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Uptake of Copper, Chromium, Lead and Cadmium by Leafy Vegetables grown in contaminated soils of Musi Embankment

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Abstract : *Leafy vegetables rich in essential nutrients, antioxidants, fibers and metabolites are commonly consumed in diet by human populations across the globe. In Hyderabad city, leafy vegetables Amaranthus and Rumex sp are usually grown on the embankments of the River Musi which is one of the grossly polluted water bodies by heavy metals. Leafy vegetables grown in such soils tend to accumulate metals in leaf surface due to their high translocation and transpiration rate. Prolonged consumption of leafy vegetables grown in metal contaminated soils pose cumulative deleterious health hazards to humans. Thus, we investigated the uptake of commonly occurring metals like copper, chromium, lead and cadmium in Amaranthus and Rumex sp and their rhizosphere samples. Samples collected from nearby organic farms served as controls, and the results are compared with FAO/WHO permissible limits for crops to evaluate their food safety. Inductively coupled spectrophotometer analysis results indicate that the metals in soils, Amaranthus sp and Rumex sp from organic farm are well within the FAO/WHO permissible limits. Although, the uptake of all metals studied is relatively high in the above samples from Musi embankment compared to control (organic farm samples), significant uptake of cadmium is ($p<0.05$) is observed in two species from both the ecosystems, while the uptake of cu is significant in Amaranthus ($p<0.05$), above the FAO/WHO permissible limits in Musi embankment. From this study, it is suggested that soils of Musi embankment contain toxic metals and their uptake is more in Amaranthus sp which may pose public health concerns.*

Keywords: *Heavy metals, Leafy vegetables, rhizosphere, Food safety*

I. Introduction

Rapid industrialization and unplanned urbanization results in insufficient land and water resources. Due to depletion of these natural resources, waste water from industries often containing heavy metals is being used for irrigation of vegetable crops in and around Hyderabad City, Telangana State (Swapna Priya et al. 2015). Due to their persistence and cumulative behavior, heavy metals concentrate through food chains and cause toxic effects to the human beings [1]. Although, toxicological implications of heavy metals were recognized much earlier, their assessment in soil rhizosphere and uptake in vegetables, leafy vegetables and fruits is one of the marginalized areas of research. Therefore, hyper-accumulation of metals in water and soil ecosystems needs serious attention [2]. Prolonged application of wastewater containing metals leads to the accumulation of metals in soil rhizosphere, and deterioration of soil quality [3].

In recent years, leafy vegetable consumption is increasing gradually, particularly among the urban community of India. Green leafy vegetables contain lots of vitamins and minerals, rich in fiber, iron, folic acid, vitamin C, vitamin K, potassium, magnesium, beta-carotene (vitamin A), antioxidants, etc. Moreover they are shown to reduce risk of cancer and heart diseases and increase the production of osteocalcin, a bone protein [4]. In view of their dietary significance, safety and quality are the most important aspects to be considered [5]. In Hyderabad city, leafy vegetables *Amaranthus* and *Rumex sp* are usually grown on the embankments of the River Musi which is one of the grossly polluted water bodies by heavy metals [6-7]. Leafy vegetables grown in such soils tend to accumulate metals in leaf surface due to high translocation and transpiration rates, and their prolonged consumption pose cumulative deleterious health hazards to humans.

In view of their wide consumption, we investigated the uptake of commonly occurring metals like copper, chromium, lead and cadmium in *Amaranthus* and *Rumex* sp and their rhizosphere samples, grown on the embankments of the River Musi. Samples collected from nearby organic farms served as controls, and the concentrations of heavy metals are compared with FAO/WHO permissible limits [8] for crops, to evaluate their food safety. The corresponding results are presented in this paper.

II. Materials And Methods

Soil samples from the rhizosphere and the edible leaves of two leafy vegetables, namely *Amaranthus* sp. and *Rumex* sp. were collected from the farms grown in the embankments of the Musi River (near Nalla cheruvu, Boduppal) Hyderabad, Telangana State and indicated by name 'Musi Bank' (MB). Soil and plant samples were also collected from leafy vegetables grown in organic farms of Venkateshwara Nagar village (about 27 km from Ibrahimpatnam, Hyderabad) in Nalgonda District, Telangana State served as control and indicated by 'Organic Farm' (OF).

Sample Collection:

Edible leaves and soil samples were collected in polyethylene bags, labeled accordingly and brought to the Department of Biotechnology laboratory at our institute for metal analysis. The leaves were washed with tap water and then with distilled water to remove dust and other impurities. Four top soil composite samples were collected in the study zone (2 from Musi bank and 2 from Organic farm) at a depth of 0-10 cm. One gram soil was taken into petriplates, separately and then oven dried at 80^0 C for 4-5 h, in order to remove all the water content present in the samples. Edible leaves are also treated similarly. The dry vegetable samples were powdered with a mortar and pestle and sieved through a sieve (pore size 2 mm) to bring them to uniform size. The samples were then kept at room temperature for further analysis.

Sample Preparation for Metal Analysis

To 1 gram of the each sample 6 ml of the acid mixture, HCl: HNO_3 (1:3) was added and the volume was raised to 25 ml with double distilled water. The solution was then kept for digestion and the mixture was heated to boiling point on an electric plate heater until the formation of nitrous fumes had stopped. Digestion was stopped when sample solution reduced to nearly 12.5 ml. The cooled samples were then filtered through Whattman no.42 filter paper and the volume of filtrate was made up to 100 ml with 5% HNO_3. All the samples were subsequently analyzed with inductively coupled plasma spectrophotometer (Thermo). The concentration of all the metals is expressed in mg kg^{-1} in dry weight. All the values expressed are mean of three replicates and unpaired Student's 't'test is conducted to test the level of significance of the differences between the means of samples collected from organic farm and musi bank.

III. Results And Discussion

Inductively coupled spectrophotometer analysis results indicate that the metals in *Amaranthus* sp and Rumex sp are in the order Cu (0.12 mg $kg\text{-}^1$)>Cr (0.08 mg $kg\text{-}^1$) >Pb (0.06 mg $kg\text{-}^1$) > Cd (0.03 mg $kg\text{-}^1$) and Cu (0.13 mg $kg\text{-}^1$)>Pb (0.07 mg $kg\text{-}^1$) Cr (0.06 mg $kg\text{-}^1$)> Cd (0.04 mg $kg\text{-}^1$), respectively, from organic farm and well within the FAO/WHO permissible limits for crops (Table 1). Inductively coupled spectrophotometer analysis results indicate that the metals in soils, Amaranthus sp and Rumex sp from organic farm are well within the FAO/WHO permissible limits. Although, the uptake of all metals studied is relatively high in the above samples from Musi embankment in the order of Cr(0.32 mg $kg\text{-}^1$)>Cu (0.31 mg $kg\text{-}^1$)>Pb (0.23 mg $kg\text{-}^1$)>Cd (0.22 mg $kg\text{-}^1$) and Cu (0.26 mg $kg\text{-}^1$)>Cr (0.25 mg $kg\text{-}^1$)>Cd (0.19 mg $kg\text{-}^1$), Pb (0.14 mg $kg\text{-}^1$),compared to control (organic farm samples), significant uptake of cadmium is ($p<0.05$) is observed in two species from both the ecosystems, while the uptake of cu is significant in Amaranthus ($p<0.05$), above the FAO/WHO permissible limits in Musi embankment. In light of the above results and WHO limits for heavy metals in food, the food safety of leafy vegetables is discussed with respect to toxicological effects of copper, chromium, lead and cadmium to humans hereunder.

In the present study, copper in soil samples from the rhizosphere in organic farm (control) and Musi embankment was 0.15 and 53 mg $kg\text{-}^1$ against the FAO/WHO limit of 40 mg $kg\text{-}^1$. The results show that copper accumulation in soil samples is above the permissible limits in Musi embankment which is a polluted area compared to organic farm. Copper exhibits redox potential and generates excessive free radicals leading to accumulation of O^{2-} and H_2O_2. Copper is also found in many superoxide dismutases' that detoxify superoxides to oxygen and hydrogen peroxide. However, excess concentrations of copper inhibit antioxidant enzymes [9]. While it is generally agreed that copper is not a cumulative toxic hazard to humans, it is possible that the metal could induce alterations in the antioxidant enzymes as a function of time. Research indicates that copper is not a carcinogenic metal to either animals or humans. In general, copper does not appear to be a cumulative toxic hazard for man, and an oral dose of about 200 mg/kg body weight is generally considered fatal in humans. Chromium levels observed in the current study were high in soil and plant samples collected from Musi embankment with respect to FAO/WHO permissible limits (Table 1) compared to samples from organic farm and plants grown in Musi embankment. These high levels could pose cumulative deleterious health effects to humans in the long run.

Lead is very much below the FAO/WHO limits which may be attributed to the location of these farms. According to an earlier study of Afolami et al [10], population/vehicular density usually commensurate with lead pollution. Lead is one of the most cumulative metals which can enter into the body system through air, water and food and cannot be simply removed by washing fruits and vegetables. Earlier research also reported higher concentration of lead in some plants due to contamination by pollutants in irrigation water, farm soil or due to pollution from the highways traffic [11]. For instance, cabbage accumulated higher lead concentrations compared to Pumpkin leaves from Mazimbu and Towelo in China [12]. In contrast, lower level of lead has been reported with Telfaria by Akinola and Ekiyoyo [13]. It is understandable that the site of growth significantly influences the uptake of heavy metal by vegetables. According to FAO/WHO, the safe limit for cd consumption in vegetables is 0.01 mg/kg. In the present study, cadmium concentration in soil sample from organic farm is within the permissible limits whereas it is 0.33 mg kg^{-1} against the permissible limit of 0.30 mg kg^{-1} which is insignificant. In contrary, cadmium reported in leafy vegetable crop samples is significantly above the permissible levels by FAO/WHO. Cadmium is a highly toxic and non-essential element in foods and natural waters and it concentrates preferentially in the kidneys and liver [14]. Its presence in foods could be due to multiple sources of environmental contamination [15]. Various values 0.090 mg/kg and 0.049 mg/kg for fluted pumpkin have been previously reported for leafy vegetables [16-17].

As leafy vegetables tend to accumulate cadmium in stem and leaves (edible parts) of the plants, it is imperative that such plants should not be cultivated in farms and fields irrigated by urban and industrial waste water that contains heavy metals. Therefore, to reduce the public health risk, prior treatment of sewage/industrial wastes becomes mandatory. Moreover, regular monitoring of heavy metals in the vegetables grown in wastewater irrigated areas is also necessary. It is essential that the farmers be educated and encouraged to take up organic farming which avoids use of synthetic fertilizers /pesticides that contain heavy metals.

IV. Conclusion

Prolonged consumption of leafy vegetables grown in Musi embankment may pose cumulative deleterious health hazards to humans. The results of the present study indicate that the metals in Amaranthus sp and Rumex sp are very much within the FAO/WHO permissible limits from organic farm. On the other hand, Amaranthus sp and Rumex sp samples from Musi embankment have shown the concentration in the order of Cr>Cu>Pb>Cd and Cu>Cr>Pb>Cd, respectively, which are above the WHO permissible limits and not safe for human consumption. Of the two vegetables evaluated, Amaranthus sp demonstrated a tendency to accumulate more toxic metals than Rumex sp.

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Table 1: Heavy metals in soil and leafy vegetables grown in Organic farm (OF) and Musi Bank (MB)

Metal	Permissible levels by FAO/WHO		Organic Farm (OF) (mg kg^{-1})			Musi Bank (MB) (mg kg^{-1})		
	Soil	Crop	**Soil**	***Amaranthus sp***	***Rumex sp***	**Soil**	***Amaranthus sp***	***Rumex sp***
Pb	5.0	5.0	0.12 ±0.68	0.06 ±0.02	0.07±0.05	0.34 ±0.12	0.23 ± 0.09	0.14 ± 0.80
Cu	40	0.20	0.15 ± 0.25	0.12 ± 0.67	0.13 ±0.09	53 ±1.24	0.31 ± 0.10	0.26 ± 0.76
Cd	0.30	0.01	0.06 ± 0.39	0.03 ± 0.02	0.04±0.03	0.33 ±0.09	0.22 ± 0.13	0.19 ± 0.11
Cr	2.3	0.20	0.09 ± 0.87	0.08 ± 0.05	0.06±0.04	0.37 ±0.15	0.32 ± 0.15	0.25 ± 0.09

Source: FAO (1985) and WHO (1996). All the results expressed are mean of three values

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