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A Comparative Analysis of Trace Metals in Vegetables

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ABSTRACT

The aim of this study is to assess the impact of heavy metal contaminated vegetables irrigated with polluted untreated effluent water from the sewage in Vinayakiya Nallah region of Jodhpur district. Samples of cabbage, radish and chandaliya have been analyzed for six different heavy metals viz. lead, cadmium, copper, nickel, zinc and iron. Twelve samples from each study site were taken for each vegetable and then analyzed and compared with those of natural limits and the safe limits of various agencies. It is found that concentration of each metal exceeded the natural limits in all vegetable samples. Extreme lead pollution was observed in Radish leaves whereas all are severely contaminated with cadmium toxicity. But the levels of metals are below the levels in waste water. Except the lead and cadmium all the other metals are present below the safe limits of WHO/ML. But they all exceeded the limits of FAO. Thus consumption of such vegetables by community can bring about worst health risks in near future. Sewage water treatment and metal extraction from polluted environment could reduce the health hazards.

Key words: Vinayakiya nallah, vegetables, waste water, water treatment, health hazards

INTRODUCTION

Vegetables are an important ingredient of human diet that contains essential nutrients and trace elements (Abdullah and Chmielnicka, 1990). Environmental pollution has caused the contamination of soil; on the other hand waste water irrigation resulted in the significant mixing of the heavy metal content of the agricultural land (Mapanda *et al.*, 2005). The chief cause is the waterways through which heavy metals are leached out of the soil and are taken by the vegetation. If plants decay, these toxic metals are redistributed and as a consequence their enrichment in the agricultural soil occurs. Bioaccumulation, geoaccumulation and biomagnifications may result because of entrance of these heavy metals to the ecosystem. Thus long term waste water irrigation leads to build up of heavy metals in soils and food crops (Khan *et al.*, 2008). Rapid industrialization and urbanization with insufficient environmental monitoring planning often results in discharging of the industrial and sewage waste into rivers and lakes which lead to gradual pollution of our water resources. Many times such wastewater is drained to the agricultural land where this polluted water is used for irrigating crops including vegetables. Thus polluted effluent water is found to be rich not only in organic water and nutrient and but also in heavy metals like lead, chromium, cadmium, nickel, cobalt etc that finally reach to the soil of agricultural area and leads to food chain contamination as crops and vegetables absorb them from the soil. Heavy metals are not easily biodegradable and it leads to their accumulation in human vital organs causing varying degree of illness on acute and chronic exposure (Ward *et al.*, 1995).

Leafy vegetables accumulate higher metal contents than others (Al Jassir *et al.*, 2005). The levels of heavy metals like lead, cadmium, zinc, chromium, iron, nickel etc., were examined in selected fruits and vegetables sold in local markets of Egypt (Radwan and Salama, 2006). Water, soil and crop plants have been analyzed for six heavy metals viz. Fe, Zn, Cu, Ni, Pb and Cd using AAS in area affected by polluted Bellandur Lake in Bangalore (Lokeshwari and Chandrappa, 2006). Research findings show that at least 20 million hectare of land in North and South Africa, South America, Middle East, Southern Europe, South West America, Mexico and a significant part of Central and East Asia is irrigated with untreated sewage chiefly for cultivating vegetables (Carr, 2005; Dayle, 1998). In India such studies have been done in Delhi where levels and source of heavy metals contamination along with their impact on local livelihoods have been studied by Marshall *et al.* (2003) (Executive summary to technical reports). Special focus was made on Palak/Spinach beet. Presence of trace metals was determined quantitatively in onion leaves irrigated with polluted waste water (Abdullahi *et al.*, 2009, 2008). Accumulation of toxic heavy metals in vegetables irrigated with waste water was studied (Cheraghi *et al.*, 2009) and it was found that metal concentration was many fold higher than vegetables grown in controlled area. Edem *et al.* (2009) found that concentration of Fe, Mn, Pb and Cr were highest in leaves. Copper accumulation was highest in the stem while roots had higher concentration of Zn. Six hundred samples of raw vegetables were analized and (Jawad, 2010) heavy metal concentration were found to be lower than maximum acceptable concentration for human consumption. A study on the fruits vegetables was done (Khairiah *et al.*, 2004) and Zn content was found higher in long beans than in chilies. Municipal waste water had higher amount of Mn, Fe and Cr compared to well water (Tabari *et al.*, 2008) and soil, irrigation water and leaves were analyzed and found to be severely contaminated. Study was done (Eslami *et al.*, 2007) on the investigation of heavy metal concentration in roots and leaves of radish, leek, sweet basil and parsley. Some of them contaminated high levels beyond the levels given by FAO and WHO for human consumption. Concentration of Cu, Pb and Zn were investigated in five leafy vegetables species. Both unwashed and washed leaves showed the highest amount of heavy metals in the Urban Area.

More than 80% of sewage water is discharged untreated into the environment (Drechsel and Alexandra, 2010). Consumption of waste water irrigated agricultural products puts consumers to health risks (Karanja *et al.*, 2010). In India even Holy River Ganga has been severely polluted with heavy metals (Pandey *et al.*, 2010). Risk of cadmium and lead ingestion to the population of the Uganda Capital located close to lake Victoria has been exposed (Jolocam *et al.*, 2010). It has been reported that sewage effluents contain significant amount of major essential plant nutrients and thus fertility levels of soil are increased under sewage irrigation of crops like cabbage, radish, cauliflower, spinach, etc. However studies of raw sewage irrigated crops (cabbage, radish and chandaliya) in Jodhpur district revealed that presence of toxic metals like lead, chromium, cadmium, nickel, iron, zinc, copper etc. reduces soil fertility and agricultural out puts.

Therefore, present study has been undertaken to assess the extent of trace heavy metal contamination in leafy vegetables viz., cabbage, radish and chandaliya grown under sewage irrigated water in various fields of Vinayakiya region of Jodhpur district. In this region municipal waste water of Jodhpur city flows through Nallahs (local name-Vinayakiya Nallah). A large number of crops are grown here in various farms lying besides these drains. Besides the leaching of pollutant through soil, farmers of this region irrigate crop plants using untreated waste water directly. So study of metal contamination of vegetable crops is strongly needed as no such study has been done here till date. Present study has also been done to investigate the uptake of heavy metals in crop plants to establish the advice regarding their consumption and to analyze their comparative accumulation in different vegetables grown in the fields of above mentioned site.

MATERIALS AND METHODS

Collection of samples: Samples of vegetables were randomly collected from the fields irrigated with untreated effluent water during 2009 in vicinity of Vinayakiya Nallah region of Jodhpur district. Leafy vegetables are preferred as they accumulate heavy metals in greater capacity than other vegetables. Twelve samples of each vegetable are collected from both study and controlled sites.

Pretreatment: All glass wares and containers required for experimentations were first washed with distilled water followed by soaking in 10% nitric acid for few hours. Thus it was ensured that no contamination occurred in them. The collected vegetable samples were washed with distilled water to remove dust particles. Samples were then cut into pieces of uniform size and then air dried. Air dried samples then placed in dehydrator for 2-3 days and then oven dried at 100°C. Now these dried samples of vegetables were ground into fine powder using blender and stored in polyethylene bags until for acid digestion.

Preparation of samples: The 0.5 g of well homogenized sample was weighed into a clean silica dish and 0.5 mL of 20% sulphuric acid was added. Through mixing of wet samples was done and stirring rod was rinsed with water into clean silica dish. Content of the dish was dried in an oven at 110°C. Then it was heated over a soft flame until all volatile matter was removed. Now the dish was transferred to furnace set at 250°C and temperature was raised slowly to 500°C for about 6 to 8 h. If the ash was not carbon free, 0.5 mL of nitric acid was added and dish was returned to the furnace at 500°C and ashing was done for about 30 min. It was done triplicate. Now 1 mL of nitric acid and 10 mL of water was added to the clean ash and the mixture was heated till the ash was dissolved. The content was qualitatively transferred to a 50 mL volumetric flask. Dish was heated with 10 mol of hydrochloric acid (1+1) and solution was transferred again to the same volumetric flask to volume with water.

Sample blank solutions were prepared using the same procedure described for the samples. Same quantities of reagents including water were used for sample and blank. All chemicals used were of analytical grade. The 1000 ppm stock solution of each of the metal ion was prepared and required dilutions were made for the purpose of calibration curves. Both sample and blank solutions were analyzed on AAS and concentrations of all metals were determined (MMAF, 2005).

RESULTS

The required standard conditions for AAS (Atomic Absorption Spectrophotometer) have been given in Table 1. Levels of six metals viz., Cu, Cd, Pb, Fe, Zn and Ni found in waste water of Vinayakiya Nallah region is given in Table 2. Analysis revealed that this water is highly contaminated with toxic metals that are hazardous to health. It was clearly seen that almost all the metals were found in greater amounts than the maximum safe limits given by FAO/WHO (Codex Alimentarius Commission, 2001) however concentration of copper, zinc and nickel is under the maximum permissible limits of WHO/ML of waste water irrigation. Rest of these, all the other metals exceeded the limit. Metal concentration is also higher than safe limits given by FAO (1985). The chief source of these toxic metals is the discharge from industries and domestic waste into

Table 1: Standard conditions for AAS: Atomic Absorption Spectrophotometer

Elements	λ (nm)
Cu	324.8
Pb	217.0
Zn	228.8
Cd	248.3
Fe	309.3
Ni	232.0

Source: MMAF (2005)

Table 2: Various safe limits of trace metals in vegetables

Safe limits	Cu	Pb	Zn	Cd	Fe	Ni
FAO/WHO (mg kg^{-1}) Codex Alimentarius Commission (1984)	40.00	5.00	0.60	0.30	-	-
FAO (mg L^{-1}) recommended max. conc. Of trace elements for crop production (1985)	0.20	5.00	2.0	0.01	5.00	0.20
WHO/ML (mg kg^{-1}) Under waste water irrigation	73.00	0.30	100.0	0.10	425.00	67.00
Mean heavy metal content (mg kg^{-1}) of waste water samples taken from affected area	58.45	21.72	125.19	34.68	1873.68	63.94

Source: FAO (1985) and WHO (1996)

sewage. It is natural, but when such waste water is used for the irrigation purpose, the problem becomes severe. The effluent water of Jodhpur city is discharged through these nallahs to the open fields where the selfish farmers store such water into large tanks by pumping it directly through open Nallah and use it for irrigating crops without proper treatment instead of using fresh water to make their money. Unfortunately toxic metals through this wastewater are taken up by the soil and growing crops as well. Though such water is generally rich in organic content that are seemed to be beneficial to the plants but severe contamination of it with toxic metals reduce its utility. Such metals badly contaminate the entire food chain.

Levels of different metal in vegetables are given in Fig. 1a-f. Almost in all of them metal concentration exceeded the safe limits. The various safe limits have been given in Table 2. Such vegetables should not be consumed at all.

DISCUSSION

It has been seen that concentration of copper in vegetables is below the limit of WHO/ML and FAO/WHO but above the maximum safe level of 0.20 mg kg^{-1} given by FAO. Copper toxicity was studied by Yang *et al*. (2002) and was found that root and shoots both showed increased levels of copper. Similarly, Xiong and Wang (2005) studied that copper concentration in shoots increased with increase in its concentration in soil. Thus the above mentioned leafy vegetables were found to be contaminated with copper and are toxic to consumers.

The lead accumulation in vegetables was found to be in the range of 2.32-5.76 mg kg^{-1} and almost in the limits of WHO/FAO but exceeded to much the maximum limits of WHO/ML (0.30 mg kg^{-1}) and China (0.20 mg kg^{-1}) (Chinese Department of Preventive Medicines, 1994). Undoubtedly consumption of these leafy vegetables grown in this region must be prohibited. Sometimes uptake of lead can exceed several hundred times the permissible limits for human (Wierzbicka, 1995). Thus there is a need to develop awareness in the local livelihood to not consume such contaminated vegetables.

Though the Zinc accumulation was below the limit of WHO/ML in vegetables but it exceeded the safe limits of both FAO/WHO and FAO. Maximum level of zinc tolerance for human health is

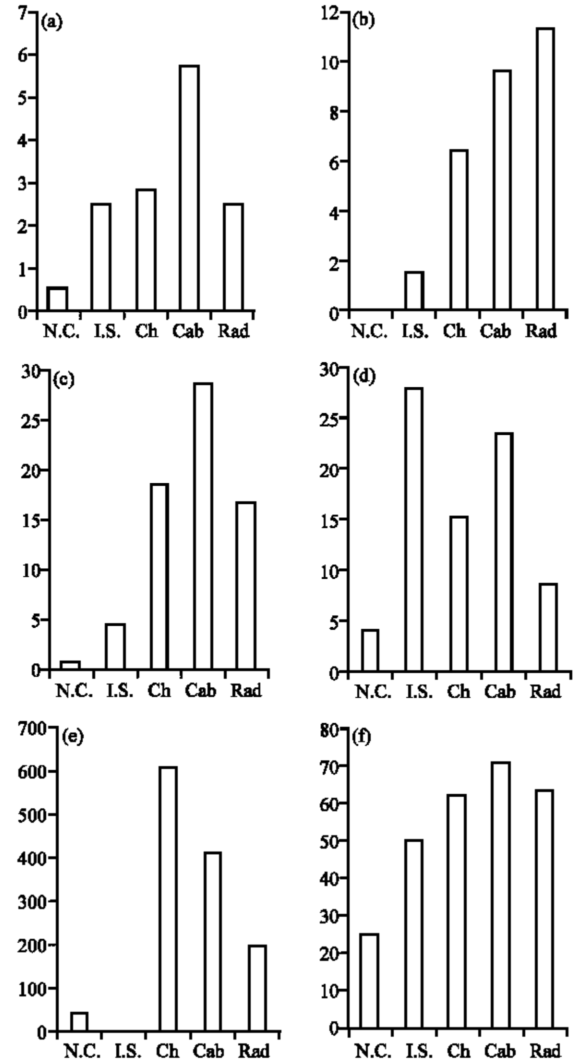

Fig. 1: Comparison of individual metal; (a) Lead, (b) Cadmium, (c) Nickel, (d) Copper, (e) Iron and (f) Zinc concentration in vegetables. N.C: Natural Concentration, I.S: Indian Standard, Ch: Chandaliya, Cab: Cabbage, Rad: Radish

20 mg kg^{-1} according to Chinese Department of Preventive Medicine (1995). Concentration of zinc was found in order: cabbage>radish>mint. The acute exposure of zinc can cause tachycardia, vascular shock, dyspeptic nausea, vomiting, pancreatic disorder, diarrhea and damage of hepatic parenchyma (Salgueiro *et al*., 2000).

Vegetable were severely contaminated with cadmium toxicity as the level is far greater than the safe limits. The consumers must be prevented from their use. The order of accumulation of cadmium: cabbage<radish<chandaliya. It has been reported that cadmium is highly mobile metal and can be easily absorbed by the plants areal parts. A relation between levels of cadmium in roots zone and its absorption was shown by Gardiner *et al*. (1995) and Rarnos *et al*. (2002). Torabian and Mahjouri (2002) found lead accumulation in the order: spinach<radish<coriander<mint.

Figure 1 gives comparative amount of iron uptake in the three vegetables and it is maximum in Chandaliya. Concentration of iron in cabbage and radish was found to be greater than the safe limits given by WHO/ML whereas in chandaliya the level is in the limit.

Levels of nickel in all of the vegetables were found to be below the safe limits of WHO/ML. The concentration of different metals in vegetable samples has been compared with natural concentration and Indian standards in Fig. 1a-f. It was seen that levels of each of metal in vegetables were many folds higher than the natural concentration and Indian standards. Overall results on comparison showed that metals in irrigation water cause a severe impact on vegetation and such vegetables should not be consumed at all.

CONCLUSION

The study reveals that untreated sewage water is the main cause of soil pollution in Vinayakiya region that lead to the increase in levels of toxic metal concentrations in the leafy vegetables grown in the fields of this area. Level of metals in vegetables will provide a base for extensive sampling and quantification of data in future. One more conclusion can be drawn from the study that as leaves are generally rich in heavy metal accumulation, it is recommended to not to grow such vegetables in farms and fields irrigated with sewage water or water contaminated by heavy metals.

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