J. Indian Chem. Soc.,
Vol. 94, September 2017, pp. 1037-1043

Assessment of heavy metals in the vegetables grown in the Suburbs of Jodhpur city

Rajshri Soni and Pallavi Mishra*

Department of Chemistry, J. N. V. University, Jodhpur-342 001, Rajasthan, India

E-mail : pallavianuk@gmail.com

Manuscript received 07 July 2017, accepted 16 August 2017

Abstract : Jodhpur city comes in the Thar Desert area of Rajasthan where water availability is very low. Due to shortage of water, irrigation with effluents is very common here, as it provides farmers a very reliable and cheap water source. There are over 10,000 textile and other industrial units. These are discarding effluent water (without treatment) directly in to the drain which are connected to five nallahs. Water from these nallah finally meets with Jojari river. Farmers are using this water directly by installing pipes and pumps for irrigation. This effluent water is contaminating the soil with toxic metal ions. The toxic metal ions from the soil infiltrate into the plant tissues and with continuous ingestion, the contaminated vegetables are causing many health problems to the living organisms. To evaluate metal toxicity in the vegetables, we have conducted a detailed study of the vegetables grown in the problematic areas. Samples were collected, prepared and then analyzed for toxic metal contents using atomic absorption spectrophotometer (AAS). The results were compared with limits prescribed by WHO. Most of the leafy vegetables grown here were found to be severely contaminated with Cd, Cu, Cr, Co, Ni, Fe and Pb. If such vegetables are consumed regularly it can contribute to various diseases including cancer, kidney failure, and heart and skin diseases. Therefore it is strongly recommended to stop the use of industrial effluent water and sewage waste water for irrigation before a prescribed treatment to stop toxic metal infiltration to the edibles and ensure safety of human life.

Keywords : Metal toxicants, industrial effluents, metal induced diseases, atomic absorption, spectrophotometer.

Introduction

Heavy metal contamination of vegetables cannot be under-estimated as these foodstuffs are important components of human diet. As most of the people of Jodhpur are vegetarian, fruits and vegetables are the only rich sources of vitamins, minerals, fibers, and also antioxidants. However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance. Rapid urban and industrial development and use of effluent water for irrigation have contributed to the elevated levels of heavy metals in the urban environment of developing countries such as India[1–3].

Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism for their body excretion[4]. Excessive accumulation of heavy metals in the agricultural soil not only results in soil contamination, but also affects food quality and safety. It is known fact that, majority of population in India suffers from malnutrition. Heavy metals are significantly responsible for health risk to humans[5]. Dietary exposure to heavy metals like cadmium, lead, zinc and copper has been observed as a risk factor to human health through vegetables consumption. Furthermore, consumption of heavy metals contaminated food can significantly reduce essential nutrients in the body responsible for decrease in immunological defenses, impaired psycho-social behavior, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer[6]. Leafy vegetables are very common in daily intake of diet by all most all populations throughout the world due to their richness in vitamins, minerals, fibers and anti-oxidative effects. However, leafy vegetables such as radish and cabbage are said to be good in absorbing heavy metals from soil[7,8].

Methods and materials :

Atomic absorption spectroscopy was used to analyze the samples for estimation of metals as described below.

Site description :

Jodhpur is one of the important industrial cities of Rajasthan where you can see numerous big and small scale industries of various product and services. Specially textile, tie and dye printing, gwargum, steel, handicrafts polishing and painting industries. The water used in these industries is directly poured into the nallah. These nallah finally meet with Jojari river. We have taken different vegetable samples from the agriculture fields near the Jojari river and shockingly discovered that irrigation was done by river's contaminated water. Pumps were installed in the nallah and Jojari river to irrigate the nearby fields with effluent and sewage water.

The field's area is marked in the map in Fig. 1 and a picture in Fig. 2 depicts vegetable fields irrigated with the Jojari river's effluent water.

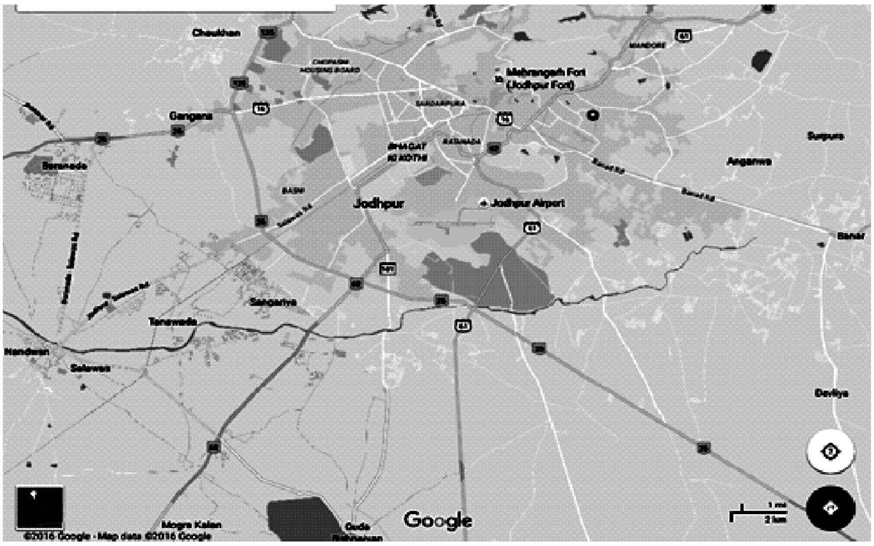

Fig. 1. Jojari river on map.

Fig. 2. Vegetables fields irrigated with effluent water.

Sample collection :

A diversity of vegetables are grown in the study area : *Brassica oleracea capitata, Brassica oleracea botrytis, Spinacia oleracea, Allium fistulosum, Coriandrum sativum, Raphanus sativus, Trigonella foenum graecum, Mentha, Chenopodium, Cucumis sativus* were collected from each site of the sampling zone in 3–5 replicates and stored in labeled polythene sampling bags and brought to the chemistry laboratory, New Campus, Jai Narayan Vyas University, Jodhpur, Rajasthan. They were washed with tap water to remove any kind of deposition like soil particles. Edible parts of vegetables were then oven dried and ground into powdered form and then digested in the acids.

Preparation of samples :

The 0.5 g well homogenized sample was weighed into a clean silica dish and 0.5 mL of 20% sulphuric acid was added. Thorough mixing of wet samples was done with constant stirring. The rod was rinsed with water into clean silica dish. Content of the dish was dried in an oven at 100 °C. Then it was heated over a soft flame until all volatile matter was removed. Now the dish was transferred to a furnace set at 250 °C and temperature was raised slowly to 500 °C for about 6 to 8 h. If the ash was not carbon free, 0.5 mL of nitric acid was added and dish was returned to the furnace at 500 °C and ash treatment was done for about 30 min. Then, 1 ml of nitric acid and 10 ml of water was added to clean the ash and the mixture was heated till the ash was dissolved. The content was qualitatively transferred to a 50 mL volumetric flask. Dish was heated with 10 mL of hydrochloric acid (1+1) and was transferred again to the same volumetric flask. Water was added to make up the volume. Blank solutions were prepared using the same procedure described for samples[9,10]. Same quantities of reagents including water were used for sample and blank. All chemicals used were of analytical grade. The 1000 ppm stock solution of each of the metal ion was prepared and required dilutions were made for the purpose of calibration curves. Both sample and blank solutions were analyzed on Atomic Absorption Spectroscope and concentrations of all metals were determined.

Results and discussion

The concentration of heavy metals in vegetables varied depended on the species of the vegetables as listed in Table 1. The concentration values obtained in the contaminated vegetables, as shown in Table 2, were compared with the permissible limits as prescribed by WHO and FAO, as shown in Table 3. The graphs of vegetables and various metal ion concentrations found are also plotted.

Cadmium :

Cadmium is widely distributed in the environment. Its extensive use has resulted in widespread contamination of soil, air, water, vegetation, and food supplies. Cadmium and its compounds are widely used in electroplating metals, alloys and in many industrial, household, and office products, in pigments in paints, enamels, glazes textiles, and plastics[11–13].

Table 1. List of vegetables taken for analysis from the affected fields

Plant species	Family	English name	Vernacular name	Part used
Allium fistulosum	Amaryllidaceae	Spring onion	Pyaaz	Leaves and stem
Trigonella foenum graecum	Fabaceae	Fenugreek	Methi	Leaves and seeds
Coriandrum sativum	Apiaceae	Coriander	Dhania	Leaves
Spinacia oleracea	Amaranthaceae	Spinach	Paalak	Leaves
Raphanus sativus	Brassicaceae	Radish	Mooli	Leaves and stem
Mentha	Lamiaceae	Mint	Pudina	Leaves
Cucumis melo	Cucurbitaceae	Cucumber	Kakdi	Fruit
Brassica oleracea capitata	Brassicaceae	Cabbage	Patta Gobhi	Leaves
Brassica oleracea botrytis	Brassicaceae	Cauliflower	Phool Gobhi	Floral part

Table 2. Heavy metal concentration (in ppm) found in the contaminated vegetables

Samples	Fe	Co	Ni	Cu	Cd	Cr
Cauliflower	1.277	0.1847	0.4084	0.2055	0.1693	0.08824
Cabbage	0.1279	0.1516	0.2428	0.2059	0.1019	ND[a]
Radish	0.1385	0.1787	0.2375	0.1859	0.1108	0.03714
Fenugreek	0.1705	0.153	0.2373	0.2737	0.1091	ND[a]
Spring onion	0.994	0.356	0.2983	0.4633	0.1682	0.0423
Mint	0.1394	0.2406	0.3864	0.3111	0.1653	0.01192
Chandaliya	0.1352	0.1626	0.2714	0.1684	0.1152	0.08728
Coriander	0.1234	0.1503	0.2829	0.2059	0.1341	0.0133
Lattice	0.1834	0.1698	0.3951	0.2358	0.1392	0.02024
Cucumber	0.1569	0.1778	0.266	0.1663	0.1117	ND[a]

[a]ND : Not Detected in sample analysis.

Table 3. Permissible limits of heavy metals given by WHO and ICMR in ppm

Characteristics	WHO	ICMR
Iron	0.3	0.3
Cadmium	0.003	0.01
Chromium	0.05	0.05
Zinc	5–15	<15
Copper	1.0	0.05 to 1.5
Nickel	<1.0 (0.5)	0.5
Cobalt	0.09	0.09

Food generally contains less than 0.05 ppm of cadmium, providing an estimated 0.5 mg cadmium/week.

Certain compounds of cadmium (Cd) are highly toxic to humans. Cadmium is readily taken up by plants. Potential source of cadmium toxicity is the use of commercial sludge for fertilizing agricultural fields[14]. An exposure to cadmium increases calcium excretion thus causes skeletal demineralization; probably leading to increases in bone fragility and risk of fractures[15], leads to reduced birth weights and premature child birth[16–20]. Cadmium and its compounds are currently classified by IARC as a Group 1 carcinogen for humans.

In the present study cadmium was found to be in the range of 0.1019–0.1693 ppm. Higher levels were observed in all the samples. Cadmium accumulated in each vegetable was found to be much higher than the maximum permissible value (0.003 ppm) regulated by FAO/WHO which is a big threat to the health of the consumers.

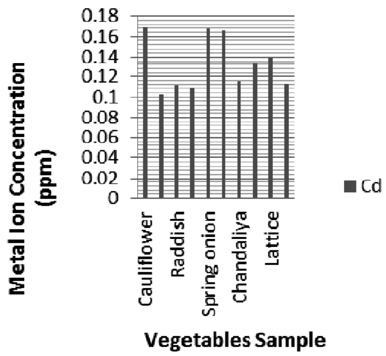

Fig. 3. Cd concentration in vegetables.

The levels of cadmium in the vegetables were varied in following order : Cauliflower > Spring onion > Mint > Lattice > Coriander > Chandaliya > Cucumber > Radish > Fenugreek.

Chromium :

Chromium enters into various environmental matrices (air, water, and soil) from a wide variety of natural and anthropogenic sources with the largest release coming from industrial establishments. Industries with the largest contribution to chromium release includes metal processing, tannery facilities, chromate production, stainless steel welding, and ferrochrome and chrome pigment production. [Cr^{VI}] is a toxic industrial pollutant that is classified as human carcinogen by several regulatory and non-regulatory agencies[21–23].

Allergic dermatitis, skin and nasal septum lesions,

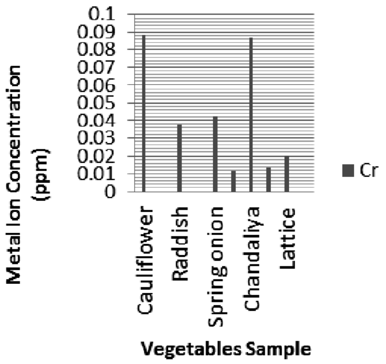

Fig. 4. Cr concentration in vegetables.

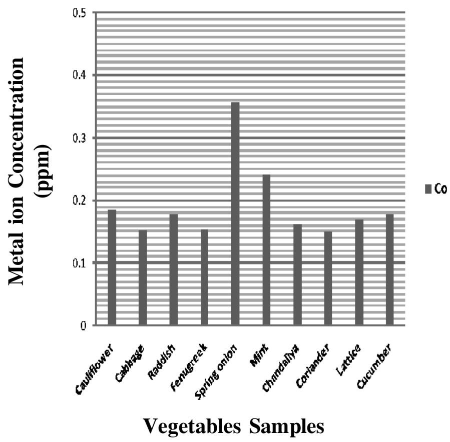

Fig. 5. Co concentration in vegetables.

and increased incidence of lung cancer[24], have been reported due to increased levels of chromium.

In the present study chromium was found to be in the range of 0.01192–0.08824 ppm. In three samples no Cr was found. The concentrations of chromium in some of vegetables were above the maximum value. The levels of chromium in the Cauliflower and Chandaliya were high. The levels of chromium in the vegetables were varied in following order : Cauliflower > Chandaliya > Cabbage > Spring onion > Radish > Lattice > Coriander > Mint.

Cobalt :

Cobalt is an essential element for life in minute amounts. The lethal dose value for soluble cobalt salts has been estimated to be between 150 and 500 mg/kg or 1 mg/m^3. However, chronic cobalt ingestion has caused serious health problems at doses far less than the lethal dose after nickel and chromium, cobalt is a major cause of contact dermatitis.

In the present study cobalt was found to be from 0.11 to 0.73 mg/L, which is higher than normal limits as prescribed by WHO/FAO.

Copper :

In humans Cu is necessary for the development of connective tissue, nerve coverings, and bone, for the function of many enzymes, electron transfer, and other factors. Copper is relatively nontoxic to most mammals. Excess intakes of copper causing acute or even chronic toxic effects are rare. Acute Cu intoxication leads to gastrointestinal effects characterized by abdominal pain, cramps, nausea, diarrhea, and vomiting[25].

In the present study copper was found to be in the range of 0.1663–0.4633 ppm. The copper in most vegetables was within limits of the maximum limit regulated by FAO/WHO except the concentrations in Spring onion and Mint was found a bit higher 0.463 and 0.311 ppm respectively. The lowest below limit concentration of Cu was obtained in cucumber.

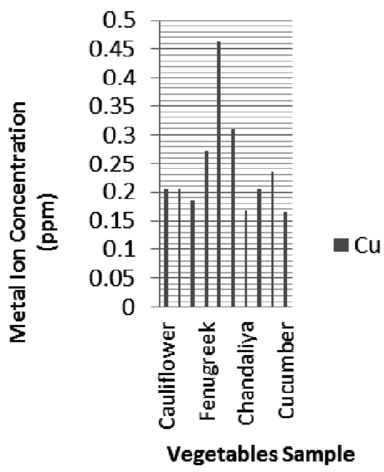

Fig. 6. Cu concentration in vegetables.

Iron :

Iron is one of the most investigated and best understood of nutrients. Iron deficiency is the most common nutritional defect worldwide[26, 27]. Over the long term, excessive accumulation of body iron not only results in excessive iron stores, but also can damage various organs when iron cannot be adequately contained in stores.

In the present study iron was found to be between 0.994–1.277 mg/L. In few samples the limit was very high than permissible limits. The levels of iron in the edible parts of vegetables were found in the range of 0.994 to 1.277 ppm. The iron accumulation exceeded the safe limit of FAO/WHO.

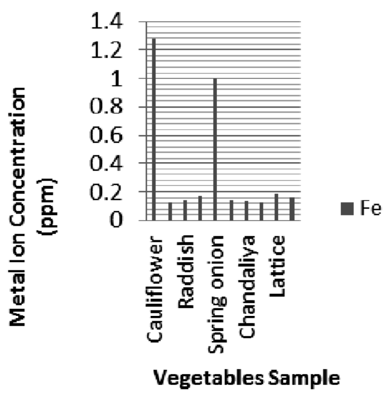

Fig. 7. Fe concentration in vegetables.

Nickel :

Excess of nickel causes damage to lungs, liver and kidney[28]. The nickel was found to be between 0.02–3.41 mg/L in all samples, which are very high values causing contamination of vegetables and affecting health.

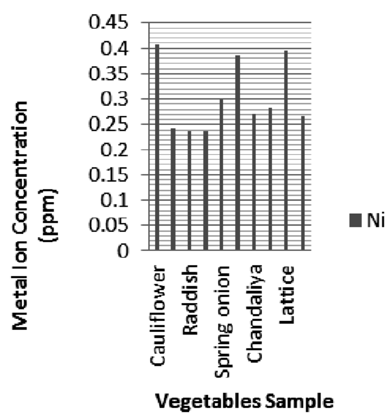

Fig. 8. Ni concentration in vegetables.

Conclusion

The samples collected from the fields irrigated with effluent water and vegetable markets showed very high concentrations of heavy metal ions. If eaten for a long time they not only accumulate in the vital body parts but also cause severe health hazards. The increased levels of Cd were observed in all the samples. Most of the samples showed high concentrations of Ni, Co, Cr, Cu and Fe and this is scary as they causes renal dysfunction, hypertension, bronchitis, and cancer. Two samples showed Pb contents which directly affects central nervous system. The speed with which cancer, kidney failure cases, hypertension, heart problems and skin problems are increasing in the problematic area, the irrigation with effluent water should be stopped immediately as most of the toxic metals are coming from textile industries, dyeing industries, paints industries, batteries, pesticides, fertilizers etc. to the soil and then to vegetables. The authorities should take strong measures to make it mandatory to set up an effluent treatment plant in each industry to stop direct throwing of effluent water in to nallah and subsequently to Jojari river. They should impose punishment on the use of effluent water for irrigation; people should be made aware of the harmful effects of contaminated vegetables use. Then only our lives and our future generations will be saved.

Acknowledgement

The authors are thankful to the UGC, New Delhi for providing financial assistance. The authors would also like to thank Dr. Rajesh Kumar, DRDO, Jodhpur for helping in carrying out the analysis by AAS.

References

1. M. A. Radwan and A. K. Salama, *Food and Chemical Toxicology,* 2006, **44**, 1273.
2. Marshall, Crop Post Harvest Program, Final Technical Report, 2004, (R7530) 8.
3. S. Khan, Q. Cao, Y. M. Zheng, Y. Z. Huang and Y. G. Zhu, *Environ. Poll.,* 2008, **152**, 686.
4. M. Arora, B. Kiran, S. Rani, A. Rani, B. Kaur and N. Mittal, *Food Chem.*, 2008, **111**, 811.
5. U. C. Gupta and S. C. Gupta, *Comm. Soil Sci. Plant Anal.*, 1998, **29**, 1491.

6. A. G. Kachenko and B. Singh, *Water, Air and Soil Pollution*, 2006, **169**, 101
7. A. Eslami, Gh. R. J. Khaniki, M. Nurani, M. Meharasbi, M. Peyda and R. Azimi, *J. Biol. Sci.*, 2007, **7**, 943.
8. H. Lokeshwari and G. T. Chandrappa, *Curr. Sci.*, 2006, **91**, 622.
9. S. E. Allen, H. M. Grimshaw and A. P. Rowland, Blackwell Scientific Publications, Oxford, London, 1986, 285.
10. Joint FAO/WHO Expert Committee on Food Additives. Summary and conclusions, In : 53rd meeting, Rome, 1–10 June (1999), 12.
11. M. Farooq, F. Anwar and U. Rashid, *Pak. J. Bot.*, 2008, **40**, 2099.
12. W. Haiyan and A. O. Stuanes, *Water, Air and Soil Poll.*, 2003, **147**, 79.
13. R. P. Singh and M. Agrawal, *Ecotoxicology and Environment Safety*, 2010, **73**, 632.
14. NRC, 1969, A report of the National Materials Advisory Board. Publ. NMAB 255. U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia.
15. S. S. Deshpande "Handbook of Food Toxicology", 1st Indian print, CRC Press, 2014, Chap. 6, 119.
16. J. Tallkvist, C. L. Bowlus and B. Lonnerdal, *Tox. Lett.*, 2001, **122**, 171.
17. X. Wu, T. Jin, Z. Wang, T. Ye and Q. Kong, *J. Occup. Environ. Med.,* 2001, **43**, 898.
18. M. C. Henson and P. J. Chedrese, *Exp. Biol. Med.,* 2004, **229**, 383.
19. T. Asami, (Ed.) J. O. Nriagu, Springer-Verlag, Berlin, 1984, 95.
20. Y. L. Zhang, Y. C. Zhao, J. X. Wang, H. D. Zhu, Q. F. Liu, Y. G. Fan, N. F. Wang, J. H. Zhao, H. S. Liu and L. Ou Yang, *J. Environ. Sci. Health (B)*, 2004, **39**, 2507
21. Agency for Toxic Substances and Disease Registry (ATSDR). U.S. Department of Health and Human Services, Public Health Service, (1998–2001) report.
22. U.S. EPA, Environmental Criteria and Assessment Office. Cincinnati, OH : United States Environmental Protection Agency; 1992, Integrated Risk Information System (IRIS), 2005.
23. W. Mertz, *Physiol. Rev.*, 1969, **49**, 163.
24. E. J. O'Flaherty, W. Mertz, C. O. Abernathy, and S. S. Olin, ILSI Press, Washington D.C., 1994, 213
25. S. Kanumakala, A. Boneh and M. Zacharin, *J. Inherit. Metab. Dis.*, 2002, **25**, 391.
26. E. DeMaeyer, M Adiels-Tegman and E. Rayson, *World Health Stat. Q*, 1985, **38**, 302.
27. R. Yip and P. R. Dallman, E. Ziegler and L. J. Filer (eds.), 7th ed., ILSI Press, Washington, D.C., 1996, 277 .
28. MMAF, 2005, Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India, New Delhi.