ISSN 0258-7122
Bangladesh J. Agril. Res. 34(4) : 545-554, December 2009

LEAD, CADMIUM AND NICKEL CONTENTS OF VEGETABLES GROWN IN INDUSTRIALLY POLLUTED AND NON-POLLUTED AREAS OF BANGLADESH

HABIB MOHAMMAD NASER[1], N. C. SHIL[2], N. U. MAHMUD[3]
M. H. RASHID[4] AND K. M. HOSSAIN[5]

Abstract

The levels of lead (Pb), cadmium (Cd), and nickel (Ni) in spinach *(Spinacia oleracea)*, tomato *(Lycopersicon esculentum)* and cauliflower *(Brassica oleracea)* and in the rizosphere soils of the industrially polluted (Konabari, Gazipur; Keranigonj, Dhaka), and non-polluted (Bangladesh Agricultural Research Institute-BARI, Gazipur) areas were studied. Four samples from each area were collected during February 2008. Their concentrations varied with the metals and locations, showing the trend: Ni>Pb>Cd and directly polluted> indirectly polluted>non-polluted soils. The order of the elements in spinach, tomato, and cauliflower and their concentration ranges in µg/g of dry weight were Ni (1.265-5.369), (2.031-4.957), (1.698-4.447); Pd (0.767-1.440), (1.027-1.968), (0.486-1.119); and Cd (0.559-1.40), (0.630-1.303), (0.506-0.782), respectively. Similarly, the order of the elements in rizosphere soils of spinach, tomato, and cauliflower and their concentration ranges in µg/g of dry weight were Ni (12.29-31.52), (13.67-31.98), (14.20-34.34); Pd (3.560-7.980), (3.900-8.447), (3.718-7.337); and Cd (1.473-3.760), (1.553-3.833), (1.640-3.670), respectively. Lead concentration was higher in tomato, followed by spinach and the least in cauliflower irrespective of the location. Cadmium and Ni concentration were found in the order of spinach>tomato>cauliflower, especially in the industrially polluted areas. Concentrations of metals in vegetable samples were related to their concentration in the corresponding soils. Lead, Cd, and Ni concentrations in the studied vegetables were higher than those found in vegetables from other countries, but they were lower than the maximum level allowed in India. Metal transfer factors from soil to vegetables are found to be significant for Cd, Pb and Ni.

Key Words: Cadmium, lead, nickel, polluted soils, vegetables.

Introduction

Environmental pollution nowadays is a big concern. Anthropogenic activities have altered the environment significantly throughout the world like mining, industry and agriculture (Wang *et al.*, 2008). Environmental contaminants are widely distributed in air, water and soils and, therefore, they will have an effect

---

[1]Senior Scientific Officer, Soil Science Division, BARI, Joydebpur, Gazipur 1701, [2]Senior Scientific Officer, Soil Science Division, BARI, Joydebpur, Gazipur 1701, [3&4]Scientific Officer, Soil Science Division, BARI, Joydebpur, Gazipur 1701, [5]Principal Scientific Officer, Soil Science Division, BARI, Joydebpur, Gazipur-1701, Bangladesh.

on the trophic chain (vegetables, animals and men) (Tiller, 1989). Heavy metals are of considerable behaviour (Omgbu and Kokogbo, 1993). Trace quantities of certain heavy elements, such as chromium, cobalt, copper, manganese and zinc are essential micronutrients for higher animals and for plant growth (Somers, 1974). Lead (Pb), cadmium (Cd), and nickel (Ni) are significant environmental pollutants. Anthropogenic activities, such as agriculture, industry and urban life increase the Pb, Cd, and Ni contents of soils and waters and, therefore, have an effect on the metal contents of vegetables (Alegria *et al.*, 1991). Vegetables absorb heavy metals from the soil as well as from surface deposits on the parts of vegetables exposed to polluted air (Buchaver, 1973; Haghiri, 1973). Moreover, the presence of heavy metals in fertilizers contributes an additional source of metal pollution for vegetables (Yusuf *et al.*, 2003).

A major pathway of soil contamination is through atmospheric deposition of heavy metals from point sources, such as metalliferous mining, smelting and industrial activities. Other non point sources of contamination affecting predominately agricultural soils are due to various inputs, such as fertilizers, pesticides, sewage sludge, organic manure and compost (Singh, 2001). Additionally, foliar uptake of atmospheric heavy metals from emission gas has also been identified as an important pathway of heavy metal contamination in vegetable crops (Kaur, 2006).

Accumulation of heavy metals by plants may depend on plant species and soil properties. These heavy metals are not abundant in soil, but there may be an accumulation of these heavy metals through urban wastes and industrial effluents. The uptake of heavy metals in cereals and vegetables is likely to be higher and accumulation of these toxic metals in human body created growing concern in the recent days. The daily vegetable consumption by an adult of Bangladesh is 130 g (Islam *et al.*, 2005). Different kinds of vegetables are grown during the year in tropical Bangladesh, but very little is known about the metal contents of vegetables (Alam *et al.*, 2003). Information regarding the accumulation of heavy metals in vegetables in industrially polluted areas in Bangladesh is scarce. But such information is vital for the production of quality vegetables as well as healthy food stuffs. In this context, the present study has been undertaken with the following objectives: i) to determine the accumulation of heavy metals in vegetables and ii) to compare the heavy metal status of vegetables and soils in polluted and non-polluted areas.

Materials and Method

Field sampling

Samples of soils and edible vegetables were taken from three agricultural areas exposed to different degrees of environmental pollution. Area 1: Direct pollution by industrial effluents, sewage sludge and municipal waste water (Konabari, Joydebpur, Gazipur). Area 2: Indirect pollution by Buriganga river flooding (Keranigonj, Dhaka). The river Buriganga is highly polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution. Area 3: The same type of vegetables samples were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, horticultural farm, regarded as non-polluted area. The collected samples included spinach *(Spinacia oleracea),* tomato *(Lycopersicon esculentum)* and cauliflower *(Brassica oleracea).* Both soil and vegetable samples were taken from four different places in each location. The plant samples represent whole parts of the plant of respective vegetable (fruits, curd, leaves, stems, and roots-wherever suitable; i.e., fruits for tomato, curd for cauliflower). Soil samples from rizosphere of respective vegetables (0-15 cm) were collected with a stainless steel auger. Samples (soils and vegetables) were taken by a random process in February 2008.

Preparation and preservation

After taking to the laboratory, all vegetable samples were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs and then were again washed with deionized water. The clean vegetable samples were air-dried and placed in an electric oven at 65 °C for 48-72 h depending on the sample size. The dry vegetable samples were homogenized by grinding using a ceramic coated grinder and used for metal analysis. All soil samples were spread on plastic trays and allowed to dry at ambient temperature for 8 days. The soil samples after drying were ground with a ceramic coated grinder and sieved through a nylon sieve. The final samples were kept in labeled polypropylene containers at ambient temperature before analysis.

Digestion and determination

One gram of dry matter was weighed into 50-ml beakers, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HClO_4$ in the ratio 5:1. The digestion was performed at a temperature of about 190 °C for 1.5 h. After cooling, the solution was made up to a final volume (30 ml) with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a VARIAN model AA2407 Atomic Absorption Spectrophotometer (AAS). Analysis of each sample was carried out four times to obtain representative results and the data reported in µg/g (on a dry weight basis). Data were arranged in a CRD and subjected to analysis of variance using the statistical software MSTAT-C. Significant differences were determined by the LSD (probability level of 0.001 was considered statistically significant).

Results and Discussion

The mean values of Pb, Cd, and Ni contents of vegetables and soils studied are shown in Table I and 2, respectively. The levels of heavy metal contents obtained in all three vegetable and soil samples from directly polluted (Konabari), indirectly polluted (Keranigonj), and non-polluted (BARI) areas differed significantly ($p<0.001$) from each other, whereas directly polluted areas showed the highest result followed by indirectly polluted and the lowest in non-polluted areas irrespective of the studied metals. Several studies have indicated that vegetables grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soils (Guttormsen *et al.*, 1995; Dowdy and Larson, 1995).

There were significant differences in the Pb, Cd, and Ni concentrations (µg/g dry wt) of different vegetable species (spinach, tomato, and cauliflower) in different locations. In all three vegetables regardless of locations, a similar trend in metal contents was observed i.e., Ni>Pb>Cd. Lead content (dry wt. basis) was found to be the highest in tomato with a range of 1.027 to 1.968 µg/g followed by spinach with a range of 0.767 to 1.440 µg/g and cauliflower 0.486 to 1.119 µg/g. The extend of Pb pollution can be regarded in the order tomato>spinach>cauliflower. Cadmium level (dry wt.) was the highest in spinach with a range of 0.559 to 1.400 µg/g followed by tomato with a range of 0.630 to 1.303 µg/g and cauliflower having 0.506 to 0.782 µg/g. In case of Ni, there was irregular pattern in metal contents among the studied vegetables. For the directly polluted area (Konabari), the trend in Ni content was spinach>tomato> cauliflower, whereas it was tomato>cauliflower>spinach for indirectly polluted (Keranigonj) and non-polluted (BARI) areas. In directly polluted area, the Ni (dry wt.) content was highest in spinach with a mean of 5.369 µg/g followed by tomato with a mean of 4.957 µg/g and minimum in cauliflower i.e. 4.447 µg/g. In indirectly polluted and non-polluted areas, Ni content was found highest in tomato with a range of 2.031 to 2.833 µg/g followed by cauliflower with a range of 1.698 to 2.660 µg/g and spinach was 1.265 to 2.318 µg/g. The order of the elements in rizosphere soils of spinach, tomato, and cauliflower and their concentrations range in µg/g of dry weight were Ni (12.29-31.52), (13.67-31.98), (14.20-34.34); Pd (3.560-7.980), (3.900-8.447), (3.718-7.337); and Cd (1.473-3.760), (1.553-3.833), (1.640-3.670), respectively. Percentage of metal contents increased in vegetables in indirectly polluted and directly polluted areas compared to non-polluted area ranged from 37 to 54 µg/g and 88 to 130 µg/g for Pb, it was 30 to 112 µg/g and 35 to 150 µg/g for Cd, and was 39 to 83 and 144 to 324 for Ni, respectively. Similarly, the increase of metal contents in soils of indirectly and directly polluted areas were 54 to 59 µg/g and 97 to 124 µg/g for Pb it was 32 to 63 µg/g and 124 to 155 µg/g for Cd, and was 63 to 82 µg/g and 134 to 156 µg/g for Ni, respectively.

Lead levels measured in vegetables in this study were higher than the reported values of Jamali *et al.* (2007) and Alegria *et al.* (1991). Jamali *et al.* (2007) reported that Pb concentrations in vegetables grown in agricultural sites dressed and irrigated with domestic waste and water, termed as TVS, were significantly ($p<0.001$) higher than control vegetable samples (soil irrigated with fresh canal water, termed as CVS). The levels of Pb in TVS, ranged from 0.12 (spinach) to 0.30 (brinjal) µg/g dry weight, while the CVS shows 0.08 µg/g (brinjal) to 0.33 µg/g (spinach). Moreover, Alegria *et al.* (1991) reported that the Pb content in lettuce, tomato and cauliflower was 0.26, 0.43, and 0.02 µg/g, respectively. Vegetables from the polluted (either directly or indirectly) area showed higher levels of Cd than those from the non-polluted area. In fact, significant differences (p<0.00l) were found in the level of Cd in all tested vegetables between polluted and non-polluted areas. Similar to Pb as reported by Jamali *et al.* (2007) that the concentration of Cd in vegetables sampled from TVS was high, ranging between 0.14 µg/g (spinach) and 0.30 µg/g (brinjal) on a dry weight basis, whereas in CVS showed ranging between 0.01 µg/g (spinach) and 0.02 µg/g (brinjal). The level of Cd in TVS and CVS vegetables was significantly lower than that of present study. Concentrations of Ni (Table 1 & 2) in vegetables and soils in this study were higher than those from the Pb and Cd in respect of three areas. Moreover, Jamali *et al.* (2007) found an increase in Ni content of brinjal and spinach from CVS to TVS as 40% and 36%, respectively.

The concentration levels of Pb and Cd in our study is higher than the allowable levels of Pb and Cd as set by the Commission of the European Communities (CEC) and World Health Organization (WHO). Lead limit set by the CEC was 0.3 µg/g fresh weight for Brassica and leaf vegetables, and 0.1 µg/g fresh weight for all remaining vegetables. The allowable level of Cd, as set by the CEC and WHO was 0.2 µg/g fresh weight for leafy vegetables and fresh herbs, 0.1 µg/g for stem and root vegetables (Jamali *et al.*, 2007). Thus, the level of Pb, Cd, and Ni concentrations in the vegetables in our study were higher than those found in such vegetables from other countries, but they were lower than the maximum level allowed by Prevention of Food Adulteration Act (PFA), 1954, India for Pb, Cd, and Ni 2.5, 1.5, and 5.0 µg/g, respectively (Jeevan Rao and Shantaram, 1999); except Ni in spinach (5.37 µg/g dry wt.).

In order to ascertain possible relationship between Pb, Cd, and Ni content of soils and vegetables analyzed, correlations between contents were calculated. The result shows (Table 3) across all vegetable samples, positive correlation between total metal content in soils and vegetables. Correlation between soil and plant of different heavy metals varies widely. The highest correlation between soil-plant was found to correspond to Pb. On the other hand, comparatively low correlation between soil-plant corresponds to Cd. In respect of location,

Table 1. Mean Pb, Cd and Ni concentration (±, standard deviation) of vegetables from directly polluted, indirectly polluted and non-polluted areas.

Location	Name of vegetables								
	spinach			tomato			cauliflower		
	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni
Directly polluted	l.440±0.025a	l.400±0.0l6a	5.369±0.177a	1.968±0.031a	1.303±0.02la	4.957±0.198a	1.1l9±0.032a	0.782±0.017a	4.447±0.157a
Indirectly polluted	1.053±0.030b	1.187±0.015b	2.3l8±0.152b	l.580±0.024b	l.130±0.032b	2.833±0.179b	0.730±0.024b	0.658±0.023b	2.660±0.l7lb
Non-polluted	0.767±0.012c	0.559±0.022c	1.265±0.1 07c	1.027±0.029c	0.630±0.018c	2.031±0.1 44c	0.486±0.025c	0.506±0.0 14c	1.698±0.133c

Values in a column followed by a common letter are not significantly different at p<0.001.

Table 2. Mean Pb, Cd and Ni concentration (±, standard deviation) of soils from directly polluted, indirectly polluted and non-polluted areas

Location	Name of vegetables								
	spinach			tomato			cauliflower		
	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni
Directly polluted	7.980±0.432a	3.760±0.092a	31.52±0.998a	8.447±0.351a	3.833±0.095a	31.98±0.761 a	7.337±0.397a	3.670±0.059a	34.34±0.982a
Indirectly polluted	5 .670±0.432b	2.270±0.082b	22.33±0.475b	6.000±0.281b	2.530±0.073b	24.83±0.850b	5 .750±0.432b	2.1 70±0.062b	23.1 5±0.793b
Non-polluted	3 .560±0.258c	I .473±0.052c	12.29±0.731c	3.900±0.258c	1 .553±0.078c	13 .67±0.575c	3.718±0.1 89c	I .640±0.067c	14.20±0.653c

Values in a column followed by a common letter are not significantly different at p<0.001.

Table 3. Correlations between heavy metal content in soils and in vegetables grown there (µg/g, *p < 0.05, *=p < 0.01, ns=non-significant).

Location	Name of vegetables								
	spinach			tomato			cauliflower		
	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni
Directly polluted	0.997**	0.887ns	0.827ns	0.915ns	0.768ns	0.949ns	0.986*	0.962*	0.934ns
Indirectly polluted	0.993**	0.988*	0.972*	0.997**	0.960*	0.887ns	0.993**	0.963*	0.986*
Non-polluted	0.994**	0.905ns	0.984*	0.995**	0.764ns	0.982*	0.993**	0.912ns	0.999**

Table 4. Transfer factor (±, standard deviation) of Pb, Cd, and Ni from soils into vegetables samples.

Location	Name of vegetables								
	spinach			tomato			cauliflower		
	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni
Directly polluted	0.181±0.010	0.373±0.010	0.171+0.011	0.233±0.007	0.340±0.009	0.155±0.009	0.153±0.013	0.213±0.004	0.130±0.008
Indirectly polluted	0.187±0.017	0.523±0.022	0.104±0.009	0.264±0.015	0.447±0.024	0.114±0.010	0.127+0.006	0.303±0.003	0.115±0.011
Non-polluted	0.216±0.018	0.380±0.029	0.103±0.014	0.264±0.022	0.406±0.023	0.148±0.005	0.131+0.012	0.309±0.021	0.119±0.004

indirectly polluted area shows the higher significant positive correlation than other areas. However, relationship between soil and plant depends, on available forms of metal ions in soil.

On the basis of these results, transfer factor (TF) of different heavy metals from soil to vegetation was calculated as the ratio between the concentrations of heavy metals in vegetables and their respective concentration in the soil samples (Table 4). The TF is one of the key components of human exposure to metals through the food chain. In all three vegetables, a similar trend as in TF was observed Cd>Pb>Ni irrespective of the location. The degree of TF showed irregular pattern in polluted and non-polluted areas, however, their values in all vegetables were different. The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of vegetable species, and is altered by innumerable environmental and human factors (Zurera *et al.,* 1987). The highest TF value 0.523, 0.447 and 0.309 was found for Cd in spinach, tomato, and cauliflower, respectively. These might be due to higher mobility of Cd with a natural occurrence in soil (Alam *et al.*, 2003), and the low retention of Cd (II) in the soil than other toxic cations (Lokeshwari and Chandrappa, 2006). Overall TF values of Pb and Cd are found to be significant and it supports the findings that accumulation of Pb and Ni is comparatively less than that of Cd in plants (Olaniya *et al.,* 1998).

The heavy metal content described in this paper was determined based on the whole plant (fruits, curd, leaves, stems, and roots-wherever suitable) which appeared to be higher in some cases when comparison was made with the findings of other scientists where estimate was made only on edible parts of plant. For example, Alam *et al.* (2003) reported that the lowest Pb levels were found in lady's finger *(Abelmoschus esculentus*-0.143 µg/g dry wt.) and the highest in ghotkol *(Typhonium trilobatum* -1.69 µg/g dry wt.); where only the edible part of each vegetable was used for analysis.

High concentration of these metals in polluted area's vegetables might be due to high contents of metals in the soil as caused by irrigation with metal contaminated water released from industries. At Keranigonj (indirectly polluted area), the river Buriganga is highly polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution. During rainy season, the river water overflooded and submerged the banks and polluted the cultivated land. However, the higher concentrations of Pb, Cd and Ni in industrially polluted area (Konabari) indicates that industrial activities, such as textile, paint, battery, milling and chemical industries contaminate or introduce heavy metals into the soil. These findings corroborate with the findings of Srikanth and Reddy (1991), who showed that sludge and industrial polluted soils have more Cd and Pb than soil free from sludge and industrial pollution.

Conclusion

Industrial effluents and urban pollution associated with sewage sludge, municipal waste water might have increased the levels of Pb, Cd, and Ni intake of the vegetables and soils. All these metals have toxic potential, but the detrimental impact becomes apparent only after decades of exposure. Monitoring of heavy metals in plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain. These findings suggest further work taking into consideration of variations in different metals uptake for various plant species, fertilization, and different types of polluted soils.

References

Alam, M.G.M., E.T. Snow and A. Tanaka. 2003. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *The Sci. Total Environ.* **308**: 83-96.

Alegria, A., R. Barberfi., R. Boluda., F. Errecalde., R. Farr and M.J. Lagarda. 1991. Environmental cadmium, lead and nickel contamination: possible relationship between soil and vegetable content. *Fresenius J. Anal. Chem.* **339:** 654-657.

Buchaver, M.J. 1973. Contamination of soil and vegetation near zinc smelter by zinc, cadmium, copper and lead. *Environ. Sci. TechnoL* **7:** 131-135.

Dowdy, R.H. and W.E. Larson. 1975. The availability of sludge-borne metals to various vegetable crops. *J. Environ. Qual..* **4:** 278-283.

Guttormsen, G., B.R. Singh and A.S. Jeng. 1995. Cadmium concentration in the vegetables crops grown in sandy soils as affected by Cd levels in fertilizer and soil pH. *Fert. Res.* **41:** 27-32.

Haghiri, F. 1973. Cadmium uptake by plants. *J. Environ. Qual.* **2:** 93-96.

Islam, M. R., M. E. Hoque., M. Jahiruddin and M. Isalm. 2005. Heavy metal contamination of vegetables grown in Chapainawabganj, Bangladesh and its implication to daily intake for human health. *Bang!adesh J. Agric. Environ.* **1**(1): 37-48.

Jamali, M.K., T.G. Kazi., M.B. Arain., H.1. Afridi., N. Jalbani and A.R. Memon. 2007. Heavy metal contents of vegetables grown in soil, irrigated with mixtures of wastewater and sewage sludge in Pakistan, using ultrasonic-assisted pseudo-digestion. *J. Agron.Crop Sci.* **193:** 2 18-228.

Jeevan Rao, K. and M.V. Shantaram. 1999. Potentially toxic elements in soils treated with urban solid wastes. *Indian J. Environ. Health.* **41:** 364-368.

Kaur, H. 2006. M.S. thesis. Department of Biotechnology & Environmental Sciences. Thapar Institute of Engineering and Technology (Deemed University), Patiala, India.

Lokeshwari, H. and G.T. Chandrappa. 2006. Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. *Current Sci.* **91**(5): 1-6.

Olaniya, M.S., M.S. Sur., A.D. Bhide and S.N. Swarnakar. 1998. Heavy metal pollution of agricultural soil and vegetation due to application of municipal solid waste-A case study. *Indian J. Environ.Health* **40:** 160-168.

Omgbu, J.A. and M.A. Kokogbo. 1993. Determination of Zn, Pb, Cn and Hg in soils of Ekpan, Nigeria. 42 *Environ. Int.* **19:** 611-612.

Singh, B. 2001. Heavy metal in soils: sources, chemical reactions and forms. In GeoEnvironment. Proceedings of 2nd Australia and New Zealand Conference on Environmental Geotechnics: Newcastle, New South Wales'. Eds D. Smith, S. fityus and M. AIlman. 77-93.

Somers, E. 1974. The toxic potential of trace metals in foods: A review. *J. Food Sci.* **39:** 215-217.

Srikanth, R. and R. P. S. Reddy. 1991. Lead, cadmium and chromium levels in vegetables grown in urban sewage sludge-Hyderabad, India. *Food Chem.* **40:** 229-234.

Tiller, K.G. 1989. Heavy metals in soils and their environmental. *Advan. Soil Sci.* **9:** 113-142.

Wang, P.F., S.H. Zhang., C. Wang., J. Hou., P. C. Guo and Z.L. Lin. 2008. Study of heavy metal in sewage sludge and in Chinese cabbage grown in soil amended with sewage sludge. *African J. Biotech.* **7**(9): 1329-1334.

Yusuf, A.A., T.A. Arowolo and O. Bamgbose. 2003. Cadmium, copper and nickel levels in vegetables from industrial and residential areas of Lagos City, Nigeria. *Food Chem. Toxicol.* **41:** 375-378.

Zurera, G., B. Estrada., F. Rincon and R. Pozo. 1987. Lead and cadmium contamination levels in edible vegetables. Bull. *Environ. Contamin. Toxicol.* **38:** 805-812.