academicJournals

Vol. 8(23), pp. 3019-3024, 20 June, 2013
DOI : 10.5897/AJAR2013.6955
ISSN 1996 - 0840 © 2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Health risk assessment of heavy metals in seasonal vegetables from north-west Himalaya

Geeta Tewari* and Chitra Pande

Department of Chemistry, Kumaun University, Nainital, Uttarakhand, 263002, India.

Accepted 14 June, 2013

Heavy metal contamination in agricultural soils may lead to the disorder of soil functionality, retardation in plant growth and influence human health through a contaminated food chain. The present study was undertaken to examine zinc, copper, lead and nickel content in soils and vegetables collected from different agricultural fields in Tarai region of Kumaun Himalaya. Ten surface soil (0 to 20 cm) and 20 vegetable samples in summer season were collected and analyzed for content of heavy metals. Heavy metal analyses in soil and vegetables samples were performed on an Atomic Absorption Spectrophotometer. Mean values of three replicates were taken for each determination. Ladyfinger was found to be the best accumulator of all detected metals. The present study indicates that children ingest significant amount of metals as compared to the adult. However, the content of these metals were below the permissible limits except Zn content in ladyfinger collected from Bajpur. The regular monitoring these metals in soils, vegetables and in other food items is necessary to prevent accumulation of these metals in the food chain. There is more risk of metal accumulation in children as compared to adults.

Key words: Heavy metals, agricultural soils, vegetables, health risk, food chain.

INTRODUCTION

Agriculture and animal husbandry are the main occupations of the local population in the Tarai region of Kumaun. Farmers either apply synthetic fertilizers and other agrochemicals that degrade local eco-systems (KumaonInfo.com). Fertilizers contain not only major elements necessary for plant nutrient and growth, but also trace metal impurities such as Cd, Pb, Hg, As or Ni (Williams and David, 1973). Heavy metal contamination in agricultural soils may lead to the declination of soil functionality, retardation in plant growth and influence human health through a contaminated food chain.

Heavy metals are one of the major contaminating agents of our food supply (DMello, 2003; Abdollatif et al., 2009). Food and water are the main sources of essential metals and also the media through which we are exposed to various toxic metals. Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda et al., 2005). Vegetable constitute an important part of the human diet since they contain both trace elements and toxic elements over a wide range of concentrations. Metal accumulation in vegetables may pose a direct threat to human health (WHO, 1996).

Concentration of traces heavy metals in plants is essential for good health and growth of animals and human beings but the metals should be within permissible limits. Concentrations higher or lower than the recommended permissible limits may causes various diseases like tumors, heart disease, psychic conditions that damage the memory and intellectual abilities of

*Corresponding author. E-mail: geeta_k@rediffmail.com.

Table 1. Physicochemical properties of soil samples collected from different sites.

K_1- IGL Tank, Kashipur	**K_2**- Mukandpur farm, Kashipur	**B_1**- Sood Colony, Bhona farm Bajpur
B_2- Sugar Mill, Bajpur	**G_1**- Fresh Water, Rushi	**G_2**- Sever Water, Rushi
L_1- Ghodanala, Lalkuan	**L_2**- Tiwari Nagar, Lalkuan	**R_1**- Jha farm, Rudrapur
R_2- Phulsungi, Rudrapur		

human beings (Gerhardssor, 1995). From the above views, it was decided to investigate the concentration of selected heavy metals like copper, lead, zinc, cadmium and nickel in the soils and vegetables from the contaminated and noncontaminated sites. Furthermore, the daily intake of these metals is calculated for both adult and children.

MATERIALS AND METHODS

Collection of samples

Study area

Five sites have been selected for soil and vegetable collection. Each site consists of one agricultural field and the other a polluted location. In Kashipur, the two sites were: one rich in organic wastage from the Indian Glycol Limited, the other being from the Agricultural farm of Mukundpur. The two sites in Lalkuan are Ghoranala irrigated by Lalkuan paper mill effluent and Tewarinagar, an agricultural non polluted site. The two sites in Bajpur were an agricultural farm in Bhona farm, Sood colony and sludge rich area near Sugar Mill. The Rushi area in Nainital was again divided in to two sites, one was the domestic sewage water irrigated area and the other, a fresh water. The two sites from which sampling were done in Rudrapur; one agricultural site and the other polluted due to heavy traffic.

Sample collection

Both soil and plant samples were collected in the month of May and June. Two kinds of vegetable samples were collected from each site. From Kashipur, green Chillies (*Capsicum annum* L.), Mentha (*Mentha viride*), Ghyia Tori (*Sponge luffa*) (*Luffa cylindrica* L.), and Ladyfinger (*Abelmoschus esulentus* (L.) Moench); from Bajpur, Ghyia Tori (*Luffa cylindrica* L.), Lady finger (*Abelmoschus esulentus* (L.) Moench); from Rushi, Radish leaves (*Raphanus sativa)*, radish roots, cauliflower (*Brassica oleracea* var. *capitata* alb.), cabbage (*Brassica oleracea*); from Lalkuan Ghyia Tori, Lady finger and Ghyia Tori, Lady finger from Rudrapur. Composite surface soil (0 to 20 cm) samples (from a bulk of soil made up of 10 different soil samples per farm) were also collected from the same vegetable farms and labeled properly.

Sample preparation

The soil samples were air-dried, ground into fine powder using pestle and mortar and passed through a 2 mm sieve. These processed soil samples (in triplicates) were used for determining the pH, EC (Jackson, 1958), organic carbon (%OC) by Walkley Black method (Walkley and Black, 1934), Organic matter, Texture and CEC (Bower et al., 1952) (Table 1). Well-mixed samples of 2 g soils were taken in 250 ml glass conical flasks and digested with 8 ml of aqua regia on a sand bath for 2 h. After evaporation near to dryness, the samples were dissolved with 10 ml of 2% nitric acid, filtered (Whatman No. 42) and then diluted to 50 ml with distilled water (Lokeshwari and Chandrappa, 2006). Blanks were prepared to check for background contamination by reagents used.

Vegetables were thoroughly washed to remove all adhered soil particles. Samples were cut into small pieces, air dried for 2 days and finally dried at 100±1°C in a hot air oven for 3 h. The samples were ground in warm condition and passed through 2 mm sieve. Dry plant tissue was finely ground and wet-ashed using HNO_3: H_2SO_4: $HClO_4$ (10:1:4v/v) (Piper, 1942).

Total heavy metal analysis

Heavy metal analysis in soil and vegetables (on dry weight basis) samples was performed on an Atomic Absorption Spectrophotometer (GBC Mode Hens AA dual Scientific Equipment) using acetylene gas as fuel and air as an oxidizer. Average values of three replicates were taken for each determination.

Data analysis

The daily intake of metals (DIM) was calculated by the following equation:

$$DIM = \frac{|M| \times K \times I}{W}$$

Where |M|, K, I and W represent the heavy metal concentrations in plants (mg/kg), conversion factor, daily intake of vegetables and average body weight, respectively. the conversion factor used to convert fresh green vegetable weight to dry weight was 0.085, as described by Rattan et al. (2005). The average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively, while average daily vegetable intakes for adult and children were considered to be 0.345 and 0.232 kg/person/day respectively, as reported in literature (Ge, 1992; Wang et al., 2005).

RESULTS AND DISCUSSION

Physicochemical properties

The physical properties of the soils from the ten mentioned sites have been determined. These are pH, EC and CEC values (in triplicate) in summer season. The values of pH ranged in a narrow interval from 7.00 to 8.33, which suggest neutral to alkaline conditions for all the soils in the study area. The EC range was from 0.103

Table 2. Relative percentage of clay, silt and sand in the soils were classified as sandy loam, loam and loamy.

Soils sampling site	pH (1:2) soil water suspension	EC (1:2) (dSm^{-1})	CEC ($cmol_c\ kg^{-1}$)	% OC	Sand (%)	Silt (%)	Clay (%)	Texture
K_1	8.33±0.06	0.154±0.001	32.11	2.628±0.368	60	30	10	Sandy loam
K_2	7.43±0.06	0.106±0.001	16.52	1.747±0.069	76	16	8	Sandy loam
B_1	7.60±0.00	0.199±0.001	20.23	1.761±0.055	44	42	14	Loam
B_2	7.50±0.00	0.198±0.001	37.06	3.372±0.439	62	24	14	Sandy loam
G_1	7.23±0.06	0.584±0.054	47.28	3.318±0.156	76	18	6	Loamy sand
G_2	7.63±0.06	0.204±0.006	32.44	1.957±0.082	88	6	6	Loamy sand
L_1	8.23±0.06	0.204±0.006	16.37	2.561±0.246	46	36	18	Loam
L_2	7.00±0.00	0.103±0.000	19.29	1.655±0.062	70	18	12	Sandy loam
R_1	7.20±0.00	0.129±0.008	24.89	1.689±0.149	46	40	14	Loam
R_2	7.80±0.10	0.163±0.003	26.70	0.662±0.073	52	34	14	Loam

to 0.584 dSm^{-1} while CEC ranged from 16.37 to 47.28 $cmol_c\ kg^{-1}$.

Percentage organic carbon (%OC) in the samples ranges between 0.662 (Rudrapur) to 3.372 (Sugar Mill, Bajpur) (Table 1). The percentage of organic matter was highest in Bajpur soils. The cation exchange capacity (CEC) of the soil samples ranged between 16.37 to 47.28 $cmol_c\ kg^{-1}$. As shown in Table 1, the soil samples collected from Rushi displayed the highest mean CEC value; those from the Lalkuan had the least value. The CEC values also showed the similar trend as the highest CEC value was recorded for Rushi village (47.28 $cmol_c\ kg^{-1}$) (Table 1). The relative percentage of clay, silt and sand in the soils were in the range (6 to 18%) for clay, (6 to 42%) for silt and (44 to 88%) for sand. The soils were classified as sandy loam, loam and loamy sand (Table 2).

Metal concentration in soils

The results of the analysis indicated that concentrations of heavy metals (mg kg^{-1}) in agricultural soil collected from different sites ranged from a minimum of 42.400 (Rudrapur) to a maximum of 137.858 (Rushi) for Zn, 25.500 (Rudrapur) to 108.325 (Rushi) for copper, 4.800 (Rudrapur) to 32.283 (Rushi) for Pb and 2.283 (Rudrapur) to 13.725 (Lalkuan) for Ni (Figure 1). The upper limits of heavy metal concentrations were below the upper limits of Prevention of Food Adulteration Act (PFA) standards (300, 270, 500 and 150 mg kg^{-1} for Zn, Cu, Pb and Ni respectively (Awasthi, 2000).

Metal concentration in vegetables

The heavy metal concentration in edible parts of vegetables from agricultural fields of tarai region of kumaun Himalaya shown in Figure 2. The range of various metals in vegetables was 9.500-62.667, 2.677-28.000 and 0-1.833, 0-1.000 mg kg^{-1} for zinc (Zn), copper (Cu), lead (Pb) and nickel (Ni) respectively. Heavy metal concentration was in the order of Zn>Cu>Pb>Ni for all the vegetables. Heavy metal concentration was in order of the highest mean content of Zn, Cu, Pb and Ni was detected in ladyfinger ranged from 62.667 to 12.833 mg kg^{-1} for zinc (Zn), 2.667 to 26.00 mg kg^{-1} for copper (Cu), 0.0 to 1.833 mg kg^{-1} for lead (Pb) and 0.0 to 0.667 for nickel (Ni). Zinc permissible limit for edible parts of crops is 50 mg kg^{-1} established by Awasthi (2000). Analyzed data showed that there was not any pollution in tested vegetables except Tori (62.667 mg kg^{-1}) collected from Bajpur. Zinc toxicity interferences Cu metabolism (Barone et al., 1998). An acute oral Zn dose may cause tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatic and damage of hepatic parenchyma (Salgueiro et al., 2000). Zinc accumulation can occur in vegetables grown on heavy metal contaminated soils and cause serious health risk to consumers. Long et al. (2003) investigated that excess amount of Zn in growth media caused toxicity to cabbage, celery and spinach. Bigdeli and Seilsepour (2008) observed that Zn concentration in celery, mint, dill, spinach and green pepper were more than Zn permitted level in Shahre Rey-Iran. Maximum lead limit established for edible parts of crops by Singh et al. (2010) found highest zinc content in cabbage (20 mg kg^{-1}). Awasthi (2000) is 2.5 mg kg^{-1}. Lead concentration in all tested vegetables is within the permissible level, so they are suitable for consumption. Highest lead concentration was found in bhindi collected from Lalkuan (0.577 mg kg^{-1}). Lead accumulation can exceed several hundred times more than maximum permissible level in many plant parts (Wierzbicka, 1995). Lead accumulation in the food chain may adversely affect human health. Previous report from Iran (Bigdeli and Seilsepour, 2008) showed that lead concentration in all the tested vegetable samples was more than maximum

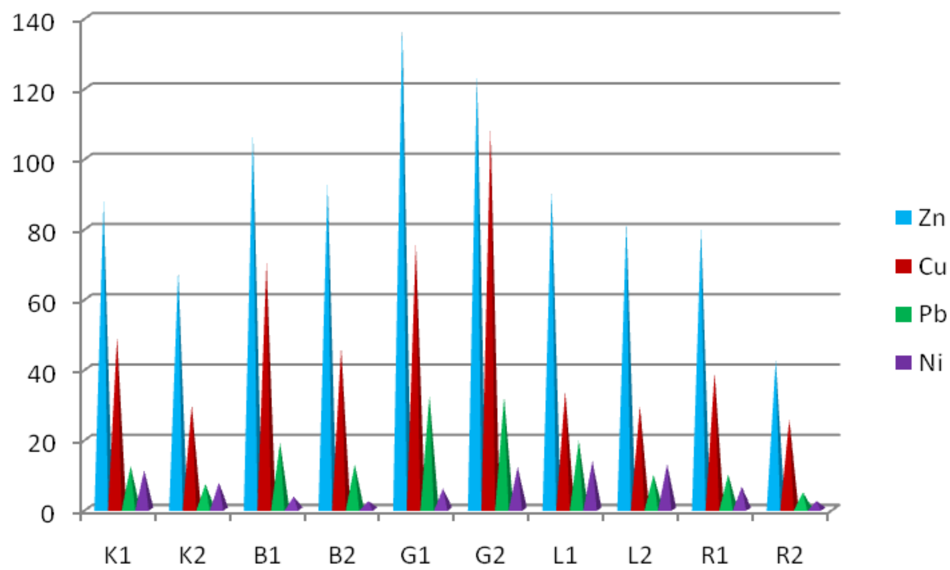

Figure 1. Concentration of metals in different soils.

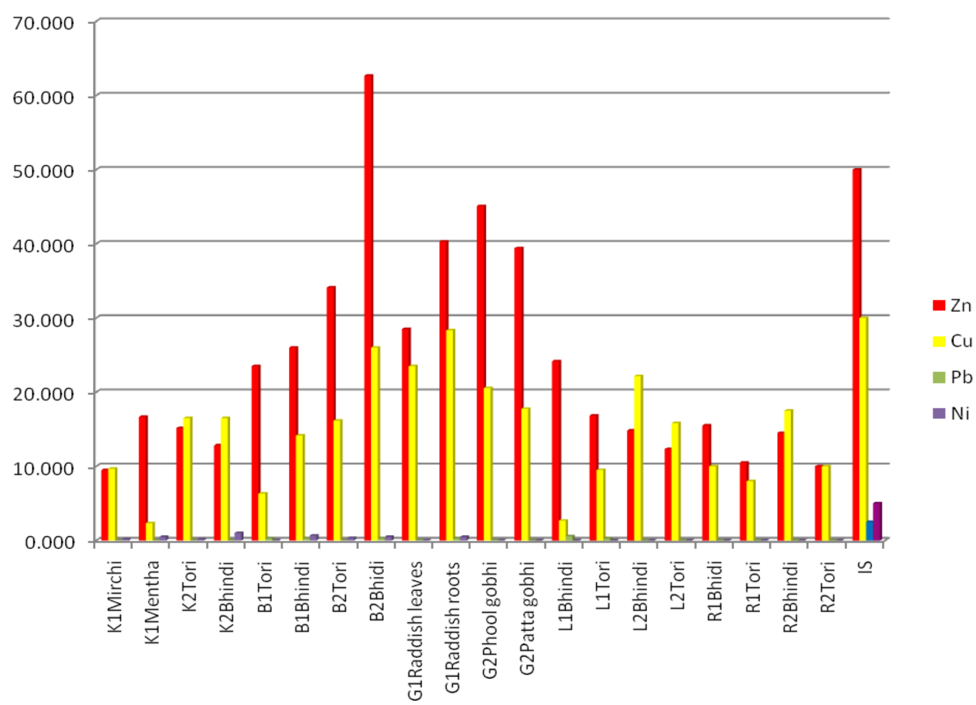

Figure 2. Concentration of metals in different vegetables (IS = Indian Standard).

permitted concentrations of WHO standards. According to Singh et al. (2010), highest Pb content was present in cauliflower (19.000 mg kg^{-1}). Indian standard for maximum permitted concentration of copper is 30 mg kg^{-1} (Awasthi, 2000). Copper concentration in all collected vegetables were within the permissible limits. Highest copper content was observed in raddish root collected from Rushi village (28.333 mg kg^{-1}). Bigdeli and Seilsepour (2008) showed that the copper levels found in vegetables were within the safe limits in all the tested samples. Yang et al. (2002) found that Cu levels in both root and shoot increased in three tested vegetables, but root Cu concentration increased more sharply than shoot with increasing Cu levels in growth media. Copper

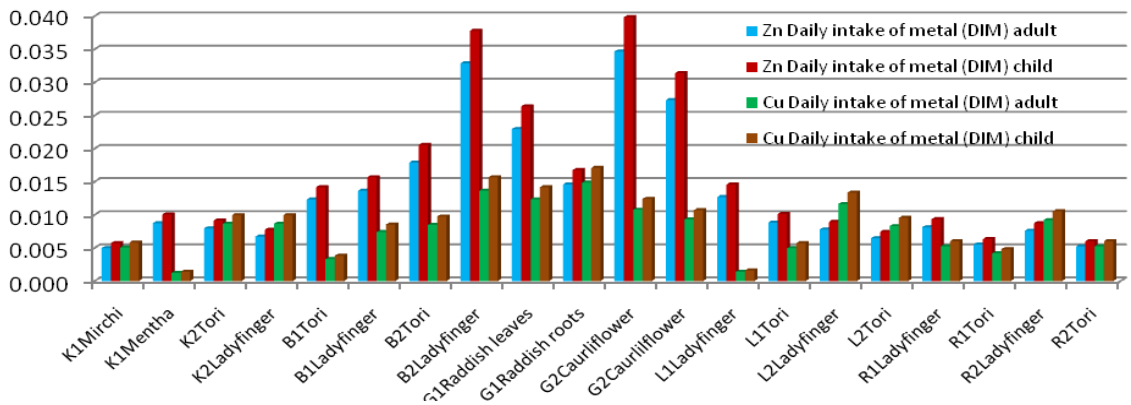

Figure 3. Daily intake of Zn and Cu by adult and child.

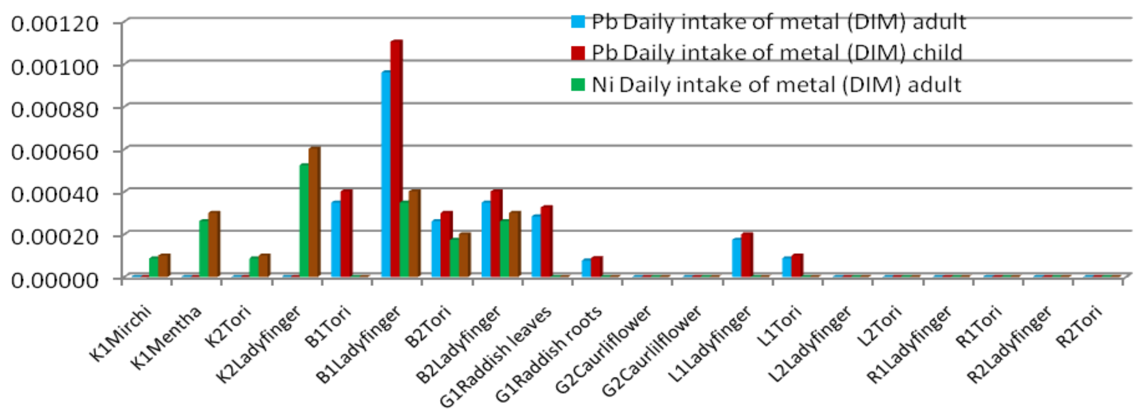

Figure 4. Daily intake of Pb and Ni by adult and child.

accumulation in the Chinese cabbage was significantly influenced by Cu concentration in soil (Xiong and Wang, 2005). Copper concentration in tomato (9 mg kg^{-1}) was observed to be highest (Singh et al., 2010). Permissible limit for Ni in edible crops was 1.500 mg kg^{-1} (Awasthi, 2000). Highest Ni content was found in Bhindi (1.000 mg kg^{-1}) collected from Kashipur and it was lower as compared to concentration of nickel reported by Singh et al. (2010) in lady finger (10 mg kg^{-1}). The highest concentration was present in Brinjal (22.000 mg kg^{-1}). Khan et al. (2008) have reported higher concentration of Ni in radish plants grown at waste water irrigated areas of Beijing than the clean water irrigated ones. Overall, vegetables accumulate significant amount of heavy metals but the content of these metals were below the permissible limits except Zn content in ladyfinger collected from Bajpur (Figure 2).

Daily intake of metals

In order to observe the health risk of any pollutant, it is very important to estimate the level of exposure, by detecting the routes of exposure to the target organisms. Out of several pathways food chain is the most important pathway to determine the way of exposure to human. The daily intake of metals was determined by average vegetable consumption of both adults and children. The consumption of some vegetables collected from contaminated sites, showed high capacity of metal accumulation which further transfers these metals to adults and children. A reference value for tolerable daily intake was established by standard of FAO/WHO (2007). The results of our calculated daily intake rate for all metals were below the tolerable daily intake rates. The present study indicates that children ingest significant amount of metals as compared to the adult but is nearly free to risk (Figures 3 and 4). The highest intakes of Zn, Cu, Ni and Pb were from the consumption of caurliflower (Rushi), caurliflower (Rushi), bhindi (Bajpur) and bhindi (Bajpur), respectively, for both adults and children. Singh et al. (2010) observed that daily intake rate of Cd in palak, amaranthus and cabbage and for Pb in palak and amaranthus were above the tolerable daily intake rate.

Conclusion

The heavy metals concentrations were higher in soil samples as compared to vegetable samples and the reason might be due to strong adsorptive nature of soil. The present study indicates that children ingest significant amount of metals as compared to the adult but is nearly free to risk. The regular monitoring these metals in soils, vegetables and in other food items is necessary to prevent accumulation of these metals in the food chain.

ACKNOWLEDGEMENTS

The authors are grateful to Director, USERC, Dehradun for financial support, Head, Chemistry Department, Kumaun University, Nainital for providing the necessary laboratory and Head, Department of Environmental Science, G.B.P.U.A. & T., Pantnagar for providing AAS facility.

REFERENCES

Abdollatif GA, Ardalan M, Mohammadi MT, Hosseini HM, Karimian N (2009). Solubility test in some phosphate Rocks and potential for direct application in soil. Word App. Sci. J. 6:182-190.

Awasthi SK (2000). Prevention of food Adulteration Act No. 37 of 1954. Central and State Rules as Amended for 1999, third ed. Ashoka Law House, New Delhi.

Barone A, Ebesh O, Harper RG (1998). Placental copper transport in rats: Effects of elevated dietary zinc on fetal copper, iron and metallothionien. J. Nutr. 128(6):1037-1041.

Bigdeli M, Seilsepour M (2008). Investigation of metals accumulation in some vegetables irrigated with waste water in Shahre Rey-Iran and toxicological implications. J. Agric. Environ. Sci. 4(1):86-92.

Bower CA, Reitemeter RF, Fireman M (1952). Exchangeable cation analysis of saline and alkali soils. Soil Sci. 73(4):251-262.

DMello JPF (2003). Food Safety: Contaminants and Toxins. CABI Publishing , Wallingford, Oxon, UK, Cambridge, MA P. 480.

Ge KY (1992). The status of nutrient and metal on Chinese in the 1990s Beings people's Hygiene Press, pp. 415-434.

Gerhardssor L (1995). Health effects and biological monitoring, the toxicity of lead, trace and toxic elements in nutrition and health. In: Abdullah SB, Vohora MA (eds). (1995).

Jackson ML (1958). Soil Chemical Analysis. Prentice Hall Inc. pp. 30-36.

Khan S, Lin A, Zhang S, Huc Q, Zhu Y (2008). Accumulation of polycyclic aromatic hydrocarbons and heavy metals in lettuce grown in the soils contaminated with long-term waste water irrigation. J. Hazard. Mater. 152:506-515.

KumaonInfo.com- http://www.kumaoninfo.com/agriculture.php.

Lokeshwari H, Chandrappa GT (2006). Impact of heavy metal contamination of Bellandur lake on soil and cultivated vegetation. Curr. Sci. 91(5):622-627.

Long XX, Yang XE, Ni WZ, Ye ZQ, He ZL, Calvert DV, Stoffella JP (2003). Assessing zinc thresholds for phytotoxicity and potential dietary toxicity in selected vegetable crops. Common. Soil Sci. Plant Anal. 34(9-10):1421-1434.

Mapanda F, Mangwayana EN, Nyamangara J, Giller KE (2005). The effects of long-term irrigation using water on heavy metal contents of soils and vegetables. Agric. Ecosys. Environ. 107:151-156.

Piper CS (1942). Soil and Plant Analysis. The University of Adelaide, Adelaide, Australia.

Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK (2005). Longterm impact of irrigation with sewage effluents on heavy metal contents in soils, crops and ground water – a case study. Agric. Ecosys. Environ. 109:310-322.

Salgueiro M, Zubillaga J, Lysionek M, Sarabia A, Caro MI, Paoli R (2000). Zinc as an essential micronutrient: A review. Nutr. Res. 20(5):737-755.

Singh A, Sharma RK, Agrawal M, Fiona MM (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. Trop. Ecol. 51(2S):375-387.

Walkley A, Black IA (1934). An examination of the Digestion method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-263.

Wang X, Sato T, Xing B, Tao S (2005). Health risk of heavy metals to the general public in Thinjin, China via consumption of vegetables and fish. Sci. Total Environ. 350:28-37.

WHO (1996). Trace Elements in Human Nutrition and Health, Geneva.

FAO /WHO (2007). Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the thirty eight session of the Codex committee on food hygiene. Houston, United States of America, ALINORM 07/30/13.

Wierzbicka M (1995). How lead loses its toxicity to plants. Acta Soc. Bot. Pol. 64:81-90.

Williams SH, David DJ (1973). The effect of super phosphate on the cadmium content of soils and plants. Aust. J. Soil Res. 11:43-56.

Xiong ZT, Wang H (2005). Copper toxicity and bioaccumulation in Chinese cabbage (*Brassica pekinensis* Rupr.). Environ. Toxicol. 20(2):188-194.

Yang XE, Long XX, Ni WZ (2002). Assessing copper thresholds for phytotoxicity and potential dietary toxicity in selected vegetables crops. J. Environ. Sci. Health B37(6):625-635.