World Applied Sciences Journal 6 (12): 1602-1606, 2009
ISSN 1818-4952

Health Risk Assessment of Heavy Metals for Population via Consumption of Vegetables

[1]Sajjad Khan, [2]Robina Farooq, [2]Shagufta Shahbaz,
[1]Mohammad Aziz Khan and [2]Maria Sadique

[1]Department of Biochemistry, NIMS College of Medicines, Abbottabad, Pakistan
[2]Department of Environmental Science,
COMSATS Institute of Information Technology, Abbottabad, Pakistan

Abstract: The heavy metals pollution is one of the problems that arise due to the increased uses of fertilizers and other chemicals to meet the higher demands of food production for human consumption. Health risk assessment for heavy metals of the population is a very good technique because such assessment would be useful to give information about any threat regarding heavy metals contamination in vegetables. For health risk assessment different methods are used by different researchers. In this review paper different methods, for assessment of the heavy metals concentration in the human body contributed by contaminated vegetables, are discussed. These methods include the daily intake of metals (DIM), daily dietary index (DDI), provisional tolerable daily intake (PTDI), along with the methods used for the health risk assessment. The health risk assessment methods include hazard quotient (HQ) and health risk index (HRI).

Key words: Health risk · Heavy metals · Vegetables

INTRODUCTION

Food safety is a major public concern worldwide. The increasing demands for food and food safety has drawn the attention of researchers to the risks associated with consumption of contaminated foodstuffs i.e. pesticides, heavy metals and or toxins in vegetables [1, 2].

Heavy metals contamination is a major problem of our environment and they are also one of the major contaminating agents of our food supply [2, 4]. This problem is receiving more and more attention all over the world, in general and in developing countries in particular. The biological half-lives of these heavy metals are long and have potential to accumulate in different body organs and thus produce unwanted side effects [5-7].

Lead and Cadmium are the most toxic and the most abundant metals in food.

Excessive accumulation of these heavy metals in human bodies creates the problems like cardiovascular, kidney, nervous and bone diseases [5,8-10].

It is known that serious systemic problems can develop as a result of increased accumulation of dietary heavy metals such as cadmium and lead in the human body [11]. Heavy metals are extremely persistent in the environment; they are non biodegradable and non thermo-degradable and thus their accumulation readily reaches to toxic levels [12].

Heavy metals can impair important biochemical systems, constituting an important threat for the health of plants and animals. The adverse health effects of several chemical elements have been documented throughout history: Greeks and Roman physicians were able to recognize symptoms of acute lead and arsenic poisoning long before toxicology became a science. Currently, the advances of toxicology has improved our knowledge about human exposure to toxic elements and their health effects, such as developmental retardation, several types of cancer, kidney damage, endocrine disruption, immunological disorders (autoimmunity) and even death.

Significant contamination of seeds, plants and plant products with toxic chemical elements due to

Corresponding Author: Dr. Robina Farooq, Department of Environmental Sciences,
COMSATS Institute of Information Technology, Abbottabad, Pakistan
E-mail: drubina@ciit.net.pk

contaminated soil and water has been observed as result of release of these toxicants into the sea, rivers, lakes and even into irrigation channels. Afterwards, the consumption of contaminated vegetables constitute an important route of animal and human exposure.

The tradition of growing vegetables within and at the edges of cities is very old [13]. It should be realized that most of these cultivated lands are contaminated with heavy metals contributed mainly through vehicular emissions, pesticides and fertilizers, industrial effluents and other anthropogenic activities. These contaminated soils have resulted in the growth of contaminated vegetables [14-16]. Heavy metals in soils reduce the yield of vegetables because of disturbing the metabolic processes of plants [17, 18]. Singh and Kumar in 2006 concluded that soil, irrigation water and some vegetables from peri-urban sites are significantly contaminated by the heavy metals i.e. Cu, Cd, Pb and Zn [19]. It was also concluded that Cd and Pb were of more concern than Cu and Zn.

The heavy metals not only affect the nutritive values of vegetables but also affect the health of human beings and therefore, the safe limits of these heavy metals are lowered regularly in these vegetables. This regulation is the responsibility of National and International regulatory authority [20].

Mostly, the concentrations of heavy metals are higher in soils than vegetables grown on the same soils. This indicates that only a small portion of soil heavy metals is transferred to the vegetables and the root acts as a barrier to the translocation of heavy metals within plant [21].

The results of heavy metals contamination differed from area to area as the application of fertilizers and other human activities differ at each site. It is studied that phosphate fertilizers are the main source of soil heavy metals pollution. This pollution is because of the presence of cadmium as an impurity in phosphate rocks. Because of the massive application of these fertilizers, the contamination of heavy metals in soil is resulted [22].

Most of the heavy metals are the natural constituents of earth's crust and from there they are taken by plants and thus transferred to food chain. These metal concentrations vary from soil to soil. Metals concentration of vegetables mainly depends on the texture of soil or media on which they grow but this also depends on the type and nature of plant [23].

Transfer of Heavy Metals from Soil to Vegetables: As the vegetables are the source of human consumption so the soil-to-plant transfer quotient is the main source of human exposure. A convenient way for quantifying the relative differences of bioavailability of metals to plants is the transfer quotient. So for human Health Risk Index (HRI) transfer quotient should be assessed [24]. The transfer quotient for Cd and Cu were higher than other metals i.e. Pb and Fe [25]. The higher transfer quotient of heavy metal indicates the stronger accumulation of the respective metal by that vegetable.

Transfer quotient of 0.1 indicates that plant is excluding the element from its tissues [26]. The greater the transfer coefficient value than 0.50, the greater the chances of vegetables for metal contamination by anthropogenic activities will be and so the need for environmental monitoring of the area will be required [27].

From the recent studies conducted by researchers it is concluded that the transfer coefficient of 0.2 indicates the anthropogenic contamination for leafy plants than 0.50 by Kloke *et al.,* 1984 [28, 29]. They argued that Kloke *et al.* gave a generalized transfer coefficient for soils and plants based on the root uptake of metals. Leafy vegetables accumulate much higher contents of heavy metals as compared to other vegetables. This is because leafy vegetables have higher translocation and transpiration rate as compared to other vegetables in which transfer of metals from root to stem and then to fruit is longer which results in lower accumulation than leafy vegetables [30]. The trend of transfer of these metals was in the order Cd > Cu > Pb > Fe [25].

Many researchers have used the pollution index of soils and sludges to identify element contamination resulting in the increased overall element toxicity [31]. Although the results differ from place to place and researcher to researcher but the basic concept remains the same. Pollution index is calculated by the average ratio of the metal concentration in sample to the tolerable/ permissible levels of soil for the plant growth suggested by [29].

Daily Intake Estimate of Pb, Cu, Cd and Zn: There are many methods for estimating the consumer based health risk assessment in which the Provisional tolerable Daily Intake (PTDI) is also one of the methods. This PTDI is a reference value established by [8, 9]. Mohammad and Ahmed [20] stated that by this method the potatoes contributed 1μg, 2μg, 0.08mg and 0.72 mg of Pb, Cd, Cu and Zn, respectively on the basis of the average 100g/ person /day consumption of potatoes. Similarly for the vegetables diet/person/day is 116.7g. They stated that if the mean concentrations of heavy metals (Pb, Cd, Cu and Zn) remain the same (0.26, 0.04, 3.86 and 13.5), respectively in vegetables, they will contribute 30µg, 4.67µg, 0.45mg and 1.58mg to the daily intake, respectively. They also concluded that PTDI for the Egyptian population were lower than the safe limits by WHO/FAO which are (214µg, 60µg, 3mg and 60mg) respectively, for Pb, Cd, Cu and Zn.

Risk Assessment: Risk of intake of metal-contaminated vegetables to human health was characterized by Hazard Quotient (HQ). This is a ratio of determined dose to the reference dose (R_fD). The population will pose no risk if the ratio is less than 1 and if the ratio is equal or greater than 1 then population will experience health risk. This risk assessment method has been used by researchers [28, 32, 33] and proved to be valid and true. The following equation is used;

$$HQ = [W_{plant}] \times [M_{plant}] / R_fD \times B$$

Where $[W_{plant}]$ is the dry weight of contaminated plant material consumed (mgd^{-1}), $[M_{plant}]$ is the concentration of metal in vegetables (mg kg^{-1}), R_fD is the food reference dose for the metal (mgd^{-1}) and B is the body mass (kg). The values of R_fD for heavy metals were taken from Integrated Risk Information System [2] and Department of Environment, Food and Rural Affairs [34].

Daily Dietary Index: As food crops are contaminated by heavy metals so their daily intake needs to be evaluated for comparison as given by US-EPA. Daily dietary index was determined by the following formula:

$$DDI = X \times Y \times Z / B$$

Where
X = metal in vegetable
Y = dry wt. of the vegetable
Z = approximate daily intake
B = average body mass of the consumers

Daily Intake of Metals (DIM): This is determined by the following equation.

$$DIM = C_{metal} \times C_{factor} \times D_{food\ intake} / B_{everage\ weight}$$

Where
C_{metal} = heay metals conc. in plants (mg/kg)
C_{factor} = conversion factor
$D_{food\ intake}$ = daily intake of vegetables.

The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight [15].

Health Risk Index (HRI): By using Daily Intake of Metals (DIM) and reference oral dose we obtain the health risk index. The following formula is used for the calculation of HRI.

$$HRI = DIM / R_fD$$

If the value of HRI is less than 1 then the exposed population is said to be safe [35].

CONCLUSION

Determination of heavy metals concentration in vegetables and food products is important for health risk assessment during food consumption. This kind of study can be used as a tool for the farmers so that they may adopt such strategies which lead them to save the population by minimizing the problems related to metal toxicities. Such assessment for the contaminants is required for the well-being of the population.

REFERENCES

1. D'Mello, J.P.F., 2003. Food safety: Contaminants and Toxins. CABI Publishing, Wallingford, Oxon, UK, Cambridge, MA. pp: 480.
2. Abdollatif Gholizadeh, A., M. Ardalan, M.T. Mohammadi, H.M. Hosseini and N. Karimian., 2009. Solubility Test in Some Phosphate Rocks and their Potential for Direct Application in Soil. World App. Sci. J., 6(2): 182-190.
3. Zaidi, M.I., A. Asrar, A. Mansoor and M.A. Farooqui, 2005. The heavy metals concentration along roadside trees of Quetta and its effects on public health. J. Appl. Sci., 5(4): 708-711.
4. Khair, M.H., 2009. Toxicity and accumulation of copper in *Nannochloropsis oculata* (Eustigmatophycea, Heterokonta). World App. Sci. J., 6(3): 378-384.

5. Jarup, L., 2003. Hazards of heavy metals contamination. Br. Med. Bull., 68: 167-182.
6. Sathawara, N.G., D.J. Parikh and Y.K. Agarwal, 2004. Essential havy metals in environmental samples from western India. Bul. Environ. Contam. Toxicol., 73: 756-761.
7. Ata. S., F. Moore and S. Modabberi, 2009. Heavy Metal Contamination and distribution in the Shiraz Industrial Complex Zone Soil, South Shiraz, Iran. World. App. Sci. J., 6(3): 413-425.
8. WHO., 1992. Cadmium. Environmental Health Criteria, Geneva. Vol., 134.
9. WHO, 1992. Lead. Environmental Health Criteria, Geneva. Vol. 165.
10. Steeland, K. And P. Boffetta., 2000. Lead and cancer in humans: where are we now? Am. J. Ind. Med., 38: 295-299.
11. Oliver, M.A., 1997. Soil and human health: a review. Eur. J. Soil Sci., 48: 573-592.
12. Bohn, H.L., B.L. McNeal and A.G.O. Connor, 1985. Soil Chemistry, second ed. Wiley-Inter Sci. Pub., New York, USA.
13. Smit, J., 1996. Urban Agriculture, Progress and Prospect 1975-2005. Report 18, Cities Feeding People Series, March 1996, IDRC, Canada.
14. Jackson, A.P. and B.J. Alloway., 1992. The transfer of cadmium from agricultural soils to human food chain, in: D. C. Adriano (ed), Biogeochem. of trace metals, Lewis Publ., F. L. B. Raton., pp: 109-158.
15. Rattan, R.K., S.P. Datta, P.K. Chhonkar, K. Suribabu amd A.K. Singh, 2005. Long-term impact of irrigation with sewage effluents on heavy metals content in soils, crops and groundwater- a case study. Agr. Ecosys. And Environ., 109: 310-322.
16. Sanayei, Y., N. Ismail and S.M. Talebi, 2009. Determination of Heavy Metals in Zayandeh Rood River, Isfahan-Iran. World App. Sci. J., 6(9): 1209-1214.
17. Sanders, J.R., S.P. McGarth and T. Adams, 1987. Zinc, Cu and Ni concentration in soil extracts and crops grown on four soils treated with metal loaded sewage sludges. Environ. Poll., 44: 193-210.
18. Al-Qurainy, F. and A. Abdel-Megeed, 2009. Phytoremediation and Detoxification of Two Organophosphorous Pesticides Residues in Riyadh Area. World App. Sci. J., 6(7): 987-998.
19. Singh, S. and M. Kumar, 2006. Heavy metal load of soil, water and vegetables in peri-urban Delhi. Environ. Monit. And Assessm., 120: 79-91.
20. Mohammad, A.R. and K.S. Ahmed, 2006. Market basket survey for some heavy metals in Egyptian Fruits and vegetables. Food and Chem. Toxicol., 44: 1273-1278.
21. Davies, B.E. and H.M. White, 1981. Trace elements in vegetables grown on soils contaminated by base metal mining. J. Plant. Nutr., 3: 387-396.
22. Zhou, Q., Y. Wu and X. Xiong, 1994. compound pollution of Cd and Znand its ecological effect on rice plant. Chin. J. Appl. Ecol., 5: 428-441.
23. Kabata-Pendias, A. and H. Pendias, 1984. Trace Elements in Soils and Plants. CRC, Press Boca Raton, FL.
24. Cui, Y.L., R.H. Zhu, R.H. Zhi, D.Y. Chen, Y.Z. Huang and Y. Qiu, 2004. Transfer of metals from soils to vegetables in an area near a smelter in Nanning, China, Environ. Intl., 30: 785-791.
25. Khan, S., Q.Y.Z. Cao, Y.Z. Huang and Y.G. Zhu., 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ. Poll., 125(3): 686-692.
26. Thornton, M. and E. Farago, 1997. Geochemistry of Arsenic.In: C. O. Abernathy, R. L. Calderon and W. R. Chappell, Editors, Arsenic, Exposure and Health Effects, Chapman & Hall, London, pp: 27.
27. Sponza, D., N. Karaoglu., 2002. Environmental geochemistry and pollution studies of Aliaga metal industry district. Environ. Int., 27: 541-553.
28. Sridhara Chary, N., C.T. Kamala and D. Samuel Suman Raj, 2008. Ecotoxicol. And Environ. Safe., 69(3): 513-524.
29. Kloke, A., D.R. Sauerbeck and H. Vetter, 1984. The contamination of plants and soils with heavy metals and the transport of metals in terrestrial food chains. In: J. O. Nriagu, Editor, Changing Metal Cycles and Human Health: Report of the Dahlem Workshop on Changing Metal Cycles and Human Health, Germany, Springer, Berlin., pp: 113-141.
30. Itanna, F., 2002. Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiopian. J. Health Dev., 6: 295-302.
31. Chon, H.T., J.S. Ahn and M.C. Jung, 1997. Environmental contamination of toxic heavy metals in the vicinity of some Au-Ag mine in Korea. In: Heikki Papunen, Editor, Mineral deposits: research and exploration- where do they meet? Balkema Publication, pp: 895-898.

32. Chien, L.C., T.C. Hung, K.Y. Chaong, C.Y. Yeh, P.J. Meng and Shieh, 2002. Daily intake of TBT, Cu, Zn, Cd, nd As for fishermen in Taiwan. Sci. Total Environ., 285: 177-185.
33. Wang, X., T. Sato, B. Xing and S. Tao, 2005. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Sci. Total Environ., 350: 28-37.
34. DEFRA (Department of Environment, Food and Rural Affairs), 1999. Total diet study-aluminium, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, tin and zinc. The Stationery Office, London.
35. IRIS., 2003. Integrated Risk Information System-database, US Envrion. Protec. Agency.