MONITORING OF HEAVY METALS IN VEGETABLES AND SOIL OF AGRICULTURAL FIELDS OF KATHMANDU VALLEY

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ABSTRACT

Evaluation of heavy metals in vegetables and soil of agricultural fields of Kathmandu valley was conducted. Highest accumulations of copper (65.5 mg kg^{-1}), lead (46.75 mg kg^{-1}) and cadmium (2 mg kg^{-1}) from Shankhamul; nickel (29.25mg kg^{-1}) from Nakhu; cobalt (15.25mg kg^{-1}) and manganese (675 mg kg^{-1}) from Balkhu; chromium (73.75 mg kg^{-1}) from Banasthali, zinc (162 mg kg^{-1}) and iron (75636 mg kg^{-1}) from Khusibun were recorded in soil of agricultural fields. Highest accumulations of Cu, Co and Zn were recorded in spinach and Pb in red radish; Ni, Cr and Fe was recorded in broad leaf mustard and Mn in cress leaf while considering the mean of each vegetables studied. Concentration of non-essential but toxic metal like Pb was higher than the normal plant value (0.1–10 mg kg^{-1}) in all the vegetables (except potato) collected from different sampling sites.

Key words: Heavy metals, soil, vegetables.

INTRODUCTION

Altogether fifty three heavy metals are present in nature, but only seventeen are available to living cells (Weast 1984). Among these Fe, Mo and Mn are important as micronutrients; Zn, Ni, Cu, V, Co, W and Cr are of low importance as trace elements, but are toxic beyond limit. Heavy metals like Cd, As, Hg, Ag, Sb, U and Pb have no biological function which is more or less toxic to living organisms (Godbold and Hüttermann 1985, Nies 1999). Heavy metals once accumulated as contaminants can neither be destroyed nor can be altered by chemical or physical means, and are circulated in the ecosystems. Heavy metals present in the atmosphere are ultimately accumulated in the soil through precipitation and fall out (Chamberlain 1960, Lagerwerff 1971, Bohn 1972, Little 1973, Buchaver 1973).

Vascular plants are endlessly exposed to shower of potentially toxic heavy metals from the air and equally absorb heavy metals from soil via root system. Tolerance of heavy metals in plants is either by detoxification mechanism or accumulation in different plant parts or cell organelles (Reilly 1969, Bringezu *et al.* 1999) or in vacuoles or in cell wall (Chettri *et al.* 2000).

Biomonitoring of toxic heavy metals (Cu, Pb, Ni, Co, Cr, Cd, Zn, Mn) studied in air by using mosses (Shakya *et al.* 2004) and lichens (Chettri *et al.* 2001, Devkota *et al.* 1997) of Kathmandu valley indicated high amount of heavy metals pollution. The main river system of Kathmandu valley is river Bagmati with its five tributaries - Hanumante, Dhobi-khola, Tukucha, Bishnumati and Nakhukhola, flowing through the heart of the valley has been reported to be contaminated with heavy metals (Cu, Cr, Pb and Cd) (Gautam and Agrawal 1994). Water bodies from such polluted river system are heavily used in irrigation for vegetable production in the Kathmandu.

Based on these facts it is hypothesized that toxic heavy metals are deposited in the soil of agricultural fields and also in vegetable crops grown on such fields. Therefore this study was conducted to reveal if the level of toxic heavy metals in soils of such fields and vegetables grown in them are within the critical plant tissue concentration range or not.

MATERIALS AND METHODS

Sampling sites and materials

The present study was conducted in Kathmandu valley that has dusty and smoky atmosphere due to pollution of heavy traffic and emissions from various factories. Vegetables like *Brassica juncia* var. *cuneifolia* (broad leaf mustard), *Lepidium sativum* L. (cress leaf), *Spinacia oleracea* L. (spinach), *Raphanus sativus* L. (radish), *Brassica rapa* L. (turnip), *Daucus carota* L. (carrot) and *Solanum tuberosum* L. (potato) have been considered for the present study. The vegetables and soil samples were collected directly from 12 different sampling sites (i.e. fields) located near the main riverside of Kathmandu valley. Sampling sites, such as Banasthali, Shovabhagawati and Khusibun are located near Bishnumati river; Chhapro and Thimi near Manohora river; Shankhamul, Kusingal and Nakhu near Bagmati river; Kalopul and Ghatteculo near Dhobikhola; and Balkhu near Balkhu Khola. Representative soil samples at each sampling site were obtained by mixing soil samples collected from 10 different points, each from horizontal slices of 10-cm depth and an area 10X10 cm^2. Soil samples were oven dried at 70^0C - 100^0C for 72 h till constant dry weight (DW) and then sieved with 0.25mm mesh to obtain uniform soil particles. Vegetable samples were also collected from the same sampling sites and were washed thoroughly with tap water, air-dried and then oven dried at 70^0C for 72 h till constant dry weight. The soil samples after oven dry were homogenized into representative samples of each field. Similarly each parts/each vegetable were homogenized by using mortar and pestle to prepare representative samples.

Sample digestion and analysis of heavy metals

Representative samples (1 g dw) of vegetables and soil were wet digested in concentrated HNO_3 (Chettri *et al.* 1997, Sawidis *et al.* 1995) at 200^0C up to continuous heating of 4-5 h and the filtered through ashless filter paper (Whatman 589^3), maintaining definite final volume with double de-ionized water. Concentrations of heavy metals like Cu, Pb, Ni, Co, Cd, Cr, Zn, Fe and Mn in the filtrate were measured by using Perkin Elmer (2380) Atomic Absorption Spectrometer (AAS) with their respective wavelength (Welz 1985). For each case triplicate samples were tested. Two plant materials of NBS standards (National Bureau of Standards, USA) with Nos. 1573 (Tomato leaves) and 1575 (Pine needles) were also analyzed, following the same procedure and the metal recoveries ranged from 94 to 99 percent.

RESULTS AND DISCUSSION

Heavy metal concentrations in the soil samples collected from agricultural fields of Kathmandu valley are given in Table 1. Although soil concentrations of Cu, Pb, Zn and Fe in some fields and Cd in all fields, exceeded the normal soil values but lie below critical soil value. The soil concentration of Ni, Co, Cr and Mn were mostly within the normal soil value, except Cr at Banasthali. Soil Cu in Banasthali, Nakhu, Shankhamul, and Khusibun were slightly higher than normal soil value. Soil Cu ranged from 15 mg kg^{-1} (Kusingal) to 65. mg kg^{-1} (Shankhamul). Soil Pb in Banasthali, Manohora, Nakhu, Shankhamul, Kusingal, Shovabhagawati and Balkhu exceeded normal soil value, but was below critical soil values (Kabata-Pendias and Pendias 1984). Soil Pb ranged from 30.5 mg kg^{-1} (Kalopul) to 46.75 mg kg^{-1} (Shankhamul).

Table 1. Concentrations of trace metals in soils (mg kg^{-1} dry weight) in soils of agricultural fields, generally located near the river side of Kathmandu valley.

Biotops numbers	Places	Cu	Pb	Ni	Co	Cd	Cr	Zn	Fe	Mn
^{NSV}B		30	35	50	1-40**	0.35	70	90	40000	1000
^{UCSV}KP		125	400	100	-	8	100	400	-	3000
4	Banasthali	34.5*	37.25*	22.25	12	1.5	73.75*	70.50	26719	312
8	Chhapro	18.48	32.76	17.36	10.92	1.68	31.08	72.24	22500	142
12	Manohora	23.0	37.25*	14.25	7.5	1.05	29.0	117.0*	26928	48
20	Nakhu	34.5*	36.5*	29.25	8.75	1.25.	32.0	90.0	32670	443
28	Thimi	21.32	31.46	12.5	6.25	1.04	29.12	81.12	18009	-*
48	Kalopul	20.10	30.5	12.0	5.75	1.0	33.5	141.0*	23661	127
52	Ghatteculo	20.10	34.5	9.9	8.10	1.5	33.0	117.0*	61322*	141
65	Shankhamul	65.5*	46.75*	19.5	10.75	2.0	19.75	115.5*		283
72	Kusingal	15.0	36.0*	12.5	7.5	2.0	15.25	70.5	14157	128
79	Shovabhagawati	23.08	37.44*	15.6	8.06	1.56	14.76	76.72	21900	247
88	Khusibun	43.25*	33.0	14.75	8.5	0.75	33.0	162.0*	75636*	-
95	Balkhu	26.25	39.25*	27.5	15.25	1.0	23.75	79.5	18711	675

*exceeded normal soil values, **Normal soil value as proposed by Swaine 1955, ^{NSV}B Normal soil value as proposed by Bowen 1979, ^{UCSV}KP upper critical soil value as proposed by Kabata-Pendias and Pendias 1984.

Concentration of Ni and Co in soil lies below normal soil value. Nickel concentration in soil ranged from 9.9 mg kg^{-1} at Ghatteculo to 29.25 mg kg^{-1} at Nakhu. Similarly soil Co ranged from 5.75 mg kg^{-1} at Kalopul to 15.25 mg kg^{-1} at Balkhu. Soil Cd ranged from 0.75 mg kg^{-1} (Khusibun) to 2 mg kg^{-1} (Shankhamul and Kusingal). Soil Cr was mostly below the normal soil value (70 mg kg^{-1}) but it was high only at Banasthali (73 mg kg^{-1}). Soil Zn in Manohora, Kalopul, Ghatteculo, Shankhamul and Khusibun exceed normal soil value and its concentration ranged from 70.5 mg kg^{-1} at Kusingal and Banasthali to 162 mg kg^{-1} at Khusibun. Iron concentration in most of the field were found below normal soil value (40,000 mg kg^{-1}), except at Ghatteculo and Khusibun where it was very high with 61322 mg kg^{-1} and 75636 mg kg^{-1}, respectively and lowest in Thimi (18009 mg kg^{-1}). Soil Mn is low (48 mg kg^{-1}) at Manohora and is high (675 mg kg^{-1}) at Balkhu, and are lying below normal soil value. Table 1, indicates increased trend of heavy metals contamination in soil e.g. in Banasthali with Cu, Pb, Cr; in Manohora with Pb and Zn; in Nakhu with Cu and Pb; in Kalopul and Ghatteculo with Zn; in Shankhamul with Cu, Pb, Cd and Zn; in Kusingal, Shovabhagawati and Balkhu with Pb; in Khusibun with Cu, Zn and Fe. The high concentrations of heavy metals in the agricultural fields of Kathmandu valley may be due to precipitation or fall out of atmospheric pollution, as has been pointed out by biomonitoring studies using mosses and lichen (Shakya *et al.* 2004, Chettri *et al.* 2001, Devkota *et* *al*. 1997). Besides this, heavy metals must have been added due to use of polluted river water for irrigation (Gauatm and Agrawal 1994) or due to use of chemical fertilizer (Sharply and Menzel 1987, Galloway *et al*. 1982). In some places like Shankhamul concentrations of Cu, Pb and Cd in the soil are high but accumulation in vegetables are low. The possible reason for this may be due to soil factors (soil pH, organic matter, clay contents etc.) which vary in different area. Increased organic matter (Zimdahl & Foster 1976, Gadd and Griffths 1978, Bassuk 1986) and increased clay particles (Hodgson 1963) can bind metal cations and become unavailable to plants and organisms in the soil.

Accumulation of heavy metals in edible portions of vegetables

Heavy metals present in edible portions of studied vegetables are given in Table 2. Cu concentration in broad leaf mustard (17.75 mg kg^{-1}) from Khusibun and spinach from most of the sampling sites was slightly above the normal plant value. Among the leafy vegetables, highest Cu accumulation (25 mg kg^{-1}) was found in spinach leaves (Table 2.) from Shankhamul area. Bioaccumulation of Cu was highest in spinach leaves>cress leaf > broad leaf mustard> >turnip >carrot> red radish>white radish = potato tuber. Copper accumulation was less in root of carrot (4-6.5 mg kg^{-1}) and radish (3.5 mg kg^{-1} - 5.75 mg kg^{-1} than in most leafy vegetables. Within the same environment different vegetables have different accumulation. This may be due to differences in ligands at the binding sites of each vegetable. Besides this, high pH, lime, organic matter and phosphate reduce its uptake (Streit and Stumm 1993).

Lead accumulation in most vegetable crops except potato exceeds normal plant tissue concentration (Table 2). Highest accumulation of Pb was observed in red radish and lowest in potato. High Pb accumulation above 20 mg kg^{-1} was observed in all vegetables except potato. Although Pb is immobile in soil (Streit and Stumm 1993), there was high Pb accumulation in both leafy and root vegetables, and clearly indicates that green and leafy vegetables of Kathmandu valley accumulate Pb through both root uptake and atmospheric fall out. Deposition of Pb in vegetables is directly related to the exhaust emissions of leaded gasoline on one side and wear and tear of tires on the other sides (Djingova and Kuleff 1993).

Among the leafy vegetables, cress leaf showed high Cd accumulation where as turnip showed (Table 2) high accumulation among roots. Although most of leafy vegetables showed more Cd accumulation compared to roots, even bioaccumulation of Cd in spinach leaf is mostly greater than in soil showing tendency of hyperaccumulation. The plant Cd values are within the ranges of normal plant values. Chromium accumulation in all vegetables was found within normal plant value and ranges from 0.25 mg kg^{-1} to 4.75 mg kg^{-1} in spinach. This might be due to very lower chromate uptake which occurs only in hexavalent form and is rapidly reduced to immobile trivalent form (Streit and Stumm 1993) in the soil.

Hyperaccumulation (higher than soil values) of Zn was also seen in red radish of Kusingal, Shovabhagawati and Khusibun, but not observed in white radish. Similarly, hyperaccumulation of Zn in plant tissue was also observed in broad leaf mustard collected from Kusingal, cress leaf from Khusibun and spinach from Shankhamul. In most of the cases Zn hyperaccumulation was observed exceeding critical plant concentration of 200 mg kg^{-1} (Davis and Beckett 1978). Zinc accumulation in spinach collected from Shankhamul showed 462 mg kg^{-1} which exceeds critical plant tissue concentration. The possible reason for hyperaccumulation of Zn in plant tissue is due to easy transportation from the roots into the aerial parts.

Table 2. **Concentrations of accumulated heavy metals in edible vegetable parts and soils (mean value in mg kg-^{1} DW).**

Vegetable parts/ Places	Cu	Pb	Ni	Co	Cd	Cr	Zn	Fe*	Mn
^{NPV}A	5-15	0.1-10	1-2.7	-	.1-2.4	0.2-10	20-400^{B}	140	-
^{RVCPC}KP	20-100	20-300	10-100	-	5-30	5-30	100-400	-	300-500
Broadleaf									
Thimi	6.5	25.25*	7	3.5	1	2.75	57	6284*	67
Manohora	7.75	23*	4.25	1.25	1	4.25	49.5	573*	42.25
Kalopul	8.0	16.50	3.25	6	0.5	1.75	51	4167*	25.75
Banasthali	3.0	17.75	4.75	1.5	0.75	4.5	37.5	5859*	27.25
Shankhamul	11.25	28.25*	5	2.75	1.5	2.25	88.5	5463*	38
Kusingal	9.25	31.75*	6.75	3.75	1.5	2.25	118.25	6336*	30
Shovabhagawati	9.75	28.75*	4.25	2.25	1.25	3.25	54	4851*	37.25
Khusibun	17.75*	34.75*	4.5	0.25	0.75	2.25	105	8361*	74.5
Balkhu	11.5	15	7	3	0.75	3	75	7866*	73.75
Mean	**9.42**	**24.56**	**5.19**	**2.69**	**1.00**	**2.92**	**70.64**	**5528.89**	**46.19**
Cress leaf									
Thimi	7.25	29*	3.5	3.25	0.5	3.5	52.5	526.5*	72.75
Manohora	9.5	22*	2.75	2	1.5	1.5	84	1647*	48
Khusibun	13.26	31.72*	6.24	2.08	1.3	3.12	363.48	4062*	187.2
Mean	**10.00**	**27.57**	**4.16**	**2.44**	**1.10**	**2.71**	**166.66**	**2078.50**	**102.65**
Spinach									
Thimi	14.75	37.5*	6	4	1.25	4.75	79.5	3735*	90.75
Banasthali	13.25	22.25*	4	3	0.75	2.75	96	5157*	98.5
Chappro	14.85	17.05	3.85	4.4	1.1	1.93	247.5	15939*	111.1
Shakhamul	25*	12.75	7.25	1.25	0.5	2.5	462*	6993*	72
Shovabhagawati	7.5	7	2.5	1.5	0.25	0.25	150	171*	5
Manohora	15.6*	31.98*	5.46	2.6	1.04	3.12	96.72	828.36*	3.12
Mean	**15.16**	**21.42**	**4.84**	**2.79**	**0.82**	**2.55**	**188.62**	**5470***	**63.41**
Carrot									
Chappro	6.5	19.25	0.25	0.75	0.25	1.25	30	220.5*	9.75
Banasthali	4	17.75	3.25	2	0.25	0.25	43.5	210*	10.5
Manohora	5.5	20.5*	3.5	2	0.25	0.25	34.5	396*	11.75
Ghatteculo	4.25	23.5*	3	0.25	1.25	0.75	57	450*	127.75
Shakhamul	5.5	20.75*	5.5	2.2	1.1	0.28	112.6	2039.4*	26.13
Mean	**5.15**	**20.35**	**3.10**	**1.44**	**0.62**	**0.56**	**55.52**	**663***	**37.18**

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Radish®									
Kusingal	3.75	20*	0.5	2.25	0.25	0.75	102	612*	2
Shovabhagawati	5.75	33.75*	3.25	2.25	1.25	0.75	162	1971*	18.5
Khusibun	5.2	39.05*	2.8	2.86	0.26	0.78	92.04	1263.6*	26.78
Mean	**4.90**	**30.93**	**2.18**	**2.45**	**0.59**	**0.76**	**118.68**	**1282***	**15.76**
Radish (w)									
Thimi	3.75	22.5*	3.25	0.25	0.25	1.25	40.5	873*	13
Ghatteculo	3.75	27.75*	6	2	0.75	0.75	147.5	2331*	14
Shovabhagwati	3.5	28.82*	2	0.25	0.25	1.5	49.5	153*	14
Mean	**3.67**	**26.36**	**3.75**	**0.83**	**0.42**	**1.17**	**79.17**	**1119**	**13.67**
Turnip									
Thimi	7.75	16.25	1.5	4.25	0.75	0.5	99	390*	21
Manohora	5.25	24.75*	4.25	0.75	0.25	1.25	48	3429*	27.27
Kusingal	3	25.25*	0.5	1.75	1	0.25	73.5	342*	8.75
Mean	**5.33**	**22.08**	**2.08**	**2.25**	**0.67**	**0.67**	**73.5**	**1387***	**19**
Potato									
Sankhu	4	5.75	1.5	1.5	0.25	1.25	45	87	11.5
Pachakhal	3.75	9.75	0.25	1.5	0.7	0.25	52.5	108	8.25
Manohora	3.25	4.75	0.25	2.5	0.5	1.25	42	87	18.25
Mean	**3.67**	**6.75**	**0.67**	**1.83**	**0.48**	**0.92**	**46.5**	**94**	**12.67**

*exceeded normal plant value, ^{NPV}A normal plant value of Alloway (1968), ^{B}Bowen (1979), ^{RVCPC}KP Range value of critical plant concentration of Kabata-Pendias and Pendias (1992).

Although, Ni accumulation is higher than the normal plant value, but is below the value of critical plant concentration (10 mg kg^{-1}). High mean value of Ni content was seen in leafy vegetables than in roots. Cobalt accumulation ranged from 0.25 mg kg^{-1} to 6.0 mg kg^{-1} in broad leaf mustard. Highest mean value of Co was observed in spinach.

Accumulation of Fe is extremely higher in all vegetables than normal plant value (140 mg kg^{-1}), except potato. Fe concentration is high in the order of broad leaf mustard > spinach > cress leaf > turnip > radish > carrot > potato. High Fe accumulation above the normal plant concentration in all vegetable crops may be due to bioaccumulation of it as iron phosphate in the vascular bundles along the veins of a leaf. Sometime the accumulation of iron phosphate is in such an extent that the adjoining tissues become even markedly deficient in iron (Streit and Stumm 1993). Water logged condition and mobile organic complex, low organic matter and chelates increase the Fe uptake.

Among all the studied vegetables, bioaccumulation of Mn was high (ranges from 48 mg kg^{-1} to 187.2 mg kg^{-1}) in cress leaf. In all the plants Mn concentration was found to be below the critical plant concentration.

As the vegetables under study are herbaceous species and accumulated high amount of Pb, Zn and Fe in most cases, therefore, can be used for monitoring air/soil pollution as suggested by Ernst and Leloup (1987). Root of carrot, radish and turnip also accumulated different heavy metals (especially Pb) and supports the view of Witting (1992) that underground parts may act as a suitable bioindicators, and is possibly due to a moderate mobility of Fe, Mn, Zn, Cu and Mo (Ziegler 1988) in the xylem and phloem of root and their accumulation in parenchymatous tissues of cortex layer (Kelepertsis and Andrulakis 1983).

For bioaccumulation of heavy metals in different vegetables various mechanisms like binding metal with organic acids, proteins or other ligands (Lee *et al.* 1978, Rauser and Curvetto 1980, Godbold *et al.* 1984) can be speculated. Similarly, adsorption of metals in different plant parts like cell wall, middle lamella or cell organelles (Reilly 1969, Barcelo and Poschenrieder 1990, Bringezu *et al.* 1999, Chettri *et al.* 2000) can be suggested for their bioaccumulation.

CONCLUSIONS

From the present study it can be concluded that in some agricultural fields the concentration of Cu, Pb, Cd, Zn and Fe are above the normal soil value and reflect the possibility of soil pollution. Accumulation of Pb in both leafy and underground vegetables (except in potato tuber), indicated that the highly toxic metal Pb has been entering our food chain through vegetables. Although the green vegetables are the good sources of Zn, Cu, Fe necessary for our good health, but by the accumulation of toxic metals like Pb and Cd, the essential micronutrients would be deficient in our daily diet. In heavy metal contaminated areas leafy vegetables, which are good accumulator, should be avoided for commercial farming and should be substituted by non-accumulator plant like potato.

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