusion

Heavy metal contamination of the food chain as a result of urbanization and industrialization is of great concern because of potential health hazard due to dietary intake of contaminated products. Crop plants, especially vegetables, are vital to the human diet and in particular, provide the nutrients to maintain normal health. The prolonged application of fertilizers, pesticides have resulted in the accumulation of heavy metals, especially in vegetables. Exposure to heavy metals by consumption of contaminated vegetables and its toxicity is a serious concern. Policies and programs need to be adapted so that edaphic conditions and agricultural practices are taken into account, and appropriate measures developed for ameliorating heavy metal uptake by crops for a given set of conditions. A better understanding of the soil-water-food crop transfer mechanisms is prerequisite for devising effective remediation technologies. To alleviate the consequences of heavy metal contamination, better management and remediation practices should be required.

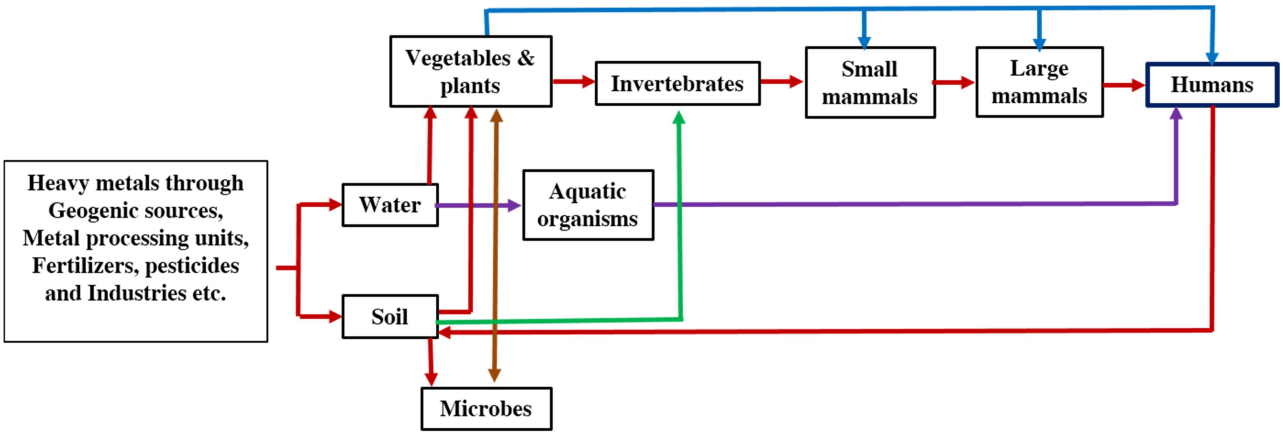

Fig 2. The flow of heavy metals through food chain (Kumar *et al*., 2019)

Table 1. Harmful effects of toxic heavy metals on plants and humans

S. No.	Heavy metal	Effects on plants	Effects on humans	Reference
1	**AS**	Seed germination and seedling height reduction in rice crop	Cardiovascular, neurologic and developmental anomalies	Abbas *et al*., 2018
2	**Cd**	Seed germination reduction, decrease in nutrient use efficiency and reduced shoot and root length in wheat crop	Bone demineralization, renal dysfunction	Loi *et al*., 2018
3.	**Co**	Antioxidant enzyme activities reduction; decrease in plant sugar, starch, amino acids, and protein content in mungbean	Severe health effects on the lungs, including asthma and pneumonia	Jayakumar *et al*., 2008
4	**Cr**	Inhibition of germination process; plant biomass reduction in garlic	Multi-organ toxicity, nose ulcers and cancer of the respiratory tract	Medda and Mondal, 2017
5.	**Pb**	Reduction in germination percentage; suppressed growth; reduced plant biomass; decrease in plant protein content in maize crop	Kidney failure, affect CNS and PNS, damage to the reproductive systems	Hussain *et al*., 2013

References

Kumar, S., Prasad, S., Yadav, K.K., Shrivastava, M., Gupta, N., Nagar, S., Bach, Q.V., Kamyab, H., Khan, S.A., Yadav, S. and Malav, L.C., 2019. Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches-A review. Environmental research, 108792.

Gupta, N., Yadav, K.K., Kumar, V., Kumar, S., Chadd, R.P. and Kumar, A., 2019. Trace elements in soil-vegetables interface: translocation, bioaccumulation, toxicity and amelioration-a review. Science of the Total Environment, *651*, 2927-2942.

He, Z., Shentu, J., Yang, X., Baligar, V.C., Zhang, T., Stoffella, P.J., 2015. Heavy metal contamination

of soils: sources, indicators, and assessment. J. Environ. Indicators 9, 17-18.

CWC (Central Water Commission), 2018. Status of trace and toxic metals in Indian Rivers.

Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation, Central Water Commission. River Data Compilation-2 Directorate Planning and Development Organization. April 2018.

Maurya, P.K., Malik, D.S., Yadav, K.K., Kumar, A., Kumar, S., Kamyab, H., 2019. Bioaccumulation and potential sources of heavy metal contamination in fish species in River Ganga basin: possible human health risks evaluation. Toxicol. Rep. 6, 472–481.

Rahimi, G., Kolahchi, Z., Charkhabi, A., 2017. Uptake and translocation of some heavy metals by rice crop (*Oryza sativa*) in paddy soils. Agriculture (poľnohospodárstvo) 63, 163−175.

Chen, Z.F., Zhao, Y., Zhu, Y., Yang, X., Qiao, J., Tian, Q., Zhang, Q., 2010. Health risk of heavy metals in sewage- irrigated soils and edible seeds in Langfeng of Hebei Province, China. J. Sci. Food Agric. 90, 314-320.

Tasrina, R.C., Rowshon, A., Mustafizur, A.M.R., Rafiqul, I., Ali, M.P., 2015. Heavy metals contamination in vegetables and its growing soil. J. Environ. Anal. Chem. 2, 2.

Blaylock, M. J., Huang, J. W., 2000. "Phytoextraction of metals," in Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment, I. Raskin and B. D. Ensley, Eds., pp. 53–70, Wiley, New York, NY, USA, 2000.

Onakpa, M.M., Njan, A.A., Kalu, O.C., 2018. A review of heavy metal contamination of food crops in Nigeria. Annals Global Health 84, 488–494.

Abbas, G., Murtaza, B., Bibi, I., Shahid, M., Niazi, N.K., Khan, M.I., Hussain, M., 2018. Arsenic uptake, toxicity, detoxification, and speciation in plants: physiological, biochemical, and molecular aspects. Int. J. Environ. Res. Public Health 15, 59.

Loi, N.N., Sanzharova, N.I., Shchagina, N.I., Mironova, M.P., 2018. The effect of cadmium toxicity on the development of lettuce plants on contaminated sod-podzolic soil. Russian Agric. Sci. 44, 49-52.

Jayakumar, K., Jaleel, C. A., Azooz, M. M., 2008. Phytochemical changes in green gram (Vigna radiata) under cobalt stress. Global Journal of Molecular Sciences, 3(2), 46-49.

Medda, S., Mondal, N.K., 2017. Chromium toxicity and ultrastructural deformation of Cicer arietinum with special reference of root elongation and coleoptile growth. Annals Agrarian Sci. 15, 396-401.

Hussain, A., Abbas, N., Arshad, F., Akram, M., Khan, Z. I., Ahmad, K., ... Mirzaei, F., 2013. Effects of diverse doses of Lead (Pb) on different growth attributes of Zea-Mays L. Agricultural Sciences, 4(5), 262.

Chibuike, G.U. and Obiora, S.C., 2014. Heavy metal polluted soils: effect on plants and bioremediation methods. Applied and environmental soil science, 2014.

Shrivastava, M., Kumar, S., Yadav, S., & Manasvini, K. L. (2019). Deficiency and Toxicity of Trace Elements in Salt-affected Soils. Indian Society of Soil Salinity and Water Quality (Registered under Societies Registration Act XXI of 1860) Editorial Board, 11(1), 31-44.