Heavy Metals Transport in the Soil Profiles under the Application of Sludge and Wastewater

A. Behbahaninia, S. A. Mirbagheri, and A. H. Javid

***Abstract*—**Heavy metal transfer in soil profiles is a major environmental concern because even slow transport through the soil may eventually lead to deterioration of groundwater quality. The use of sewage sludge and effluents from wastewater treatment plants for irrigation of agricultural lands is on the rise particularly in peri-urban area of developing countries. In this study soil samples under sludge application and wastewater irrigation were studied and soil samples were collected in the soil profiles from the surface to 100 cm in depth. For this purpose, three plots were made in a treatment plant in south of Tehran-Iran. First plot was irrigated just with effluent from wastewater treatment plant, second plot with simulated heavy metals concentration equal 50 years irrigation and in third plot sewage sludge and effluent was used. Trace metals concentration (Cd, Cu) were determined for soil samples. The results indicate movement of metals was observed, but the most concentration of metals was found in topsoil samples. The most of Cadmium concentration was measured in the topsoil of plot 3, 4.5mg/kg and Maximum cadmium movement was observed in 0-20 cm. The most concentration of copper was 27.76mg/kg, and maximum percolation in 0-20 cm. Metals (Cd, Cu) were measured in leached water. Preferential flow and metal complexation with soluble organic apparently allow leaching of heavy metals.

***Keywords*—**Heavy metal, sludge, soil, transport.

I. Introduction

THE results of packed-column studies may be overly optimistic in predicting soil immobilization of metals, bypass flow via preferential flow paths in field soils may allow significant metals transport to groundwater [1]. The lack of significant metal deposition in subsoil may not be reliable evidence for immobility of sludge-application metals [2].

Alloway and Jackson (1991) cited several studies reporting some downward metal translocation in soil, noting a potential correlation with climate [3]. Soluble and colloidal organics have been shown experimentally to mobilize metals [4]. Land application of sludge or compost can have both beneficial and harmful aspects. Its organic matter content, which constitutes approximately 50% of the solid fraction, may improve soil physical properties. Nitrogen and phosphorus, ranging from 2 to 8% and 1 to 4% respectively, in sewage sludge and sludge compost are nutrients essential for growth of crops. Municipal sludge, however, often contain undesirable chemicals which may be toxic to plants and/or eventually toxic to animals and human that consume edible parts of such plants [5]. Adsorption and transport of reactive solutes when no equilibrium conditions are dominant may impact significantly their mobility indexes of metals correlated positively and significantly with the total content of metals and negatively with the clay content [6]. The large city of Tehran in Iran produces about 2 millions m³/day of wastewater, which is planned to be treated in wastewater treatment plants and the effluent and sludge from treatment plants is going to be used for the irrigation of crops is more than one hundred thousands hectare of agricultural lands is the plains south of Tehran. This is the main reason to research, the effects sewage sludge and effluents from treatment plants on heavy metals accumulation in soils, their mobility in the soil profile, deterioration of groundwater quality and metals accumulation in plants.

Paper submitted June 26, 2008. This work was supported by Azad University, Science and research, Wastewater treatment plant, Shosh, South of Tehran, Iran

Azita Behbahaninia is with Islamic Azad University, Roodehen branch, Department of Environment, Iran (phone: +98-9121323734; fax:+98-21-88950037; e-mail : Azitabehbahani@yahoo.com).

S. A. Mirbagheri is with Civil and Environmental Engineering Department, K.N Toosi University of Technology, Tehran, Iran (e-maiil: Seyedahmad_mirbagheri@yahoo.com).

A.H. Javid is with Department of Environmental Engineering, Islamic Azad University, Science and Research Campus, Tehran Iran (e-mail: ahjavid@gmail.com.

II. Procedure

For this field study, three plots of agricultural land, each size 2 by 6 m, were made in a wastewater treatment plant in south of Tehran. A drainage pipe was installed in one meter depth of each plot to collect the leached water. Some chemical- physical properties of the soil measured. Plots were irrigated under different option from wastewater and sludge. First plot was irrigated just with effluent from wastewater of treatment plant; second plot was irrigated with simulated heavy metals solution the concentration of each element in solution was equal to 50 years irrigation. Third plot was irrigated with wastewater and sludge application. After 1 year, in September 2007 soil samples were collected in the soil profile from the surface to 100 cm in depth. Soil samples were taken from o to 20 cm depth for every 3 cm depth and then from 20-100 cm depth each sample was taken for each 10 cm depth, overall 45 soil samples were taken from all of plots. Samples were digested and extracted in HNO_3 4N solution and 12 hours on water bath[7] ,finally flask contains were filtered and concentrations of Cd and Cu were determined an atomic absorption by spectrophotometer (AAS, Perkin Elmer model 560) .The concentration of Cd and Cu in the effluents and sludge also, were measured before each irrigation. Leached water from each plot was sampled and heavy metals were measured.

TABLE II
CU CONCENTRATION WITH SOIL DEPTH (MG/KG)

Depth (cm)	Plot 1	Plot 2	plot 3
0	5.59	17.39	27.76
3	3.28	12.56	27.18
6	3.24	23.62	26.02
9	1.2	11.87	25.14
12	0.5	8.96	24.88
15	0.5	6.39	14.36
18	0.5	5.36	10.51
21	0.5	5.33	8.6
25	0	1.5	6.41
30	0	1.5	2.58
35	0	0.8	2.58
40	0	0.8	0.55
45	0	0	0.55
50	0	0	0

TABLE III
CD CONCENTRATION WITH SOIL DEPTH (MG/KG)

Depth (cm)	Plot 1	Plot 2	Plot 3
0	1.36	3.5	4.5
3	1.34	3.24	4
6	1.26	2.8	3.2
9	1.04	2.5	2.9
12	1.02	2.1	2.75
15	0.98	1.7	2.74
18	0.45	0.8	2.5
21	0.44	0.8	2
25	0.25	0.48	2
30	0.25	0.35	2
35	0.25	0.28	1.5
40	0.01	0.28	1.5
45	0.01	0.27	1.5
50	0.01	0.25	0.95

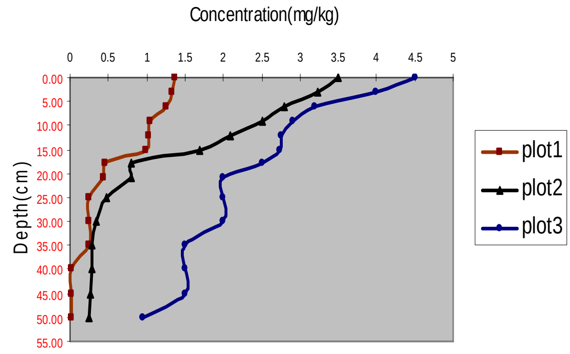

Fig. 1 Distribution of Cd with depth

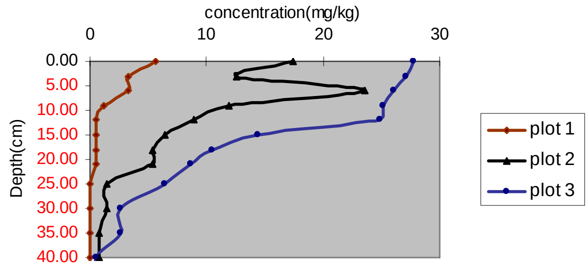

Fig. 2 Distribution of Cu with depth

TABLE IV
THE MEAN CONCENTRATION OF HEAVY METALS IN LEACHED WATER

Number plot	Cd	Cu
Plot 1	0.019	0.121
Plot 2	0.025	0.210
Plot 3	0.017	0.180

TABLE I
SOME OF PHYSICO-CHEMICAL PROPERTIES OF THE SOIL

Plot Number	pH	CEC meq/lit	Texture	CaCO3 percent	Organic matter percent	Soil moisture percent	Soil porosity percent
1	7.76	36.62	loamy	12.25%	0.36	35.7934	0.52
2	7.94	44.25	loamy	11.25%	0.375	40.9814	0.52
3	7.64	42.62	loamy	10.75%	0.495	37.1495	0.51
4	7.57	41.5	loamy	10.5%	0.42	38.9744	0.52

III. RESULT

Some physico-chemical properties of soil samples are presented in Table I. as the table shows; the soil texture is loamy. Table II and Table III show concentration of Cd and Cu in different depth. Fig. 1 shows Cd movement in different layer in soil and Fig. 2 shows distribution of Cu in the soil profile. Concentration of Cd and Cu in leached samples for 3 plots was obtained in Table IV.

IV. CONCLUSION

The results indicate movement of metals was observed, but the levels are different. According to Fig. 1, Cd, accumulated in soil surface layers and had low vertical movement. The most of Cadmium was found in topsoil of plot 3, concentration of Cd was 4.5mg/kg and maximum Cd movement was observed in 0-20cm .Concentration of Cd was decreased after 20 cm. The most Cu was obtained in topsoil plot 3, 27.76mg/kg and maximum of movement was observed 0-20 cm. Concentrations of metals in the surface zone in plot 3 of the sludge application plot were substantially greater than the other plots. Although the most concentration is in plot 3 under sludge application but penetration in other plots was observed more than plot 3. Heavy metals remained in topsoil layer which is a result of chemical reaction between heavy metals and organic matter and firm bounds with these components [8].Table IV shows concentration of Cu and Cd in leached water, most of leaching was found in plot 2 that we used simulated heavy metals solution. In despite of movement of heavy metals is ineligible but in field study we should notice to preferential flow.

Preferential flow can accelerate the movement of water and solutes through soil profiles. Water and solute traveling in preferential flow pathways in soils i.e. soil fracture, shrink-swell cracks, root and worm holes, or, in coarse soils, fingering phenomena often bypass the bulk of the soil matrix [9].Camoberco et al. (1996) found that the combined effects of preferential flow paths and soluble organics enabled metals with low (Cd, Zn) and high (Cu, Pb) organic affinities to move through undisturbed soil columns (which preserve preferential flow paths) with equal rapidity. In contrast, conventional packed soil columns immobilized all applied metals, whether or not soluble organics were present.

Therefore preferential flow phenomena are important because heavy metals can lead to groundwater and change quality of groundwater. It was concluded that the use of wastewater and sludge application in agricultural lands enriched soils with heavy metals to concentrations that may pose potential environmental and health risks in the long-term.

REFERENCES

[1] V.J.Camobrccoo, B.K.Richards, T.S.Steenhuis, J.H.Peverly, “Movement of heavy metals through undisturbed and homogenized soil columns.161 (11):740-750, 1996.

[2] B.K Richars, T. S. Steenhuis, J. H. peverly and M.B Mcbride, “Metal mobility at an old heavily loaded sludge application site” Environmental pollution J., vol .99,pp.365-377,1998.

[3] B. Alloway, A.Jackson, “The behavior of heavy metals in sewage sludge-amended soil,” Sci. Total Environ J., vol.100, pp.151-176, 1991.

[4] R. Gerritse, et al,”Effect of sewage sludge on trace element mobility in soils,”Environ. Qual. J.Vol11pp.359-364.

[5] E. Epstain, "Effect of sewage sludge on some soil physical properties,” Environ.Qual J., Vol.4, pp.139-142, 1975.

[6] H. Zhang and H. M. Selim, “Modeling the transport and retention of Arsenic in soils,” Soil Sci.Soc.Am.J., vol.70, pp1677-1687, August. 2006.

[7] A. Chang et al., “accumulation of heavy metals in sewage sludge – treated soils” Environ Qual J. vol. 13, pp.87-90, 1984.

[8] R. Salmasi, A. Tavasoli,” Pollution of south of Tehran ground waters with heavy metals,” Int. J. Environ. Sci. Tech. , Vol. 3, No. 2, pp. 147-152, Spring 2006.

[9] Van Erp, “long term heavy metal leaching from soils, sewage sludge and soil sewage mixtures”Environ. Sci.Technol. vol.25, pp.706-711, 1991.