Bull Environ Contam Toxicol (2012) 89:129–132
DOI 10.1007/s00128-012-0613-z

Metal Contamination in Market Based Vegetables in an Industrial Region, India

Mayuri Chabukdhara · Arvind K. Nema · Sanjay K. Gupta

Received: 16 November 2011 / Accepted: 19 March 2012 / Published online: 4 April 2012

Abstract Concentrations of metals were determined in market vegetables in Ghaziabad industrial region. The average concentrations of metals (mg/kg dry wt.) in vegetables ranged from 0.57 to 9.77, 0.72 to 22.17, 2.76 to 46.63, 2.53 to 5.53, 28.87 to 65.94, 6.77 to 74.1, 8.43 to 161.1, 23.46 to 36.55 and 4.74 to 24.18 for Cu, Cr, Pb, Cd, Zn, Mn, Fe, Ni and Co, respectively. Pb, Cd and Ni were above the recommended limit in all the examined vegetables.

Keywords Metals · Vegetables · Industrial region · Contamination

Dietary intake of metals via vegetables is an important issue owing to food quality and safety. Metals can only change their chemical form; they cannot be degraded or destroyed. Vegetables are exposed to heavy metals either by absorbing them from contaminated soil as well as from deposits on parts of the plants exposed to the polluted air. Excessive and long term intake of metals via vegetables can cause serious health risk to consumers. Heavy metals can cause diseases related to cardiovascular, kidney, bone, etc., and are also implicated in causing carcinogenesis, mutagenesis and teratogenesis (WHO 1992; Steenland and Boffetta 2000; Jarup 2003; Oskarsson et al. 2004). Keeping in view of the potential toxicity, non-degradable nature and cumulative behavior as well as the consumption of vegetables, it is prerequisite to test and analyze these vegetables to ensure that the levels of metals meet the agreed international requirements. In the last two decades, Ghaziabad has expanded more than any other city in terms of industrialization and urbanization in Uttar Pradesh, India. Thus, food safety issue becomes a matter of concern in rapidly urbanizing region. Our objectives were to: (1) determine the level of nine metals (copper, chromium, lead, cadmium, zinc, manganese, nickel, iron and cobalt) in the selected vegetables sold in the local markets of Ghaziabad industrial region, India (2) compare the metals concentrations with the recommended limits (3) evaluate the health risk associated with metals contaminations in the vegetables.

M. Chabukdhara (✉) · A. K. Nema · S. K. Gupta
Environmental Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
e-mail: mayuri_chabukdhara@yahoo.co.in

Materials and Methods

Vegetable samples were collected from the local markets in the Ghaziabad city. The vegetables collected include: Spinach (*Spinacea oleraceae* L.), Carrot (*Daucas carota* L.), Mustard (*Brassica campestris* L.), Turnip (*Brassica rapa* L.), Radish (*Raphanus sativus* L.), Potato (*Solanum tuberosum* L.), Cauliflower (*Brassica oleracea* L.) and Beet (*Beta vulgaris* L.). All vegetables were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs and then were again washed with deionized water and oven-dried at 90°C for 24 h. Vegetable samples were digested by following the method described by Allen et al. (1986). In brief, one gram of vegetable samples was digested (wet acid digestion) with 15 mL of concentrated HNO_3, $H2SO_4$, and $HCIO_4$ in 5:1:1 ratio at 80°C until a transparent solution was obtained. Metals were determined using atomic absorption spectrometry (model 4141, ECI). Wavelengths for Cu, Cr, Pb, Cd, Zn, Mn, Fe, Ni and Co were 324.8, 357.9, 217.0, 228.8, 213.9, 279.5, 248.3, 232.0 and 240.7 nm, respectively. The

detection limits of Cu, Cr, Pb, Cd, Zn, Mn, Fe, Ni and Co were 0.006, 0.007, 0.0025, 0.005, 0.005, 0.003, 0.005, 0.0025, and 0.006 μg/mL, respectively. Recovery test was done by spiking with varied amounts of standard solutions of the metals and recoveries obtained were in the range of 92.5 %–107.6 %. The daily intake of metals (DIM) was determined by the following equation:

$$DIM = [C_{metal}][K][D_{intake}]/B_{average\ weight}$$

where, C_{metal}, K, D_{intake} and $B_{average\ weight}$ represents the heavy metal concentration in plant (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 daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively, as used in previous studies (Ge 1992; Wang et al. 2005). The health risk index (HRI) was calculated as suggested by US EPA (2002):

$$HRI = DIM/R_fD$$

where, DIM and R_fD represents daily intake of metals and reference oral dose respectively. Oral reference doses used for calculation were 0.04, 0.3, 0.001, 0.004, 0.02, 1.5, 0.06 and 0.14 mg/kg/day for Cu, Zn, Cd, Pb, Ni, Cr, Co and Mn, respectively RAIS 2003. The $HRI < 1$ indicates the exposed population to be safe.

Results and Discussions

The mean concentrations of metals (Cu, Cr, Pb, Cd, Zn, Mn, Fe, Ni, and Co) in vegetables sampled from the local markets in Ghaziabad are shown in Fig. 1. The concentrations of metals were also compared with the safe limits for metals set by FAO/WHO 2001 and Prevention of Food Adulteration (PFA) Act 1954 (Awasthi 2000). Pb and Cd were above the recommended limit in all the examined vegetables (Fig. 1). The relatively high Pb found in all vegetables could be attributed to deposition from industrial and vehicle fume. Cd may have its origin from contaminated irrigation water and atmospheric deposition. No international standards or guidelines exist for Cr, Fe, Mn, Co or Ni. On comparing Cr levels with Indian standards (Awasthi 2000), it is observed that except for the Turnip, all vegetables were within safe limits (Fig. 1) while Ni level exceeded the limit in all examined vegetables (Fig. 1). Metals contaminations reported in previous studies have been listed in Table 1. Cr and Ni levels in all the tested vegetables in the present study exceeded those reported in the previous studies (Song et al. 2009; Sharma

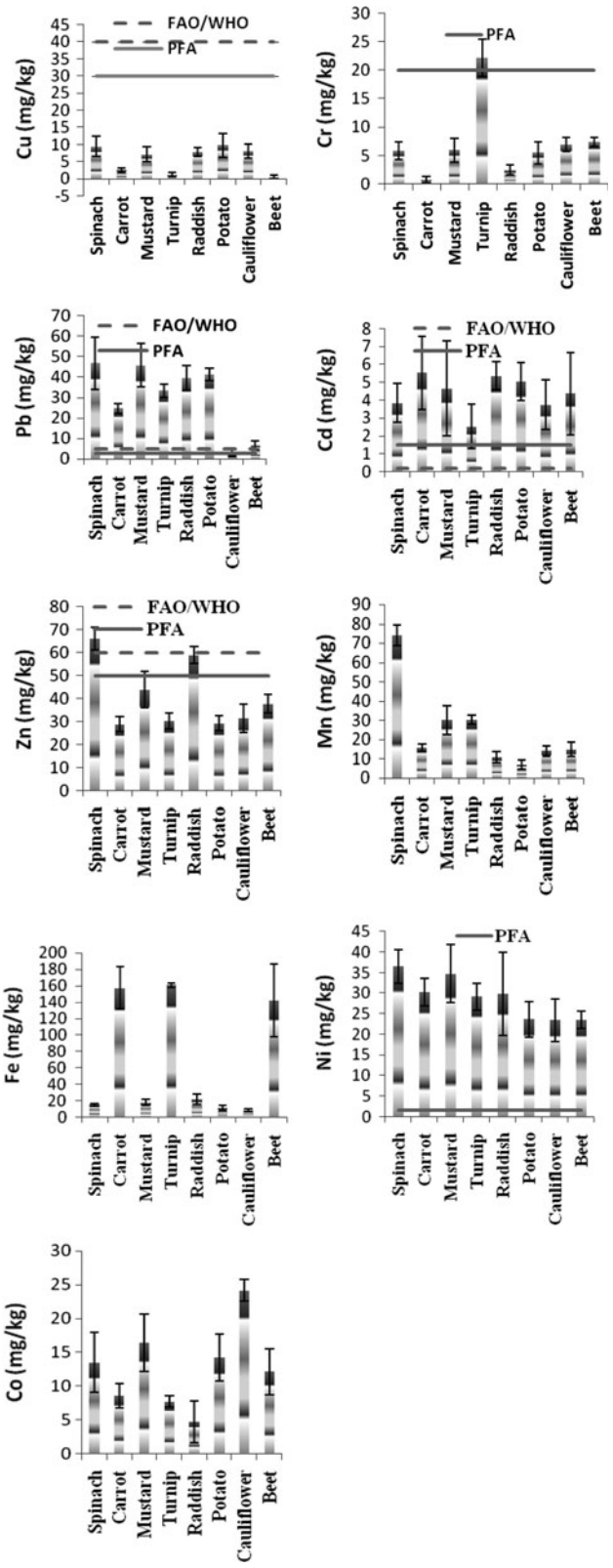

Fig. 1 Mean concentrations of metals (mg/kg dry wt.) in the market vegetables

Table 1 Metals reported in vegetables in literature data of similar studies in the world (mg/kg dry wt.)

Vegetables	Cu	Cr	Pb	Cd	Zn	Ni	References
Spinach, Egypt	4.5	–	0.34	0.11	20.89		Radwan and Salama (2006)
Spinach, India	27.6	–	1.44	1.96	57.56	–	Sharma et al. (2009)
Spinach China (fw)	0.7	0.089	0.031	0.018	2.99	0.07	Song et al. (2009)
Carrot, Egypt	1.5	–	0.18	0.01	8.03	–	Radwan and Salama (2006)
Carrot, China	0.53–0.8	–	0.003–0.004	0.14–0.15	3.229–5.127	–	Zheng et al. (2007)
Radish, China (fw)	0.34	0.031	0.074	0.012	2.48	0.07	Song et al. (2009)
Potato, Egypt	0.83	–	0.08	0.02	7.16	–	Radwan and Salama (2006)
Potato, Pakistan	0.10	0.15	0.16	0.08	–	0.8	Parveen et al. (2003)
Potato, China, fw	1.03	0.029	0.067	0.015	3.77	0.054	Song et al. (2009)
Cauliflower, India	35.72	–	1.56	2.57	63.63	–	Sharma et al. (2009)
Cauliflower, China, fw	0.6	0.02	0.03	0.014	5.45	0.68	Song et al. (2009)

Table 2 Estimated HRI for adults via consumption of vegetables

Vegetables	Cu	Cr	Pb	Cd	Zn	Mn	Fe	Ni	Co
Spinach	0.124	0.002	**6.115**	**2.019**	0.115	0.277	0.026	0.959	0.118
Carrot	0.033	0.0002	**3.235**	**2.901**	0.050	0.059	0.275	0.794	0.075
Mustard	0.093	0.0021	**5.997**	**2.439**	0.0768	0.113	0.031	0.912	0.144
Turnip	0.015	0.008	**4.358**	**1.327**	0.053	0.114	0.282	0.763	0.0676
Radish	0.102	0.0008	**5.169**	**2.817**	0.103	0.0413	0.037	0.783	0.041
Potato	0.128	0.0019	**5.403**	**2.633**	0.0511	0.025	0.020	0.62	0.125
Cauliflower	0.106	0.0024	0.362	**1.962**	0.0551	0.053	0.015	0.615	0.2114
Beet	0.007	0.0026	0.8433	**2.292**	0.066	0.056	0.248	0.618	0.1064

Letters shown in bold letters are with HRI >1

Table 3 Estimated HRI for children via consumption of vegetables

Vegetables	Cu	Cr	Pb	Cd	Zn	Mn	Fe	Ni	Co
Spinach	0.142	0.0023	**7.03**	**2.322**	0.132	0.319	0.0304	**1.10**	0.136
Carrot	0.038	0.0003	**3.72**	**3.335**	0.058	0.067	0.316	0.913	0.086
Mustard	0.106	0.0024	**6.89**	**2.804**	0.0883	0.129	0.0358	**1.05**	0.1651
Turnip	0.017	0.009	**5.009**	**1.526**	0.0609	0.131	0.3238	0.877	0.077
Radish	0.117	0.0009	**5.94**	**3.238**	0.1184	0.047	0.0432	0.90	0.047
Potato	0.147	0.0022	**6.211**	**3.027**	0.0588	0.029	0.0234	0.713	0.143
Cauliflower	0.1223	0.0028	0.416	**2.255**	0.0634	0.061	0.0169	0.707	0.243
Beet	0.008	0.0029	0.969	**2.635**	0.0758	0.064	0.2856	0.710	0.122

Letters shown in bold letters are with HRI >1

et al. 2009; Parveen et al. 2003). Zn is essential to neutralize the toxic effects of Cd. In this study, the highest quantity of Zn was found in Spinach (65.94 mg/kg). Further, Zn values exceeded the FAO/WHO (2001) safe limit in Spinach and Indian safe limit in Radish (Fig. 1). To appraise the health risk associated with heavy metal contamination of market vegetables in the vicinity of Ghaziabad industrial area, DIM and HRI were calculated. The DIM for Cu, Cr, Pb, Cd, Zn, Mn, Fe, Ni and Co ranged from 0.0003 to 0.0051, 0.0004 to 0.011, 0.001 to 0.024, 0.001 to 0.003, 0.015 to 0.035, 0.003 to 0.039, 0.004 to 0.084, 0.012 to 0.019 and 0.002 to 0.013, respectively, for adults and from 0.0003 to 0.006, 0.0004 to 0.0013, 0.001 to 0.028, 0.002 to 0.003, 0.017 to 0.039, 0.004 to 0.045, 0.005 to 0.097, 0.014 to 0.022 and 0.003 to 0.014, respectively, for children. HRI values for adult and children are shown in Tables 2 and 3. Overall HRI ranged: 0.007–0.128 (Cu), 0.0002−0.008 (Cr), 0.362–6.115 (Pb), 1.327–2.901 (Cd), 0.05–0.115 (Zn), 0.025–0.277 (Mn), 0.015–0.282 (Fe), 0.62–0.959 (Ni), and 0.041 to 0.2114 (Co) in adults and in

children HRI ranged from 0.008 to 0.147 (Cu), 0.0003 to 0.009 (Cr), 0.416–7.03 (Pb), 1.526–3.335 (Cd), 0.058–0.132 (Zn), 0.029–0.319 (Mn), 0.017–0.324 (Fe), 0.707–1.1 (Ni), and 0.047–0.243 (Co). DIM and HRI values indicated that the intake of Pb and Cd contaminated vegetables can pose serious health threat to the local consumers. Mapanda et al. (2007) also reported potential health risk due to Cd intake via leafy vegetables, in Harare, Zimbabwe. Based on HRI values the health threat of individual vegetables for Pb was of the order: Spinach > Mustard > Potato > Radish > Turnip > Carrot > Beet > Cauliflower and for Cd it was: Carrot > Radish > Potato > Mustard > Beet > Spinach > Cauliflower > Turnip. Singh et al. (2010) also reported potential health risk due to Pb, Cd and Ni contamination in locally produced vegetables in Varanasi, India. Regular monitoring of metals in vegetables and other food items should be performed and appropriate safety measures should be taken at the time of transportation, storage and marketing of vegetables. In addition, the source of vegetables should also be monitored and suitable measures should be taken to deal with the contamination.

References

Allen SE, Grimshaw HM, Rowland AP (1986) Chemical analysis. In: Moore PD, Chapman SB (eds) Methods in plant ecology. Blackwell Scientific Publication, Oxford, London

Awasthi SK (2000) Prevention of food adulteration act no. 37 of 1954. Central and state rules as amended for 1999, 3rd edn. Ashoka Law House, New Delhi

FAO/WHO (2001) Codex alimentarius commission. Food additives and contaminants. Joint FAO/WHO food standards program 2001

Ge KY (1992) The status of nutrient and meal of Chinese in the 1990s. People's Hygiene Press, Beijing, pp 415–434

Jarup L (2003) Hazards of heavy metal contamination. Br Med Bull 68:167–182

Mapanda F, Mangwayana EN, Nyamangara J, Giller KE (2007) Uptake of heavy metals by vegetables irrigated using wastewater and the subsequent risks in Harare, Zimbabwe. Phys Chem Earth 32:1399–1405

Oskarsson A, Widell A, Olsson IM, Grawé KP (2004) Cadmium in food chain and health effects in sensitive population groups. Biometals 17:531–534

Parveen Z, Khuhro MI, Rafiq N (2003) Market basket survey for lead, cadmium, copper, chromium, nickel and zinc in fruits and vegetables. Bull Environ Contam Toxicol 71:1260–1264

Radwan MA, Salama AK (2006) Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food Chem Toxicol 44:1273–1278

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

RAIS, Risk Assessment Information System (2003) Guidance for developing ecological soil screening levels (Eco-SSLs)

Sharma RK, Agrawal M, Marshall FM (2009) Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. Food Chem Toxicol 47:583–591

Singh A, Sharma RK, Agrawal M, Marshall FM (2010) Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food Chem Toxicol 48:611–619

Song B, Mei L, Chen T, Zheng Y, Yunfeng X, Xiaoyan L, Ding G (2009) Assessing the health risk of heavy metals in vegetables to the general population in Beijing, China. Environ Sci 21:1702–1709

Steenland K, Boffetta P (2000) Lead and cancer in humans: where are we now? Am J Indus Med 38:295–299

United State, Environmental Protection Agency, Region 9 (2002) Preliminary remediation goals. http://www.epa.gov/region09/waste/sfind/prg.2002

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

WHO (1992) Cadmium. In: Environmental health criteria, Geneva, p 134

Zheng N, Wang Q, Zhang X, Zheng D, Zhang Z, Zhang S (2007) Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. Sci Total Environ 387:96–104