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Monitoring of Heavy Metal Contamination in Dietary Vegetables

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ABSTRACT
Reports of increasing concentrations of heavy metals in vegetables are currently a major cause of concern for human health. The samples of cauliflower and spinach were collected from different locations such as kitchen garden and local vegetable markets in Delhi. These vegetables were tested for the presence of heavy metals (Pb, Cu, Cr and Zn). Analysis was carried out using washed and unwashed samples. The concentrations of these metals were determined using Atomic Absorption Spectrophotometer. The unwashed samples showed higher concentrations of heavy metals in comparison to washed samples. Specifically, the concentrations of Cu and Cr were much higher in the vegetables procured from areas which were irrigated with polluted water as compared to vegetables grown in kitchen garden. These findings highlight the need to educate farmers on the implications of their current agricultural practices.

Key words: Heavy metals, Vegetables, Yamuna river, pollution

INTRODUCTION

Industrialization in urban areas has lead to environmental pollution which has resulted in undesirable changes in the atmosphere, hydrosphere and lithosphere. Emissions from industries, vehicles and rampant use of pesticides for the growth of crops have polluted water bodies, soil and air. Fresh vegetables and fruits, which contain carbohydrates, proteins and minerals, constitute our daily diet necessary for a healthy body. The polluted water bodies and soil cause contamination of the biomass of vegetables with heavy metals. Heavy metals can also get deposited on the surface of vegetable from atmosphere or they may be absorbed by the roots of crop plants from the soil and get deposited on the plant tissues. Although vegetable surface can be washed to remove contaminants but it is not possible to remove absorbed heavy metals. Consumption of vegetables contaminated with heavy metals over a long period of time can adversely affect the functioning of various organs in the human body. Human health is, thus, at great risk. Several reports have been published regarding heavy metals in vegetables in different countries for the awareness of general public. Yusuf and Oluwole (2009) reported high concentrations of heavy metals in vegetables in urban areas and demonstrated that washing of vegetables reduced some of the heavy metal contaminations. Maleki and Zarasvand (2008) observed high degree of heavy metals contamination in vegetables cultivated around urban area. Singh and Singh (2014) demonstrated that Pb in spinach was 5.5 mg Kg^{-1} dry weight, Cd was 0.3 mg Kg^{-1} dry weight and Cu was 0.03 mg Kg^{-1} dry weight.

Reports indicate increasing cases of cancer and other life threatening diseases in India. To overcome these problems one should be aware of the causes of all these diseases. Present work carries significance because of the reported prevalence of heavy metal contamination of vegetables and their ill effects on human beings upon consumption. In industries, cadmium is obtained as a by-product from the extraction of zinc, lead and copper. Lead is present in drinking water and is used in paints, pigments, plastic in lead acid batteries and in making alloys, etc. (Jaishankar et al. 2014). Most of the irrigation in Delhi region is done using Yamuna water. It is a well-known fact that the Yamuna water is highly polluted. Delhi, Agra and Mathura are the major cities contributing towards pollution in river Yamuna (Mishra 2010). This pollution is caused by dumping of garbage, untreated sewage and effluents from industries. Further deterioration is happening due to over abstraction of water resulting in higher accumulation of heavy metals in Yamuna water. Cheap paints used for making idols contain high concentrations of Pb and Cr which get merged in the river during festivals, causing heavy metal pollution in the river (Kaur and Mehra 2012). Agriculture

runoff, dumping of dead bodies, cattle washing, poor sanitation by citizens are few more causes leading to biological pollution in NCR. Malik et al. (2014) showed that industrial pollution in Yamuna river is much above the limits set by various pollution controlling agencies. Keeping in view the earlier reports and considering the ill effects of heavy metals in vegetables, present investigation was undertaken. In this work, we are reporting the concentration of heavy metals (Cr, Cu, Pb and Zn) in two selected vegetables (Spinach and Cauliflower) collected from the farms around Yamuna river, kitchen garden and vegetable market. The work also assesses the amount of heavy metals from these vegetables which are loosely bonded and, therefore, removable upon washing.

MATERIALS AND METHODS

Sample collection

Kitchen garden samples were collected from the residential complex of Gargi College, Delhi University. Market samples were obtained from Okhla Mandi, New Delhi. Polluted area samples were obtained from the farm on Yamuna bed downstream of Wazirabad barrage. Washing of vegetables refers to once washing with tap water followed by twice washing with distilled water.

Qualitative analysis

Samples were oven-dried at 60^0C and were ground using a pestle mortar. Heavy metal analysis of these samples was carried out by using semi-micro kit. Presence of Cu was tested by precipitating it first as CuS and then treating with ammonia, followed by potassium ferricyanide solution .Cr was tested with H_2O_2. Zn was tested as its hydroxide by reacting it with potassium ferricyanide solution and testing of Pb was done with KI solution.

Analytical methods

One portion of each vegetable sample was washed and the other was kept unwashed. Samples of cauliflower and spinach were oven-dried at 60^0C to a constant weight. Each oven-dried sample was ground using a pestle-mortar and sieved through muslin cloth. To 1g each of these dried samples, 12 ml of conc. HNO_3 was added in a Kjeldahl flask and samples were kept overnight for pre-digestion. After pre-digestion, each Kjeldahl flask was heated on a sand bath till the whole of the nitric acid got evaporated. Then 4 ml of perchloric acid was added to the residue and digestion was continued till a white residue was obtained. To the residue, a mixture of HCl and water (1:1) was added. The mixture was filtered using 0.45 μm pore size cellulose nitrate membrane. Final volume was made up to 50 ml with distilled water. These samples were analyzed by Flame Atomic Absorption Spectrophotometer, using acetylene-air mixture. The results were compared with the permissibility levels set by WHO/FAO.

RESULTS AND DISCUSSION

The mean concentration of heavy metals (mg Kg^{-1} dry wt.) detected in the vegetable samples obtained from various sources from Delhi are given in Tables 1 and 2. Lead was detected only in unwashed market samples. This is probably due to the vehicular dust deposition on these vegetables spread in the market. Zinc is an essential nutrient and this was found in sufficient quantities in all samples. Minor reduction of the content of Zn in all the samples indicates that this element is accumulated mainly in the tissue during the crop growth and not coming from the pollutant deposition. However, both copper and chromium showed significant reduction after washing which indicates that though these metals are accumulated in the tissue during the crop growth, also get deposited due to their presence in the atmospheric pollution. High concentrations of heavy metals in vegetables in urban areas have also been reported earlier and washing of vegetables reduced some of the heavy metal contamination. Data summarized in Table 3 provides information on the heavy metal contents of various vegetables and other crops growing in different regions reported earlier.

The present work indicates that vegetables available in Delhi and NCR do contain heavy metals but their amounts are within the permissible limit set by WHO. Further, it was observed that washing of vegetables reduces the concentration of heavy metals. The leafy vegetables grown in a polluted area had higher content of chromium. Low content of Cu and Zn in the market samples of the cauliflower is perhaps these plants are being irrigated with water

Table 1. Selected heavy metal content (mg Kg^{-1} dry wt.) in the samples of Cauliflower

Element	Kitchen Garden		Market		Polluted Area		Limit*
	Un washed	Washed	Unwashed	Washed	Unwashed	Washed	
Pb	BDL	BDL	0.125±0.004	BDL	BDL	BDL	2
Cu	2.091 ±0.028	2.072±0.032	0.741±0.011	0.0807±0 .058	2.018±0.038	1.948±0.014	10
Cr	0.694±0.008	0.487±0.005	BDL	BDL	0.575±0.007	0.443±0.012	1.3
Zn	3.945±0.003	3.705±0.01	1.339±0 .03	0.031±0.003	3.190±0.003	3.095±0.015	5

BDL- Below detechable limits; *Source: WHO (1989) recommended maximum limits

Table 2. Selected heavy metal content (mg Kg^{-1} dry wt.) in the samples of Spinach

Element	Kitchen Garden		Market		Polluted Area		Limit*
	Un washed	Washed	Unwashed	Washed	Unwashed	Washed	
Pb	BDL	BDL	0.114±0.008	BDL	BDL	BDL	2
Cu	0.228±0.01	0.159±0.005	0.264±0.008	0.206±0.008	1.949±0.07	1.776±0.05	10
Cr	0.131±0.01	0.096±0.006	BDL	BDL	0.552±0.027	0.415±0.005	1.3
Zn	4.896±0.053	2.511±0.02	2.661±0.041	2.131±0.01	3.205±0.022	3.104±0.008	5

BDL- Below detechable limits; *Source: WHO (1989) recommended maximum limits

having less of such pollutants. Heavy metals like Cd, Pb, Cr and Cu get accumulated in the edible parts of plants which, when present even in low concentrations, are harmful for mammals (Chen et al. 2007). Soil type, soil pH, plant species and fertilisers are some of the factors responsible for uptake of these metals in soluble form. These heavy metal cations get bonded to carbon atom chains present in organic matter in the soil. These are taken up by growing vegetables/plants and are more harmful in their bonded state (Ward 1995). Evapotranspiration by plants can also increase the concentration of these contaminants up to 100-1000 fold (Salido et al. 2003).

To sum up, it is evident from the present work that the levels of Pb, Cr, Cu and Zn estimated in cauliflower and spinach from Delhi region around Yamuna are in acceptable limits. Furthermore, a significant amount of surface borne heavy metals on these vegetables highlights the possible contribution from polluted air as well. So, the heavy metal contaminants in these two vegetables under investigation can be attributed to both water and air pollution. Washing of vegetables, therefore, is an essential step to get rid of the surface bound heavy metals, thereby bringing their levels all the more down for the consumer.

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Table 3. Reports of heavy metal accumulation in some vegetables

Heavy metals	Vegetables	Location	References	Remarks
Fe, As, Cr, Mn, Cu, Zn, Pb, Cd and Hg	*Solanum lycopersicum, Solanum melongena, Amaranthus tricolor L., Chenopodium album L.*, spinach, and *Coriandrum sativum*	Coal Burning Basin, Korba, India	Ramteka et al. (2016)	The highest HRI value of metals, i.e., As, Mn, Cu, Cd, Pb, and Hg was observed in spinach due to higher Cd and Pb contents
Cd and Pb	*Beta vulgaris L.*, *Abelmoschus esculentus L* and *Brassica oleracea L.*	Varanasi, India	Sharma et al. (2008)	Cd in vegetables from both production and market sites was many folds higher than the recommended EU standards
Cd and Cu	*Spinacia oleracea* and *Amaranthus caudatus*	Uttarakhand	Chetan and Patel (2015)	Toxicity caused by selected heavy metals was in order Cd>Cu, while heavy metal tolerance level was in the order Cu> Cd.
Cu, Zn, Fe, Pb, and Cd	*Lycopersicum esculentum Mill, Petroselinum crispum L., Allium cepa, Lactuca sativa, Allium sativum, Urtica dioica, Mentha piperita, Eruca sativa, Spinacia oleracea L., Anethum graveolens, Vicia faba, Beta vulgaris subsp. vulgaris, Portulaca oleracea, Vitis vinifera*	Manisa region, Turkey	Bagdatlioglu et al. (2010)	Concentrations within safe baseline levels for human consumption
Cd, Cu, Pb, and Zn	*Lactuca sativa L., Spinacia oleracea L., Allium ampeloprasum, Mentha,* and *Petroselinum crispum L.*	Port Kembla and Boolaroo, Australia	Kachenko and Singh (2006)	Cd and Pb levels exceeding maximum level set by the Australian and New Zealand Food Authority

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