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EFFECTS OF SLUDGE FROM WASTEWATER TREATMENT PLANTS ON HEAVY METALS TRANSPORT TO SOILS AND GROUNDWATER

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ABSTRACT
Heavy metals accumulation in soils under the application of sewage sludge and effluent from wastewater treatment plants is a major environmental concern. Transport of heavy metals through the soils may eventually lead to the groundwater contamination and their accumulation in soils and crops. Silt loam soils covered by sludge and effluent of Tehran wastewater treatment plant were used in this study. The vertical and horizontal distributions of sludge-borne Cd, Cr, Zn, Pb, Fe, Cu and Ni were studied within four plots. Measured loadings of heavy metals to the plots from the sludge application were Fe, 284.75; Pb, 90.28; Zn, 109.5; Ni, 60.28; Cu, 27.76; Cr, 28.58 and Cd, 4.5 mg/kg. Two hundred and forty soil samples were taken from areas within the plots and up to 100 cm depth on each side of the plots. Leachate water from the plots which contaminates groundwater was collected and the concentrations of heavy metals were measured. The determined concentration of sludge-borne in leachate Cr, Ni, Zn, Fe, Pb, Cu and Cd were 0.803, 0.785, 0.532, 0.439, 0.110, 0.180 and 0.019 mg/l respectively. The results of this study can be used for the management of effluent and sewage application in agricultural lands and crop production. The groundwater quality can be monitored and improved as well.

Key words: Contamination; Heavy Metals; Groundwater; Sewage Sludge; Wastewater

INTRODUCTION
The large city of Tehran in Iran produces about 2 millions m^3/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 in more than one hundred thousands hectares of agricultural lands in the plains south of Tehran, Varamin. Therefore study of the effects of sewage sludge and effluents from treatment plants on heavy metals accumulation in soils, crops and groundwater is necessary. One way of sludge disposal is its application on land .The reuse of sewage sludge and effluent from Wastewater Treatment Plant via land application is a desirable goal. However, heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic or industrial application (Petrus *et al*., 2005). Soil, as filters of toxic chemicals, may adsorb and retain heavy metals from wastewater. On the other hand when the capacity of soils to retain toxic metals is reduced due to continuous loading of pollutants or changes in pH, soils can release heavy metals into groundwater or soil solution available for plant uptake (Mandapa *et al*., 2004). Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts (Alloway and Ayres, 1993).In addition, there is also the possibility of transfer of these metals into environmental media, most especially shallow groundwater systems through leaching

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(Moshood, 2009). Metal transfer from sewage sludge to soil and subsequently to groundwater represents one of the most critical long-term hazards associated with the application of these wastes to soils (McBride *et al*., 1997).However; research carried out on the potential migration of heavy metals in sewage sludge-amended soils shows controversial results. The authors of some studies showed that heavy metals migration in soils is practically insignificant as metals remain at the site of input (Welch and Lund, 1987; Dowdy *et al*., 1991; Dorronsoro, 2002; Sukkariyah, 2005). This is consistent with the poorly soluble nature of heavy metals in most soils, especially basic soils (McLean and Bledsoe, 1992), in which the metals tend to accumulate at the soil surface and become part of the soil matrix. Nevertheless, several field trials and column studies (McBride *et al*., 1999; Ashworth and Alloway, 2004; Clemente, 2008; Egiarte, 2005; Toribio and Romanya, 2006; Udom, 2004; Monday, *et al*.2001) have demonstrated migration of metals at depth, and have highlighted the concern regarding groundwater contamination by these pollutants. The metals were selected based on the origin of the polluted sources observed around the study area. The presence of electroplating industries, car battery manufactures and tanneries are located in the study region. In recent years, there has been great pressure on manufactures to reduce the metal concentrations in their effluents by introducing cleaner technology and recycling.

MATERIALS AND METHODS

Four experimental plots (2 m * 6 m) were filled with collected soils from Varamin plain area.

The plots had been moldboard plowed and disked each time and there after. Some chemical physical properties of the soil measured (Black, 1965 and Page, 1965) before the sludge and effluent application and the results are summarized in Table1. A PVC drainage pipe was installed in one meter depth of each plot to collect the leached water as shown in Fig. 1. First plot was irrigated with pipe water as control plot, second plot with effluent from Wastewater Treatment Plant, third plot with sludge and tap water; forth plot with sewage sludge and effluent. The sludge was incorporated into 0-20 cm plow layer after application and disked and plowed before irrigation started. After and during each irrigation period leached water from each plot was sampled and heavy metals were measured. After 6 months irrigation with three times per week, soil samples were taken from the topsoil to 100 cm depth (each sample for every 3 cm depth), overall 250 soil samples were taken from all plots in September 2008. The soil samples were taken to the lab, all soil samples were air dried and ground to pass a No.14 u.s standard sieve through 1.4 mm mesh. Total heavy metals concentration in the soil samples were obtained by determining metal concentration in a 4 N HNO3 extract (70 ºC) by atomic absorption spectrophotometer (Varian model-200). The concentration of heavy metals, Pb, Ni, Fe, Cd, Zn, Cu and Cr in the effluents and sludge also, were measured before each period of irrigation (APHA, 2004).

RESULTS

Average concentrations of heavy metals in the effluent and sludge were shown in Table 2.

It is clear from Table 2 that iron, nickel and lead have the most concentration of heavy metals in sludge of Shoush Wastewater Treatment Plant because the presence of electroplating industries, car battery manufactures and leather tanneries which were located in the region. In recent years

Table 1: Some physical and chemical properties of the silt loam soil in the studied area

Plot number	pH	CEC (meq/L)	PO_4-P (mg/L)	Nitrogen (mg/L)	$CaCO_3$ (%)	Organic matter (%)	Soil moisture (%)	Soil porosity (%)
1	7.76	36.62	20	1.4	12.25%	0.36	35.7934	0.52
2	7.94	44.25	20	1.3	11.25%	0.375	40.9814	0.52
3	7.64	42.62	22	1.5	10.75%	0.495	37.1495	0.51
4	7.57	41.5	19	1.4	10.5%	0.42	38.9744	0.52

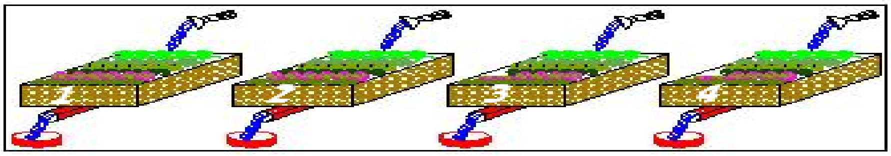

Fig.1: The plots with different irrigation

there has been great pressure on manufactures to reduce the metal concentrations in their effluents by introducing cleaner technology and recycling. The distribution in depth of some elements (Fe, Pb, Cu and Cr) in plots is presented in Fig. 2. Heavy metals concentrations at the study plots were generally in the order:

plot 4> plot 3> plot 2> plot 1

The concentrations of metals had increased significantly in the soil samples of plots compared with control plot. Fig. 2 indicates that, in control plot (plot 1) the highest concentrations were the first within 5 cm depth but in other plots, the highest concentrations were consistently from the surface to within the top 35 cm of the profile. Lower migration of these pollutants in plot 2 in comparison with other plots, is because of their low concentration in effluent of Shoush Wastewater Plant that is used for irrigation of Plot 2. Heavy metals concentrations in surface layer of plots 3 and 4 were significantly increased. This is likely to be due to sludge application in these plots.

DISCUSSION

The accumulation of the metals in the surface layer of the soils seems to be related to their high sorption capacity by soil which is a result of chemical reaction between soil solid phases including silicate clays, oxides and hydroxides of metals especially Fe amorphous minerals and also lime, organic matter and firm bounds with these compounds (Corey *et al*., 1987 and Emmerich *et al*., 1982). This property accompanying with high rate adsorption of these elements by soil solid phases, causes their retention in surface layer of the soil. Migration of the studied elements in soil is likely a product of some parameters, including soil sorption capacity, reaction rate of these elements with solid phase, water movement rate in soil and their primary concentration. The combined effect of the above-mentioned parameters, determine distribution of these metals in soil profiles and depth of movement. Movement of these elements is observed in some soils. Soil acidity, light texture, and structural features such as soil cracks, are important factors in this case (Alloway, 1990; Richards *et al*., 1998; Smith, 1996).

Table 2: Average concentration of heavy metals in effluent and sludge of Shoush Wastewater Treatment Plant

Heavy Metals Samples	Pb	Cd	Zn	Fe	Ni	Cr	Cu	Sum
Treated Effluent Shoush Plant (mg/L)	0.30	0.01	0.15	1.30	0.10	0.07	0.04	1.97
Sludge Shoush Plant (mg/kg)	185	10	40	280	190	60	80	845

Table 3 shows the average heavy metals concentration of leached water. In comparison, heavy metals concentrations of plot 4 were more than others. This table shows that it was detected no concentration of heavy metals except Zn, Cu and Fe (low content) in leached water of control plot.

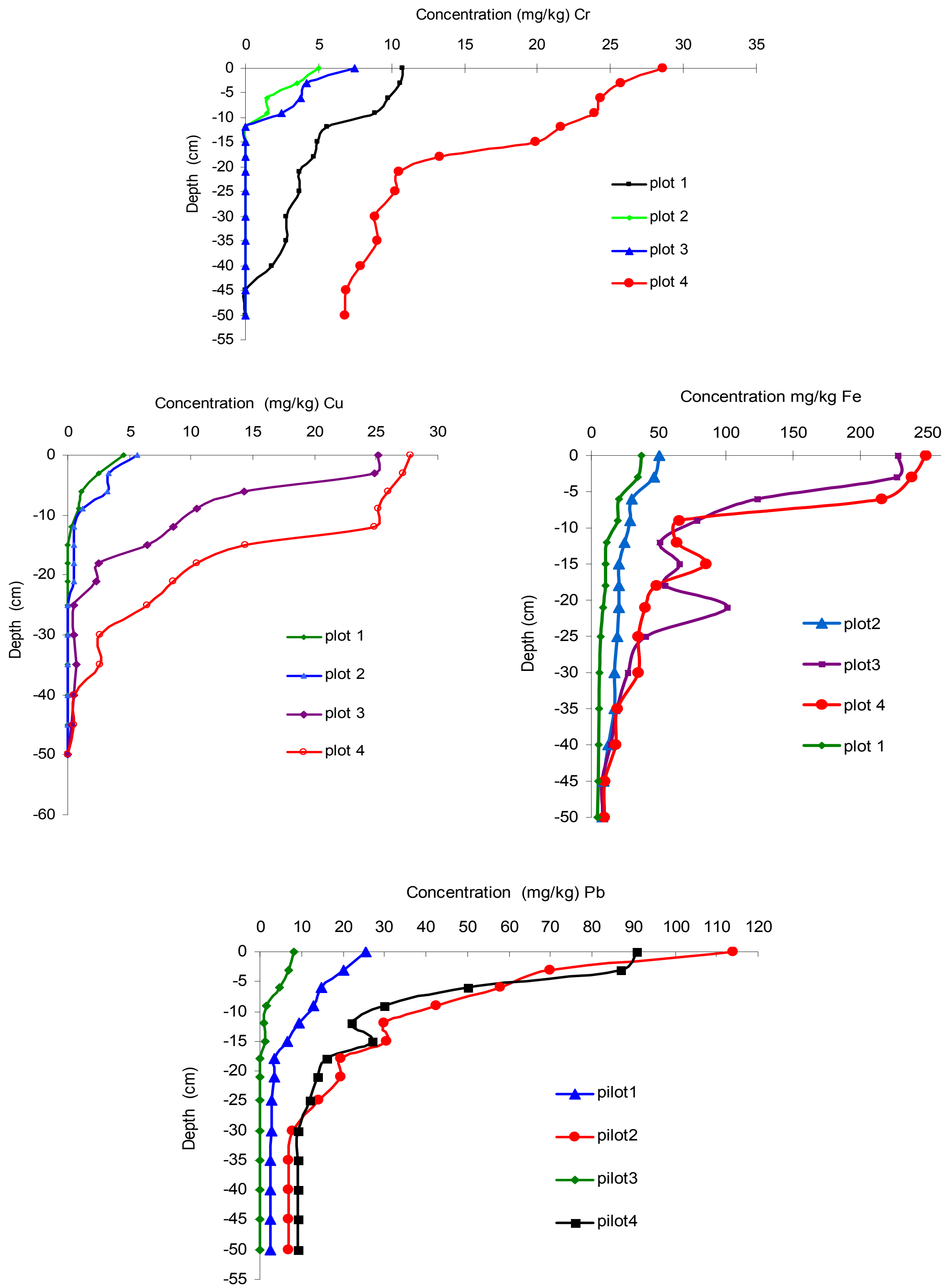

Fig. 2: Depth distribution of heavy metals in the soil profiles

Table 3: The mean concentration of heavy metals in leached water (mg/L)

Metals No. plot	Ni	Pb	Cd	Cr	Zn	Cu	Fe	sum
1	*ND	ND	ND	ND	0.050	0.040	0.090	0.18
2	0.160	0.070	0.010	0.070	0.360	0.060	0.090	0.82
3	0.260	0.110	0.010	0.270	0.360	0.120	0.400	1.53
4	0.785	0.110	0.019	0.803	0.532	0.180	0.439	2.868

The accumulation of metals was mostly observed in the surface layers. Though, preferential flow apparently allows leaching in the subsoil. Preferential flow can accelerate the movement of water and solutes through soil profiles. Water and solutes traveling in preferential flow pathways in soils; soil fractures, shrink-swell cracks, and root and worm holes (Richards *et al*., 1998). It seems pollution of groundwater by studied metals through shrink-swell cracks is likely.

Based on the results of this study, irrigation by effluent for several years and usage sewage sludge in agricultural lands increase heavy metals in soils. The concentration of heavy metals had increased significantly in the soil of plots compared with control plot. Although the most accumulation of metals observed in the surface layers, preferential flow apparently allows leaching in the subsoil. It seems pollution of groundwater by these metals through shrink-swell cracks is likely. It is essential to recognize and study the pollution sources of wastewater. The results of this study can be used for the management of effluent and sludge application in agricultural lands and crop production. The groundwater quality can be monitored and improved as well.

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