Asian Journal of Water, Environment and Pollution, Vol. 7, No. 2, pp. 97-101.

Scientific Note

Bioaccumulation of Cadmium and Lead by *Lycopersicum Esculentum* (L.): Impact on Uptake of Nutritional Elements

Uma Harikishan* and Ashok Kumar

School of Chemical Sciences, Department of Chemistry, St. John's College, Agra

✉ uma_harikishan@yahoo.co.in

Received July 2, 2008; revised and accepted April 21, 2009

Abstract: Phytoextraction is an important technique used for the decontamination of areas polluted by lead and cadmium. Consequently, an understanding of the physiological responses to tolerance of tropical species subjected to increasing levels of contamination is fundamental before considering their use as phytoextractors in contaminated areas. The objective of this study was to assess the lead (Pb) and cadmium (Cd) uptake and the tolerance of *Lycopersicum esculentum* L. The outcome of this study corroborate that *L. esculentum* is a suitable candidate for the phytoremediation of Cd(II) and Pb(II) contaminated soils. Furthermore, the concentration of Cd and Pb determined in the dry root tissue indicates that *L. esculentum* could be considered as a potential Cd and Pb hyperaccumulator.

Key words: Phytoremediation, heavy metals, nutrient uptake, soil.

Introduction

The increasing use of wide variety of metals in industries has caused a serious concern of environmental pollution. These heavy metals are non-degradable and are not acted upon by microbes. Toxicity of these heavy metals ranges from mildly harmful to lethal. In fact, metal changes the biological structure and system into inflexible and irreversible conformation leading to deformity in the body or finally death (Kudesia, 1980). Atmospheric deposition of metals has a direct effect on the contamination of crops used for human and animal consumption (De Temmerman, 2005). Of all the metals in the environment, Cd and Pb may cause some threat to the food chain because of their importance in environmental health, particularly relating to humans (Davies and Wixson, 1988; Sherlock, 1991; Jackson and Alloway, 1992). The main sources for Cd have been some soil-amended materials, such as municipal sewage sludge and phosphates, and fallout from metal production and power plants (Adrinao, 1986; Merian, 1991; Pacyna et al., 1991). The main environmental sources of Pb have been leaded gasoline, mining and smelting activities, and lead paints (Alloway, 1990). Recently, there are available remediation technologies for treating metal-contaminated soils.

Phytoremediation is a new and novel strategy to remove toxic heavy metals from soil through hyperaccumulator species. This is a low cost and eco-friendly means of reclaiming heavy metal contaminated soils, resulting from developmental activities, e.g., discharge of industrial effluents, city wastes, etc. (Panwar et al., 2002).

It was observed that Cd and Pb brought a drastic reduction in root, hypocotyls and shoot lengths of moth bean over the control (Bora et al., 2001). A concentration dependent decrease was noticed in all the parameters like seed germination, seedling height, chlorophyll content, protein content and mitotic index when different doses of Zn^{2+} and Pb^{2+} were applied to *Vicia faba* (L.) (Sinhal et al., 2007).

*Corresponding Author

It has been established that certain wild and crop plant species have the ability to accumulate elevated amounts of toxic heavy metals (Blaylock and Huang, 2000). For instance, some varieties of *Thalspi* and ecotypes of *Silene Vulgaris* have been found to be Cd accumulators (Ernst et al., 2000; Brown et al., 1994). In a study it was found that the moss *Plegiothecium* is a suitable biomonitor species for atmospheric deposition of lead, nickel and zinc (Gupta and Gupta, 2001). It has been reported that garlic has considerable ability to remove Cd from solutions and accumulate it in the roots, bulbs and shoots itself (Liu et al., 2001). At lower concentrations Cd is not toxic to plants, but at higher concentrations it is toxic and characteristically inhibits root growth and cell division in plants such as onions (Avanzi, 1950; Fiskesjo, 1988; Liu et al., 1982), garlic and bean.This study was undertaken to evaluate the hyperaccumulation of Pb and Cd by the *L. esculentum* L. plant.

Materials and Methods

Soil

The top layer of organic matter and about the first inch of soil was removed. The next few inches of soil were collected and placed in plastic bags. These samples were air-dried and passed through a 2 mm stainless steel sieve to obtain a fine powder. The soil extract was then prepared by digesting some amount of the soil with a mixture of HNO_3-H_2O_2 (1:1 v/v). The rest of the soil was extracted with ammonium acetate solution for half an hour using ultra-sonic bath extractor. The soil extracts so obtained were then filtered using Whatmann filter paper and diluted with deionized water for chemical analysis in the laboratory using AAS (Analyst-100, Perkin Elmer).

Plants

Seeds of *L.esculentum* were grown in clay pots at the rate of 10-12 seeds each pot. After germination the number was thinned to 4-3 plants per pot. When the plants became two-week old they were exposed to metal treatment on every alternate day till the termination of the experiment. During metal treatment four different pots containing plants were categorized for each metal (Cd and Pb). Then 0.01, 0.03, 0.05 and 0.07 M concentrations of metals were applied to them. After a period of 45 days the plants were harvested, washed with deionized water and dried in oven at 72° C for 28 hours. Mixture of HNO_3-$HClO_4$ was used for the wet digestion of plant material, which was then taken to the AAS for the analysis of heavy metals.

Solution Preparation

Four different concentrations, 0.01, 0.03, 0.05 and 0.07 M, of solutions were prepared for each of the metals (Cd, Pb and Co). The solutions were prepared from the following salts:

Cd solutions—Cadmium nitrate
Pb solutions—Lead nitrate
Co solutions—Cobalt nitrate

Results and Discussion

The concentrations of Cd and Pb accumulated in the roots, stem and leaves of the *L. esculentum* plants treated with 0.01, 0.03, 0.05 and 0.07 M concentrations of metal solutions are shown in Table 1. It could be observed from the table that the plant accumulated maximum levels of Pb than Cd. The roots of the plant accumulated highest amounts of Pb (542.50-5428.43 µg/g) and the levels of Pb accumulation increased with the concentration of the metal solution applied.

Table 1 shows that the ability of *L. esculentum* to concentrate Cd in the roots (242.09-1517.64 µg/g) was lesser than the ability to accumulate Pb in the roots. However, stem contained moderate levels of Pb (132.74-544.50 µg/g) and Cd (63.01-188.91 µg/g). But in case of Cd the content of metal taken up by the plant was highest in the leaves (22.29-132.64 µg/g). The Cd concentration in the leaves went on increasing as the concentration of the metal solution applied was increased from 0.01 to 0.07 M, while lowest amounts of Pb were recorded in the leaves (15.17-36.44 µg/g). As can be observed from the above table, most of the Pb has not moved to the upper parts of the plants.

Table 1: Levels of heavy metal content (µg/g dry weight) in the roots, stem and leaves of the *L. esculentum* plant after the application of metal solutions

Heavy metal treatment (M)	*Roots*	*Stem*	*Leaves*
Cadmium(II)			
0.01	242.09	63.01	22.29
0.02	638.87	95.15	41.02
0.05	1318.29	119.72	68.44
0.07	1517.64	188.91	132.64
Lead(II)			
0.01	542.50	132.74	36.44
0.02	3274.4	186.4	30.56
0.05	4302.19	295.11	24.09
0.07	5428.43	544.5	15.17

Pb uptake by plants from soils affects predominately the roots, while the upper plant parts are considerably influenced by the absorption of airborne lead (Scheffer and Schachtschabel, 1992). *L. esculentum* has the ability to uptake and accumulates Cd and Pb primarily in its roots with much lower concentrations in the shoots and leaves. These differences in root and shoot uptake might be explained by the fact that one of the normal functions of roots is to selectively acquire ions from the soil solution, whereas shoot tissue does not normally play this role.

Statistical relationship of Cd and Pb with Ca, Mg, K and Na was calculated in the roots, stem and leaves of the plant. Figure 1 shows the correlation of Cd with Ca, Mg, Na and K in the roots. As can be seen from the figure that as the concentration of Cd was increased from 0.01 to 0.07 M the concentration of Ca, Mg and K also increased. There is a strong positive correlation between Cd and Ca ($R^2 = 0.9189$), Mg ($R^2 = 0.9718$) and Na ($R^2 = 0.929$) but K had a moderate relation with Cd ($R^2 = 0.7606$) in the roots of the plant. Similarly, it was found that only K ($R^2 = 0.8962$) had a positive correlation with Pb in the roots (Figure 2) while Ca ($R^2 = 0.8915$), and Mg ($R^2 = 0.900$) had a negative relation with Pb. The relation between Na ($R^2 = 0.5931$) and Pb in the roots was statistically not significant.

In the stem of the plant (Figure 3) only Mg had a strong correlation with Cd ($R^2 = 0.9202$). Ca ($R^2 = 0.6529$), Na ($R^2 = 0.7252$) and K ($R^2 = 0.7478$) increased moderately with the increase in Cd concentration. In case of Pb, Na ($R^2 = 0.915$) and K ($R^2 = 0.6471$) increased on increasing the concentration of Pb but the concentration of Ca ($R^2 = 0.9493$) and Mg ($R^2 = 0.8283$) in the stem decreased on increasing the concentration of Pb solution (Figure 4).

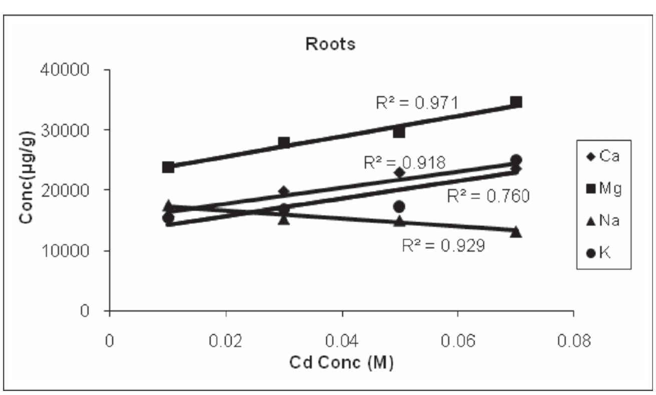

Figure 1: Interrelationship of Cd with Ca, Mg, Na and K in the roots of *L. esculentum* grown on metal treated soil.

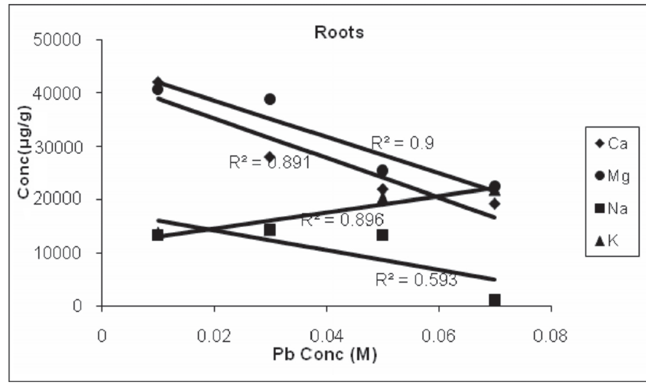

Figure 2: Interrelationship of Pb with Ca, Mg, Na and K in the roots of *L. esculentum* grown on metal treated soil.

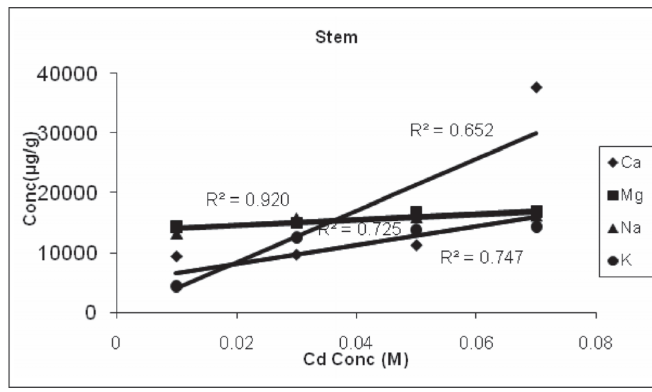

Figure 3: Interrelationship of Cd with Ca, Mg, Na and K in the stem of *L. esculentum* grown on metal treated soil.

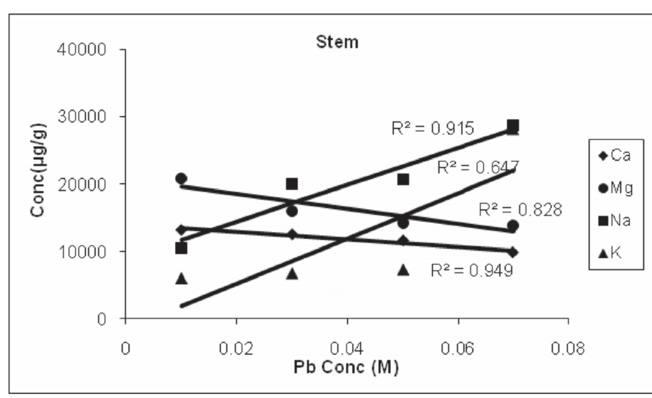

Figure 4: Interrelationship of Pb with Ca, Mg, Na and K in the stem of *L. esculentum* grown on metal treated soil.

On the other hand Na had a negative relation with Cd; on increasing the concentration of Cd the concentration of Na ($R^2 = 0.9297$) in the leaves decreased (Figure 5). In the leaves of the *L. esculentum* plant Pb (Figure 6)

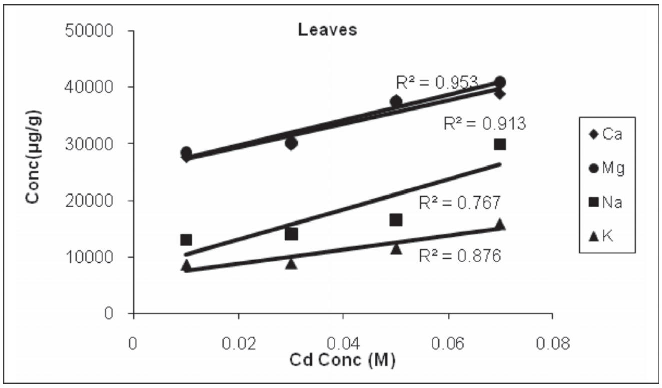

Figure 5: Interrelationship of Cd with Ca, Mg, Na and K in the leaves of *L. esculentum* grown on metal treated soil.

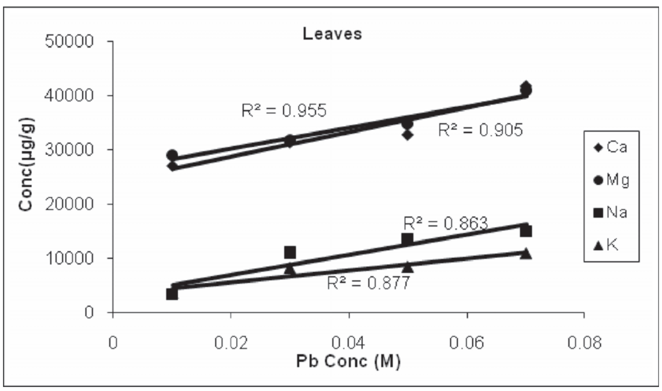

Figure 6: Interrelationship of Pb with Ca, Mg, Na and K in the leaves of *L. esculentum* grown on metal treated soil.

and Cd had a strong correlation with Ca (R^2 = 0.9055 and R^2 = 0.9138 respectively) and Mg (R^2 = 0.9557, R^2 = 0.9532 respectively). As the concentration of the metal solution applied was increased the concentration of the Ca and Mg also increased in the leaves. On the contrary, the concentration of Na and K decreased on the application of Cd and Pb metal solutions to the plant.

From the values obtained by the treatment of metal solution to the plant it can be described that in the beginning in the case of 0.01 M Cd and Pb solutions applied the concentration of Na was highest in the roots but as the concentration of the metal solution applied was increased the accumulation by the roots decreased and by the leaves increased. K was found maximum in the roots and lowest in the leaves for Pb as well as Cd applied plants.

In case of Ca, accumulation was found to increase from 0.01 to 0.07 M of Cd solution applied and was mostly transported to the leaves in maximum amounts. But in case of Pb solution applied the amount of Ca accumulation by the roots decreased as the concentration of Pb solution was increased from 0.01 to 0.07 M. In contrast to it the levels of Ca in the leaves increased as the concentration of the metal solution applied was increased.

The concentration of Mg extracted by the roots increased in case of Cd solution applied to the plants but for the Pb amended plants the concentration of Mg went on decreasing in the roots and increasing in the leaves from 0.01 to 0.07 M concentration of the solution.

From the above data it is evident that presence of all the three metals—Na, Ca and Mg—in the roots was affected by the presence of Pb in the roots, their concentrations found in the roots went on decreasing. It was also observed that Pb did not affect the amount of K in the roots.

Since cadmium was found to be maximum in the leaves, its presence only affected the concentrations of Mg and K, which were highest in the roots. Ca and Na absorption was not interfered by the application of Cd solution by the plant.

As observed from the above study, the presence of heavy metals like Cd and Pb in the nutrient system of the plant affects the normal distribution and uptake of some essential elements like Ca, Mg, Na and K in the plant. In spite of all these interferences the *L. esculentum* plant was able to survive in the metal contaminated soil and its ability to hyper accumulate toxic metals was identified.

Acknowledgement

The first author is thankful to Dr. F.M. Prasad, Principal, St. John's College, Agra for providing proper facilities of research and experimentation. The author is also thankful to Dr. C. Bhuiyan for his constant support and help during the formation of this paper.

References

Adriano, D.C. (1986). Trace elements in the terrestrial environment. Springer-Verlag, New York.

Alloway, B.J. (1990). Heavy metals in soils. Blackie, Glasson, U.K.

Avanzi, M. (1950). Observazioni sull'attivita citologica di alcuni composti chimic. *Caryologia*, **3:** 234-248.

Blaylock, J.M. and J.W. Huang (2000). Phytoextraction of metals. *In:* Phytoremediation of toxic metals using plants to clean up the environment. Raskin, L. and Ensley, B.D. (eds.). Wiley, New York, pp. 53-70.

Bora, K.K., Mathur, Sudha R. and R. Ganesh (2001). Physiological and biochemical tolerance in moth bean to heavy metal stress. *Pollution Research*, **20(1):** 135-138.

Brown, S.L., Chaney, R.L., Angle, J.S. and A.J.M. Baker (1994). Phytoremediation potential of Thalspi caerulescens and Blader Campion for zinc and cadmium contaminated soil. *J. Environ. Qua*, **23:** 1151-1157.

Davies, B.E. and B.G. Wixson (ed.) (1988). Lead in soil: Issues and guidelines. Science Reviews Limited, Northwood, U.K.

De Temmerman, L. (2005). Heavy metal deposition and potential contamination of crops. *In:* Air Pollution and Vegetation. ICP vegetation, Annual Report (2004/2005). Centre for Ecology and Hydrology, Gwynedd, U.K. 18 p.

Ernst, W.H.O., Nilisse, H.J.M. and W.M. Ten Brookum (2000). Combination toxicology of metal-enriched soils: Physiological responses of Cd resistant ecotypes of Silene vulgaris on polymetallic soils. *Environ. Exp. Bot*, **43:** 55 71.

Fiskesjo, G. (1988). The Allium test—an alternative in environmental studies: The relative toxicity of metal ions. *Mutat. Res*., **197:** 243-260.

Gupta, A. and S. Gupta (2001). Heavy metals in soil and the moss Plegiothecium denticulatum from Meghalaya. *Pollution Research*, **20(4):** 631-634.

Jackson, A.P. and B.J. Alloway (1992). The transfer of cadmium from agricultural soils to the human food chain. *In:* D.C. Adriano (ed.), Biogeochemistry of trace metals. Lewis Publication, Boca Raton, FL., pp. 109-158.

Kudesia, V.P. (1980). Toxicity of metals. *In:* Water Pollution, Kudesia, V.P. (ed.). Pragati Prakashan, Meerut, India, pp. 203-217.

Liu, D., Jiang, W. and W. Hou (2001). Hyperaccumulation of cadmium by roots, bulbs and shoots of garlic (Allium sativum L.). *Bioresource Technology*, **76:** 9-13.

Liu, D.H., Jiang, W.S. and M.X. Li (1992). Effects of Cd^{2+} on root growth and cell division of Allium cepa. *Acta Sci. Circumstantiae*, **12:** 439-446.

Merian, E. (ed.) (1991). Metals and their compounds in the environment. VCH, Weinheim, Germany.

Pacyna, J.M., Munch, J., Alcamo, J. and S. Anderberg (1991). Emission trends for heavy metals in Europe. *In:* Heavy metals in the environment. J.G. Farmer (ed). CEP Consultants Ltd., Edinburgh, UK. **1:** 314-317.

Panwar, B.S., Ahmed, K.S. and S.B. Mittal (2002). Phytoremediation of nickel contaminated soils by Brassica Species. *Environment Development and Sustainbility*, **4:** 1-6.

Scheffer, F. and P. Schachtschabel (1998). Lehrbuch der Bodenkunde. Enke, Stuuttgart, Germany.

Sherlock, J.C. (1991). Exposure of man to heavy metals from food. *In:* Heavy metals in the environment. J.G. Farmer (ed.). CEP Consultants Ltd., Edinburgh, UK. **1:** 6-15.

Sinhal, V.K. (2007). Phytotoxic and cytogenic effects of Zn^{2+} and Pb^{2+} in Vicia faba (L.). *Pollution Research*, **26(3):** 417-420.

Calendar of Events

The Water Research Conference
11 to 14 April 2010
Lisbon, Portugal
Website: http://www.waterresearchconference.com/
Contact name: Richard Hart
Organized by: Elsevier

2010 Asia Pacific Water and Sewer Systems Modelling Conference
21 to 22 April 2010
Gold Coast, Australia
Website: http://www.asiapacificwater.com
Contact name: Damian Barrett

2010 International Conference on Environmental Science and Technology (ICEST 2010)
23 to 25 April 2010
Bangkok, Thailand
Website: http://www.icest.org
Contact name: Conference Secretary

Water & Environment 2010: CIWEM's Annual Conference
28 to 29 April 2010
London, United Kingdom
Website: http://www.ciwem.org/events/annual_conference/
Contact name: Lauren Goozee
Organized by: CIWEM

Interlinks of Energy, Water, and Climate Change
23 May 2010 to 3 June 2010
San Diego, California, United States
Website: http://www-rohan.sdsu.edu/~energy/pasi/
Contact name: Prof. Asfaw Beyene
Organized by: National Science Foundation

IWA Specialist Conference "Water and Wastewater Treatment Plants in Towns and Communities of the XXI Century: Technologies, Design and Operation"
2 to 4 June 2010
Moscow, Russian Federation
Website: http://www.iwaconference.ru
Contact name: Sergey Malygin
Organized by: Sibico International Ltd

Water Matters! Global Water Conference
3 June 2010
Pittsburgh, PA, United States
Website: http://www.pittsburghwed.com/watermatters
Contact name: Lynn McMahon
Organized by: Pittsburgh World Environment Day Partnership

Water Pollution 2010: Tenth International Conference on Modelling, Monitoring and Management of Water Pollution
9 to 11 June 2010
Bucharest, Romania
Website: http://www.wessex.ac.uk/10-conferences/water-pollution-2010.html
Contact name: Alice Jones
Organized by: Wessex Institute of Technology, UK and University Politehnica of Bucharest, Romania

Symposium on Sustainable Water Resource Management and Climate Change Adaptation
16 to 17 June 2010
Nakhon Pathom, Thailand
Website: http://research.npru.ac.th/ruswem/confer/index.php
Contact name: Dr.-Ing.Phatcharasak Arlai

Urban Environmental Pollution 2010
20 to 23 June 2010
Boston, MA, United States
Website: http://www.uep2010.com/index.asp
Contact name: Gert-Jan Geraeds
Organized by: Elsevier

Water Quality 2010
23 to 24 June 2010
Leeds, United Kingdom
Website: http://www.wateratleeds.org/water-quality-2010.php
Contact name: Rebecca Slack
Organized by: water@leeds, University of Leeds

Environment Research Event 2010
27 to 30 June 2010
Rockhampton, Queensland, Australia
Website: http://cpws.cqu.edu.au/FCWViewer/view.do?page=10386
Contact name: Anna Cooke/Kartik Venkatraman
Organized by: Centre for Plant and Water Science