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Heavy Metal Accumulation in Commonly Used Vegetables: A Review

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Abstract: ***Metal contamination issues are becoming increasingly common in India and elsewhere, with many documented cases of metal toxicity in mining industries, foundries, smelters, coal-burning power plants and agriculture. The contemporary investigations into toxicity and tolerance in metal-stressed plants are prompted by the growing metal pollution in the environment .This paper aims to collate and compile the research literature pertaining to the heavy metal contamination in vegetables. It also reviews deeply about effect, uptake and accumulation of heavy metal in vegetables. Uptake and translocation factor of heavy metal from soil to edible parts of vegetables were quite distinguished for almost all elements examined. Plants grown on heavy metal polluted soils result in reduction in growth due to changes in their physiological and biochemical activities, especially when the heavy metal involved does not play any beneficial role towards the growth and development of plants. Thus, it is evident from the several research findings that presence of heavy metals has toxic effects on plants, animals and many living organisms after certain limits. Our review showed that there is tissue accumulation of heavy metals with resulting possible risks to human's health and this review may help in interdisciplinary studies to assess the ecological significance of metal stress.***

Keywords: Accumulation, Heavy metals, Physiology, Toxicity, Vegetables

1. Introduction

The over use of natural resources and rapid industrialization in developing countries have increased the accumulation of toxic industrial effluents in the soil. Among these toxic substances, presence of heavy metals which are ubiquitous in nature, cause serious harmful effects on living organisms [Nies, 1999]. Heavy metal pollution is a major environmental problem because their contamination is harmful to wild life, humans and agriculture [Gratao et al., 2005]. Heavy metals are essential micro nutrients for example, as cofactors of key metabolic enzymes, but when their concentration become high in soil, they become most toxic to the plants [Stobrawa and Lorenc-Plucinska, 2007]. Plants are sensitive to environmental conditions and they accumulate these heavy metals in their harvestable parts (*via* root uptake, foliar adsorption and deposition of specific elements in leaves) and intensity of this uptake process can change the overall elemental composition of the plant [Olajire, and Ayodele, 2003]. In the present paper we have reviewed the researches related to heavy metal accumulation in vegetable. This review will give an understanding of differences in the accumulation capacity of various vegetables and various metals.

2. Review Works

Many publications are available all around the world describing the heavy metal accumulation and toxicity; some of them are briefly discussed in the paper. Due to the number of references collected from the variety of sources, some lacks or omissions are possible.

Singh and Kumar (2006) assessed heavy metal concentration in spinach and lady's finger. Result show the heavy metal accumulation in mg/kg varied from 7 to 50 for copper, 51 to for Zinc, 1.4 to 9 for cadmium, 1.7 to 9.1 for Lead in spinach. In Lady's finger heavy metal accumulation varied from 12 to 29 for copper, 39 to 136 for Zinc, 0.4 to 6 for cadmium and 0.8 to 7.3 for lead. It was further observed that the accumulation of all the heavy metal was higher in spinach compared to lady's finger. In the same year Pandey also worked on accumulation of heavy metals (Cd, Cr, Cu, Ni and Zn) in Radish and Spinach vegetable irrigated with industrial effluent and the results showed the high accumulation of Cr, 302.0; Cu, 81.2; Ni, 155.1 and Zn 146.8 µg g-1 dry weight in spinach. Similar work done was done by L.R. Varalakshmi and A.N. Ganeshamurthy in Bangaluru.

N. Gupta et al. (2012) studied the magnitude of contamination of vegetables (Cauliflower Spinach, Coriander, Parsley, Radish and Pudina) with heavy metals (Pb, Cd, Cr, Cu and Zn) was determined in a long term wastewater-irrigated agricultural land. Among all the vegetables of sewage-irrigated study area, highest contamination of Pb (51.78 mg/kg) in radish followed by Spinach (47.69mg/kg) and Cauliflower (29.69mg/kg). Maximum Zinc was found in Spinach (148.04mg/kg) and the lowest value Cauliflower. The accumulation of cadmium is highest in spinach, (12.46mg/kg) in cauliflower, highest level of chromium in spinach (95.79mg/kg). The level of copper and nickel are highest in spinach. Of all the examined vegetables, Zn showed high and Cd showed low concentration in all the vegetables. In similar year S. Singh et al. worked on heavy metals accumulation and distribution pattern in different vegetable crops. Metal accumulation in edible parts and whole plants, root vegetables namely, radish and carrot registered lower accumulation of almost all heavy metals except Zn in radish root. However, leafy vegetables namely, spinach, amaranthus, mustard and fenugreek recorded higher accumulation of both essential and non-essential heavy metals. Cauliflower and cabbage, however, showed greater accumulation of Pb and Ni, but less accumulation of Cu and Cd.

Hassan Taghipour and Mohammad Mosaferi (2013) analysed heavy metal (Cd, Cr, Cu, Ni, Pb and Zn) in vegetables including kurrat, onion and tomato. The result show that the average mean of Cd, Cu, Cr, Ni and Zn

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concentration are 0.32 ± 0.58, 28.86 ± 28.79, 1.75 ± 2.05, 6.37± 5.61 and 58.01 ± 27.45. Cr, Cu and Zn were present in all the vegetables. In Nasik city, Maharashtra, Kailas R. Labhade (2013) detected the concentration of lead, cadmium, arsenic and copper from randomly collected samples of coriander, spinach, onion,cauliflower , brinjal, cabbage, tomato ,cucumber, potato and carrot form four different sites . Lead concentration ranges from 1.60 to 9.70 ppm for Nashik industrial area and 1.90 to 7.10 ppm for Sinnar industrial area Cadmium concentration in two out of ten samples collected from Nandur has recorded higher than the permissible limits of 1.5 µg/g. 30% vegetable sample collected from Nashik and Sinnar industrial area recorded cadmium concentration higher than the permissible limit. Concentration ranges from 0.60 to 3.30 ppm for Nashik industrial area and 0.80 to 2.20 ppm for Sinnar industrial area. Copper concentration of most of vegetable sample was within permissible limit. Only two out of 40 samples showed copper concentration above permissible limit. Concentration ranges from 4.90 to 30.80 ppm for Nashik industrial area, 6.30 to 14.20 ppm for Sinnar industrial area, 3.10 to 15.20 ppm for Nandur village and 2.20 to 7.10 ppm for Dindori. Arsenic concentration in all sample collected from Dindori and 90% sample collected from Nandur were within safe limit. Similarly in Raipur city, India, S.Gupta investigated the concentrations of copper, chromium, zinc, and lead in the most frequently consumed vegetables including Pimpinella anisum, Spinacia oleracea, Amaranthus viridis, Coriandrum sativum, and Trigonella foenum graecum in various sites. Heavy metals in vegetables in the order of Cr > Zn > Cu > Pb. Similar work was done by Jaydev and E.T. Puttaih at Banglore city on green leafy vegetable and Preeti Parashar et al. at Agra city.

E. Swapna Priya et al. (2014) was investigated heavy metal contaminations in three leafy vegetables viz., Palak , Thotakura (Amaranthus) and Chukkakura , soil and water of Musi River. Results showed that, leafy vegetable Chukkakura had the highest metal accumulation (801.78 mg kg-1) followed by Palak (550.97 mg kg-1) and Thotakura (493.34 mg kg-1). In the similar year Osama Sarwar Khan conducted the heavy metals accumulation in vegetables imported from India and compared with same vegetables collected from vegetable market in Pakistan. Green chili, capsicum, tomato and ginger were selected to analyze their heavy metal concentration. Maximum concentration of heavy metals detected by dry ash method in Indian vegetables Cu (0.34ppm) in capsicum, Cd (0.0ppm) in capsicum, Cr (0.22ppm) in Ginger, Pb (0.22ppm) in ginger and Ni (0.14ppm) in ginger while in Pakistani vegetables, it were of Cu (0.62ppm) in Tomato, Cd (0.04ppm) in Capsicum, Cr (0.17ppm) in Tomato, Pb (0.36ppm) in Ginger. Heavy metal contents determined by wet digestion method Cu (0.57ppm) in Ginger, Cd (0.01ppm) in capsicum, Cr (0.17ppm) in Ginger, Pb (0.27ppm) in capsicum while in Pakistani vegetables these were of Cu (0.19ppm) in Ginger, Cd (0.04ppm) in green chili, Cr (0.09ppm) in Tomato, Pb (0.25ppm) in Ginger.

Jaishree and T.I. Khan (2015) studied the concentration of heavy metals in crops and vegetables (Carrot, Tomato, Wheat, Brinjal, and Barley) irrigated with effluent from textile and tanning industries in Jaipur district. The range of various metals present in the effluent irrigated plants varied from 8.537-14.372 mg/g in wheat, 8.234-15.271 mg/g in carrot,10.361-13.313mg/g in Brinjal, 4.024-8.234 mg/g in tomato and 7.234-15.23 mg/g in barley. Nickel and lead found highest and Cadmium and copper found lowest in crops and vegetables. In same year Asha Verma and Shilpi bhatiya determined heavy metal concentration and harmful effects of some edible vegetables around the area of Paricha Thermal Power Station in Jhansi (Uttar Pradesh India) in Fenu Greek, Cabbage, Cauliflower, Lady's Finger and Brinjal. The maximum concentration of Cu found in Brinjal is 22.412 µg/ g. The maximum concentration of Cr was found in Cauliflower as 7.881 µg/ g and the value of Cd was found to be < 0.05 µg/ g in all samples.

Charu Jhamaria et al. (2015) estimated the accumulation of heavy metals (Pb, Cd, Cr and Ni) in vegetables spinach, tomato, lady finger and brinjal due to wastewater irrigation. In the study Cr was found to be highest (17.26 mg/Kg) in spinach followed by tomato (15.26 mg/kg), brinjal (5.1mg/kg) and lady finger (4.25 mg/Kg). Higher levels of Cr in spinach as compared to other studies at wastewater irrigated sites like (13.91 mg/kg) observed by Prabu (2009) at Ethoipia and (11.21 mg/Kg) at Agra by Kumar (2013).

In M.P, India, similar year R. Pandey and S. K. Pandey was investigated heavy metal accumulation in six commonly consumable vegetables Potato ,Tomato , Karela, Lady's finger, Brinjal ,Cabbage and area was rural with semi-urban areas and industrially growing areas. In industrial area Ni, Pb, Cu were reported in higher concentrations in tomato, Karela, Brinjal and cabbage whereas in semi urban area the range of Cu higher in tomato and Lady finger in comparison with the rural areas. In the similiar year, in Hyderabad, India, Gopi Naik Karamtothu et al. studied effect of levels of some heavy metals like Copper (Cu), cadmium (Cd), chromium (Cr) nickel (Ni), lead (Pb), Iron (Fe), Manganese (Mn) and zinc (Zn) contents of various vegetables Spinach ,Ladyfinger , pepper mint ,coriander , Tomato. The concentration ranges in mg/kg were (1.45 -2.55) for Cd, (3.10 to 4.92) Cr, (12.15- 20.50) Cu, (25.00-51.00) for Fe, (7.80 to 15.60) for Mn, (10.16 to 15.42) for Ni, (2.12 to 5.41) Pb and (16.58 to 24.08) for zinc.

In a study by the Usha kumari et al.(2016) in Ludhiana, Punjab the concentration of some heavy metals- Chromium(Cr), Zinc(Zn) , Copper(Cu), Cadmium(Cd), Nickel(Ni), and Lead(Pb) in vegetables (Cauliflower, Spinach, and Tomato). Pb and Zn had high transfer factors which are 6.77 and 6.25 respectively. Same year S. Ramteke et al. studied the risk on human health by heavy metals (Fe, As, Cr, Mn, Cu, Zn, Pb, Cd and Hg) through the intake of common vegetables i.e. tomato, brinjal, amaranthus , bathua, spinach and coriander obtained from the largest coal burning basin, Korba, India. The concentration of Fe, As, Cr, Mn, Cu, Zn, Cd, Pb and Hg in the soils (n = 6) ranged from 18,328 - 37,980, 85 - 105, 34 - 72, 314 - 760, 146 - 165, 126 - 164, 1.11 - 1.39, 116 - 148 and 0.11 - 0.21 mg/kg with mean value (p = 0.05) of 28,011 ± 6582, 96 ± 6, 57 ± 11, 597 ± 148, 153 ± 5, 145 ± 11, 1.26 ± 0.10, 133 ± 11 and 0.16 ± 0.03 mg/kg, respectively.

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3. Result and Discussion

The Result revealed that most of the researches showed that the heavy metal accumulation in many vegetable were higher than the permissible limit. Lead and Cadmium are among the most sever contaminant in all vegetables. Based on the review done the heavy metal concentration in different vegetables were found in order of Zn>Pd>Cu>Cd>Ni. Figure 1 shows average concentration of Heavy metal from the studied researches and their comparison with standard limits.

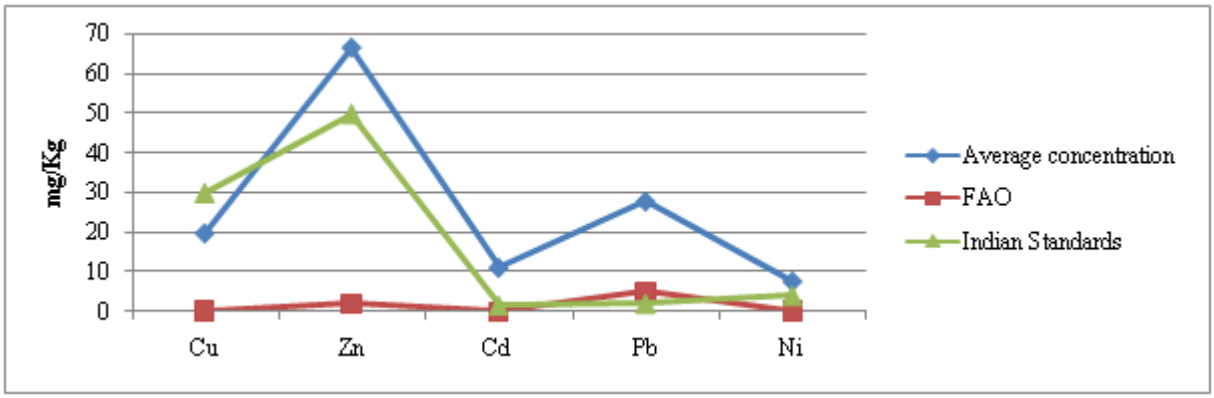

Figure 1: Comparison of Average Heavy metal content with standard limits. Sources: [1. Codex Alimentarius(1984); 2. Awasthi(2000); 3.Recommended max.conc. of trace metals for crop production1985]

Based on the reviewed researches average mean concentration of heavy metal in commonly used vegetables was calculated. Among the common vegetable species Spinach, Lady's Finger and Cauliflower accumulated high concentration of all the heavy metals and lowest accumulation was found in Tomato and Brinjal as shown in Table 1.

Table 1: Average mean concentration of heavy metal in commonly used vegetables (mg/Kg)

Vegetables	Pb	Cd	Zn	Cu	Ni
Spinach	15.075	5.089	78.32	26.27	76.03
Tomato	11.75	3.96	17.16	4.04	8.62
Brinjal	9.88	11.46	17.63	12.36	7.30
Lady's finger	15.23	1.83	59.57	25.66	8.66
Cauliflower	8.39	4.41	53.54	16.38	13.95

The order of heavy metal accumulation in vegetable is as followed: Spinach> Lady's Finger > Cauliflower > Brinjal > Tomato. From the results, it was found that the bioaccumulation of Zinc was high in almost all the vegetable. Spinach accumulated highest concentration of Nickle and lowest concentration of Cadmium. In tomato Lead was found to be highest accumulated metal and Cadmium the lowest accumulated metal. Copper was found to be highest in Brinjal, Lady's Finger and Cauliflower. Minimum accumulation of Nickle was found in Brinjal and Lady's Finger and minimum accumulation of cadmium was found in Cauliflower.

4. Suggestion

In this paper we reviewed the accumulation of the heavy metals in commonly found vegetables. As these vegetables are widely consumed by human, through these vegetable toxic elements can be transferred to human body creating disruption in various biological systems. Therefore, people consuming them are in high health risks of toxic metal exposure. It is therefore suggested that continuous monitoring of heavy metals in soil, water quality and vegetables should be done to prevent excessive build-up of these metals in the human food chain. Alternative options should be carried out in order to prevent excessive accumulation of heavy metals and all vegetables should be washed properly before consumption as washing can remove a significant amount of aerial contamination from the vegetable surface. To avoid the entrance of metals into the food chain, municipal or industrial waste should not be drained into rivers and farmlands without prior treatment and artificial chemical such as fertilizer and pesticides etc. should be avoided and used Bio-fertilizer should be encouraged.

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