Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 14 (17): 2007-2010, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.2007.2010
© 2014 Asian Network for Scientific Information

Heavy Metals Accumulation in *Rhazya stricta* L. Plant Growing on Industrial Wastewater of Riyadh City, Saudi Arabia

Adel M. Ghoneim, Soud S. Al-Zahrani, Sallem E. El-Maghraby and Abdullah S. Al-Farraj
Department of Soil Sciences, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh, 11451, Saudi Arabia

Abstract: This study evaluated the potential of *Rhazya stricta* L. growing on a surrounding area of the second industrial zone (24°39.8' N; 46°57' E), east of Riyadh, Saudi Arabia. Plant and the associated soil samples were collected and analyzed for total Cr, Fe, Ni, Cu, Zn, Cd and Pb concentration. The degree of contamination by those heavy metals in soil and transfer to *Rhazya stricta* has been estimated. The results showed a medium contamination of soil heavy metal content with respect to Cd and Pb. The total concentration of Fe, Cr, Ni, Zn and Cu in shoots of *Rhazya stricta* was 275, 5.30, 10.5, 27.5 and 8.30 mg kg^{-1}, respectively. On the other hand, the total concentration of heavy metals in the roots was as follows (mg kg^{-1}): Fe: 0.1; Cr: 0.5; Ni: 3.0; Zn: 0.8 and Cu: 1.6. Heavy metals (Cr, Ni, Cu and Zn) tended to be accumulated in the roots *Rhazya stricta* rather than the stems and leaves expect for Zn. The calculated accumulation coefficient of heavy metals in the roots was higher than that in stems or leaves. The *Rhazya stricta* plant exhibiting Translocation Factor (TF) values less than one except for total Zn (1.10-1.60). The results indicated that, *Rhazya stricta* plant could not suitable for heavy metals extraction from the contaminated studied soil but can be used as an indicator for soil contamination with some heavy metals (Cd, Cu, Pb and Zn) and also to minimize heavy metals mobility in contaminated soils.

Key words: Heavy metals, contaminated soil, plant uptake, translocation

INTRODUCTION

Environmental pollution is currently one of the most important issues facing humanity. It was increased exponentially in the past few years and reached alarming levels in terms of its effects on living creatures. Toxic heavy metals are considered one of the pollutants that have direct effect on man and animals. Industrial wastewater containing Pb, Cu, Cd and Cr for example can contaminate water resources and thus lead to a serious pollution problem Ageena (2010). Plant uptake of heavy metals from soil occurs either passively with the mass flow of water into the roots, or through active transport crosses the plasma membrane of root epidermal cells. Under normal growing conditions, plants can potentially accumulate certain metal ions an order of magnitude greater than the surrounding medium (Kim *et al*., 2003). The release of heavy metals into the environment by industrial activities presents a serious environmental threat. Heavy metals can be removed from industrial wastewater by a range of physico-chemical remediation technologies such as precipitation, ion exchange, adsorption, electrochemical processes and membrane processes (Mulligan *et al*., 2001; Cao *et al*., 2002; Kurniawan *et al*., 2006; Alhawas *et al*., 2013). However, these technologies are expensive and energy-intensive, driving towards a search of cheaper alternatives or tertiary treatment steps in both developing and developed countries Kivaisi (2001).

One of the strategies of phytoremediation of heavy metal-contaminated soil is phytoextraction, i.e., through plant uptake and accumulation into plant shoots which can be harvested and then removed from the contaminated site. Another application of phytoremediation is phytostablization where plants are used to minimize heavy metals mobility in contaminated soils. More than 450 plants are known as hyper accumulation of heavy metals into their above ground biomass including weeds, trees, grasses and vegetable crops. There has been a continuing interest in searching for native plants that are accumulated heavy metals; however few studies evaluated the phytoremediation potential of native plants under field conditions. It is important to use native and local plants for

Corresponding Author: Adel M. Ghoneim, Department of Soil Sciences, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh, 11451, Saudi Arabia

phytoremediation because these plants are often better in terms of survival, growth and reproduction under environmental stress the plants introduced from other environment. The overall objectives of this current work were: (1) to determine the concentration of some heavy metals in *Rhazya stricta* biomass growing on a contaminated soil which located in the second industrial waste water, Riyadh city, Saudi Arabia and (2) to compare heavy metals concentration in the aboveground biomass to those in roots.

MATERIALS AND METHODS

Site description and soil analysis: The experimental site has open drain canal of the surface industrial effluent second industrial zone (24°39.8" N; 46°57" E), east of Riyadh, Saudi Arabia. Composite soil samples (5 samples) were collected from the surface layer (0-5 and 5-30 cm depth) by 30×30 m. Soil samples were air-dried at room temperature for two weeks and then sieved by 2 mm stainless steel sieve. The pH and EC of samples were measured (using 1:5 ratio of w/v with demonized distilled water) by pH-meter and the electrical conductivity meter, respectively. Complex metric EDTA titration was employed for determining Ca^{++} and Mg^{++} simultaneously and individually Sparks (1996). Sodium and potassium was determined using flame photometer (Corning 400). Carbonate and bicarbonate were determined by titration with H_2SO_4 while silver nitrate was used to determine chloride (Sparks, 1996). Sulphate was determined by turbidity method as described by Tabatabai (1996). Particle size distribution was analyzed according to Gee and Bauder (1996). Calcium Carbonate content was determined using a calcimeter Loeppert and Suarez (1996). Some selected soil properties are shown in Table 1. The total content of heavy metals (Cr, Fe, Ni, Cu, Zn, Cd and Pb) in the soil samples were determined after digestion with HNO_3-$HClO_4$-HF (Hossner, 1996), then total heavy metals content were determined using ICP (Perkin Elmer, Model 4300DV).

Plant sample preparation and analysis: *Rhazya stricta* native plant based on their coverage at the site, were collected, separated into roots, stems and leaves, washed gently with demonized water for approximately 3 min to remove soil particles adhered to the plant, then, air-dried at 60° and finally ground to powder using a Wiley mill. The plant samples were acid digested with HNO_3-$HClO_4$ mixture according to Chapman and Pratt (1996). Finally, the total content of heavy metals (Cr, Fe, Ni, Cu, Zn and Cd) content in plant samples was analyzed using ICP (Perkin Elmer, Model 4300DV). Reagent blanks and internal standards were used where appropriate to ensure accuracy and precision in heavy metals analysis.

Determination of accumulation coefficient and translocation factor: Two parameters were used for evaluation of heavy metals status in the plant, Accumulation Coefficient (AC), which is defined according to (USEPA, 2000):

$$Ac = \frac{C_{root,\ stem,\ leaves}}{C_{soil}}$$

where, $C_{root,\ stem\ or\ leaves}$ = Concentration of heavy metal in *Rhazya stricta* aerial or root part (mg kg^{-1}) and C_{soil} = Concentration of heavy metal in soil sample (mg kg^{-1}).

Translocation Factor (TF) was calculated to estimate the transfer of heavy metals from roots to stems or leaves of *Rhazya stricta* as follows:

$$TF = \frac{C_{stem,\ leaves}}{C_{roots}}$$

Such parameter was evaluated for each plant part, root, stem and leaves separately.

RESULTS AND DISCUSSION

Wastewater analysis: Wastewater samples were collected from two locations in the experimental site to assess the wastewater characteristics. The results (data not shown) indicated that the wastewater of industrial zone is characterized by gray color, bad smell, high temperatures

Table 1: Selected properties of studied soil

		Cations (meq L^{-1})				Anions (meq L^{-1})				Particles size (%)				
pH	EC (dS m^{-1})	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	Sand	Silt	Clay	Texture class	$CaCO_3$ (%)
7.60	0.63	1.26	0.63	3.76	0.64	3.70	2.17	0	0.50	85	6	9	Loamy sand	15.2

Table 2: Total heavy metals concentration (mg kg^{-1}) in the studied soil compared with common range in soils

Metal type	Soil depth (cm)	Metal content (mg kg^{-1})	Common range in soils* Max	Min	Average	Enrichment factor (EF)
Cr	0-5	40	1000	1	100	1
	0-30	30	1000	1	100	1
Fe	0-5	7000	55000	7000	38000	1
	0-30	7000	55000	7000	38000	1
Ni	0-5	10	500	5	40	1
	0-30	10	500	5	40	1
Cu	0-5	8	100	2	30	1
	0-30	9	100	2	30	1
Zn	0-5	30	300	10	50	3
	0-30	20	300	10	50	2
Cd	0-5	0.1	0.7	0.01	0.06	4
	0-30	0.1	0.7	0.01	0.06	4
Pb	0-5	10	200	2	10	5
	0-30	6	200	2	10	3

*Lindsay (1979)

Table 3: Heavy metals concentration of different parts of *Rhazya stricta* and calculated accumulation coefficient

Metal type	Metal concentration (mg kg^{-1}) Roots	Stems	Leaves	Accumulation coefficient (AC) Roots/soil	Stems/soil	Leaves/soil
Cr	20.0	5.30	3.0	0.5	0.10	0.09
Fe	725	275	275	0.1	0.04	0.04
Ni	27.5	10.5	2.0	3.0	1.00	0.20
Cu	12.5	8.30	4.30	1.6	0.90	0.50
Zn	25.0	27.5	42.5	0.8	1.00	1.40
Cd	nd*	nd	nd	nd	nd	nd

*nd, not detected

and high pH at point source. Also, it contains high concentrations of soluble cations and anions. Heavy metals (Fe, Mn, Zn, Cd, Ni, Pb and Mo) on wastewater effluent samples were above permissible limits, as reported by Al-Farraj *et al.* (2013).

Contamination of soil samples: Table 2 shows the total concentration of heavy metals in soil compared with the common range of soils. The results indicated that, heavy metals concentration in soil varies with soil depth and the type of heavy metals. The total heavy metals concentration was less than that the average of common soils expect for Cd and Pb concentration according to (Lindsay, 1979). Though the soil site was predominantly contaminated with Cd, it also contained elevated concentration of Pb. The obtained results agreed well with Al-Farraj and Al-Wabel (2009). The calculated Enrichment Factor (EF) values indicated that soil has medium polluted (5>EF>1) with Cd (4) and Pb ranged from (3-5).

Heavy metal concentration in plant: Total heavy metals concentrations in *Rhazya stricta* plant vary with plant part (Table 3). Total concentration of heavy metals in plant parts ranged from non-detectable to as high as 725 mg kg^{-1}, with the maximum being in the roots of *Rhazya stricta*. The root Cr, Fe and Ni concentration were much greater than those of the stems and leaves content, indicating low mobility of those heavy metals from root to the shots and immobilization of heavy metals in roots which agreed with Stoltz and Greger (2002). The calculated Accumulation Coefficient (AC) values presented in Table 3 ranged from (0.04-3.0) with the highest AC was obtained for Ni followed by Cu element. The AC values in roots were higher than that in stems and leaves. Based on the average of AC values of all *Rhazya stricta* plant parts samples it could be concluded that roots were most efficient in taking up Ni (AC = 3.0), followed by Cu (AC = 1.60) and Zn (AC = 0.80). These results agreed well with finding of (Liu *et al*., 2005; Khan *et al*., 2008).

Table 4: Calculated translocation factor of studied heavy metals in *Rhazya stricta*

Elements	Translocation factor (TF) Stems/roots	Leaves/stems
Cr	0.30	0.70
Fe	0.40	1.10
Ni	0.40	0.20
Cu	0.70	0.50
Zn	1.10	1.60
Cd	nd*	nd

*nd: Not detected

Translocation of heavy metals in plant: *Rhazya stricta* ability to translocate heavy metals from roots to the stems and leaves is estimated using Translocation Factor (TF), which is defined as ratio of metals concentration in the stems, leaves to the roots. Enrichment occurs when a contaminated element taken up by plant is not degraded rapidly, resulting in an accumulation in the plant. Table 4 shows translocation factor values in the studied heavy metals partition in plant. The *Rhazya stricta* exhibiting TF values less than one except for Zn (1.10-1.60). Similar results were reported by Al-Farraj and Al-Wabel (2009). By comparing TF values, it could be compare the ability of different plant species in taking up heavy metals from the contaminated soil and translocations them in the plant canopy. Plant exhibiting TF values less than one are unsuitable for photextraction of heavy metals (Fitz and Wenzel, 2002).

CONCLUSION

This study was carried out to assess the extent of some heavy metals accumulation by *Rhazya stricta* growing in the second industrial wastewater, Riyadh city, Saudi Arabia. It can be concluded that *Rhazya stricta* native plant is not suitable for the heavy metal removal for the contaminated industrial wastewater site, but should be used as an indicator for soil contamination especially with Cd and Pb heavy metals.

ACKNOWLEDGMENT

The authors wish to thank King Saud University, Deanship of Scientific Research, College of Food and Agriculture Science, Research Centre for supporting the research work.

REFERENCES

Ageena, N.A., 2010. The use of local sawdust as an adsorbent for the removal of copper ion from wastewater using fixed bed adsorption. Eng. Tech. J., 28: 224-235.

Al-Farraj, A.S. and M.I. Al-Wabel, 2009. Heavy metals accumulation by ochradenus baccatus plant grown on mining area at Mahad AD'Dahab, Saudi Arabia. J. Saudi Soc. Agric. Sci. Ecosyst. Sustainable Dev., 7: 459-468.

Al-Farraj, A.S., M. Al-Sewailem, A. Aly, M. Al-Wabel and M. Al-Wabel, 2013. Assessment and heavy metal behaviors of industrial waste water: A case study of Riyadh city, Saudi Arabia. Proc. Int. Acad. Ecol. Environ. Sci., 3: 266-277.

Alhawas, M., M. Alwabel, A. Ghoneim, A. Alfarraj and A. Sallam, 2013. Removal of nickel from aqueous solution by low-cost clay adsorbents. Proc. Int. Acad. Ecol. Environ. Sci., 3: 160-169.

Cao, X., L.Q. Ma, M. Chen, S.P. Singh and W.G. Harris, 2002. Impacts of phosphate amendments on lead biogeochemistry at a contaminated site. Environ. Sci. Technol., 36: 5296-5304.

Chapman, H. D. and P.F. Pratt, 1996. Methods of Analysis for Soils, Plants and Water. University of California, Berkeley, CA., USA.

Fitz, W.J. and W.W. Wenzel, 2002. Arsenic transformations in the soil-rhizophore-plant system: Fundamentals and potential application to phytoremediation. J. Biotechnol., 99: 259-278.

Gee, G.W. and J.W. Bauder, 1996. Particle Size Analysis. In: Methods of soil Analysis. Part 1: Physical and Mineralogical Methods, Klute, A. (Ed.). 3rd Edn., SSSA and ASA, Madison, WI., pp: 377-382.

Hossner, L.R., 1996. Dissolution for Total Elemental Analysis. In: Methods of Soil Analysis, Sparks, D.L., A.L. Page, P.A. Helmke, R.H. Loeppert and P.N. Soltanpour (Eds.). SSSA and ASA, Madison, WI., pp: 46-64.

Khan, S., L. Aijun, S. Zhang, Q. Hu and Y.G. Zhu, 2008. Accumulation of polycyclic aromatic hydrocarbons and heavy metals in lettuce grown in the soils contaminated with long-term wastewater irrigation. J. Hazardous Mater., 152: 506-515.

Kim, I.S., H.K. Kang, P. Johnson-Green and E.J. Lee, 2003. Investigation of heavy metal accumulation in *Polygonum thunbergii* for phytoextraction. Environ. Pollut., 126: 235-243.

Kivaisi, A.K., 2001. The potential for constructed wetlands for wastewater treatment and reuse in developing countries: A review. Ecol. Eng., 16: 545-560.

Kurniawan, T.A., G.Y.S. Chan, W.H. Lo and S. Babel, 2006. Physico-chemical treatment techniques for wastewater laden with heavy metals. Chem. Eng. J., 118: 83-98.

Lindsay, W., 1979. Chemical Equilibrai in Soils. 1st Edn., John Wiley and Sons, New York.

Liu, W.H., J.Z. Zhao, Z.Y. Ouyang, L. Soderlund and G.H. Liu, 2005. Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China. Environ. Int., 31: 805-812.

Loeppert, R.H. and D. Suarez, 1996. Carbonate and Gypsum: Manometer Method. In: Methods of Soil Analysis. Part 3: Chemical Methods, Sparks, D.L. (Ed.). 3rd Edn., SSSA and ASA, Madison, WI., pp: 437-474.

Mulligan, C.N., R.N. Yong and B.F. Gibbs, 2001. Remediation technology for meat-contaminated soils and groundwater, an evaluation. Eng. Geol., 60: 193-207.

Sparks, D.L., 1996. Methods of Soil Analysis. Part 3: Chemical Methods. ASA and SSSA, Madison, WI., USA..

Stoltz, E. and M. Greger, 2002. Accumulation properties of As, Cd, Cu, Pb and Zn by four wetland plant species growing on submerged mine tailings. Environ. Exp. Bot., 47: 271-280.

Tabatabai, M.A., 1996. Sulfur. In: Methods of Soil Analysis, Part 3: Chemical Methods, Sparks, D.L. (Ed.). ASA and SSSA, Madison, WI., USA., pp: 921-960.

USEPA, 2000. Introduction to phytoremediation. EPA 600/R-99/107, U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH. http://www.cluin.org/download/remed/introphyto.pdf