Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 2 (4): 291-297, 2008
ISSN 1819-3412

Accumulation of Zn, Cu, Ni and Pb in Soil and Leaf of *Pinus eldarica* Medw. Following Irrigation with Municipal Effluent

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Abstract: In order to assess the long-term effect of effluent irrigation on heavy metals accumulation in soil and leaf, a case study was undertaken in two neighboring *Pinus eldarica* Medw. plantations irrigated with municipal effluent and well water (for at least 15 years) in south of Tehran. In either of both areas 16 trees were considered to collect the leaf samples. One soil profile was dug under each selected tree to take the samples in depths of 0-15, 15-30 and 30-60 cm. In laboratory, the concentration of Zn, Cu, Ni and Pb of effluent and well water, soil and leaf samples were determined. Results indicated that municipal effluent had higher concentration of Zn, Cu, Ni and Pb compared to well water. The concentrations of Zn, Ni and Pb of municipal effluent and Ni and Pb of well water were greater than the normal range. Heavy metal accumulation of soil were significantly greater in effluent-irrigated area and in depth of 0-15 cm. Pb concentration of soil irrigated with both treatments and Ni concentration of soil irrigated with municipal effluent were greater than the normal range. Zn and Cu concentrations in leaf of trees irrigated with effluent were significantly greater than those in well water. Neither Ni nor Pb was detected in leaves. In general, there was not elevation of heavy metal in leaves.

Key words: Heavy metals, municipal effluent, plantation, *Pinus eldarica* medw., soil pollution

INTRODUCTION

Thousands liters domestic, industrial and hospital effluent annually are released in Tehran and caused the environmental problems. Likewise, 80% of useful water of the Tehran's citizens is converted to municipal effluent (Tajrishi, 1998). On the other hand, unplanned expansion of industrial factories and as a result increased air pollution make this city unavoidable to develop the green space. As a matter of fact, green space and forest green belt have an effective role in producing the purified air. Since, the water deficiency in Tehran is a limiting factor to develop the green space, therefore municipal effluent can be used as water required for expansion of green spaces and reduction of air pollution in and around the city and industrial complexes (Al-Jamal *et al*., 2000; Singh and Bhati, 2005; Salehi *et al*., 2007; Sharma *et al*., 2007). Beside, the absorption of harmful heavy metals of soil by a developed root system in plantations is caused to reduce the soil toxicity whereas a helpful role is provided for environment conservation (Cromer *et al*., 1987; Stewart *et al*., 1990).

On the other hand, high concentrations of heavy metals, nutrient elements (Gupta *et al*., 1998; Yadav *et al*., 2002; Brar *et al*., 2000) and microbial load of effluents (Toze, 2006) may disturb ecosystem (Naghshinehpour, 1994). In fact, the main problem to utilize the effluent in plantations is existence of the heavy metals, because these materials are accumulated in soil and absorbed in plant

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organs. High concentration of heavy metals affects mobilization and balances distribution of the fundamental elements in plant organs via the competitive uptake (Clarkson and Luttge, 1989; Schat and Ten Bookum, 1992).

Heavy metal accumulation in soil depends on different factors such as pH, texture and cation exchange capacity. Also different plant species differently accumulate heavy metals in their organs (Datta *et al*., 2000; Yadav *et al*., 2002). Therefore, decision for application of effluent should be made based on properties of water, soil, plant and environment of each location (Naghshinehpour, 1994; Salehi *et al*., 2007).

Generally, using a prescribed model of other regions to irrigate a defined region is basically a mistake. Because there may be provided the inevitable damages to soil and water resources in long-term (Hasan Oghli *et al*., 2002). This is due to difference in conditions of climatic, plant, social, cultural and also changes in qualities of soil and effluent among the different regions and even through a time period in a region (Metealf and Eddy, 1991; Najafi *et al*., 2001).

Till now, in the country, many researches have been conducted about effect of effluent on soil and plant, but no research reported on accumulation of heavy metals in soil. This study is intend to demonstrate the effect of municipal effluent on the of heavy metals accumulation, such as Zn, Cu, Ni and Pb, in soil and leaf of *Pinus eldarica* Medw. trees planted in an urban green space in southern Tehran.

MATERIALS AND METHODS

The study area is located in Shahr-e Rey, 5 km south of Tehran (35° 37' E and 51° 23' N, elevation of 1005 a.s.l.). The climate is semi-arid with mild-cold winters and 7 months (Mid April-Mid November) dry season (Fig. 1). Average annual precipitation and average annual temperature are 232 mm and 13.3°C, respectively. The highest precipitation falls in March and the lowest in August. The warmest month occurs in August and the coldest in January 2005.

In this study, two even-aged (15 years) *Pinus eldarica* Medw. plantations have been selected. The first stand (40,000 m^2) was being irrigated with municipal effluent and the second (10, 000 m^2) by well water. The irrigation was carried on 7-10 day periods for 8 months/year (from April to November). For sampling leaf and soil, four plots of 30× 30 m were randomly identified in either of both areas. In the growing season (Letacon, 1969) in four trees selected in each plot, leaf samples were taken from the top of crown and the part affected by sunlight (Habibi Kaseb, 1992). In laboratory the leaves were washed with distilled water and dried in oven for 48 h at 80°C (Hopmans *et al*., 1990). Four leaf samples taken from each plot were mixed and became as a homogeneous sample to determine the heavy metals contents. The leaf samples were wet digested as per Jackson (1973) and estimated using Atomic Absorption Spectrophotometer (AAS). One profile was dug under each selected tree in plot (in total 4 profiles in 4 plots). The soil samples were taken from depths of 0-15, 15-30 and 30-60 cm (Tzanakakis *et al*., 2003) and in each plot mixed in similar soil layer to decrease the number

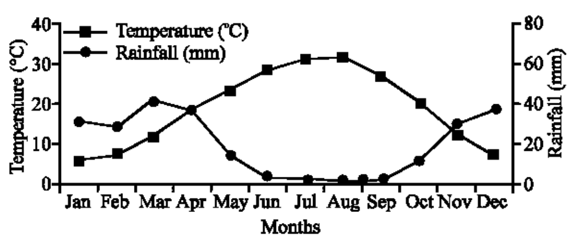

Fig. 1: Embrothermique curve of the study area

of samples (Habibi Kaseb, 1992). For determination of heavy metals (Zn, Cu, Ni and Pb), leaf and soil samples were extracted after digestion with 3:1 concentration of HCl and HNO_3 and measured by atomic absorption spectrophotometer (Gasco´ and Lobo, 2007).

Effluent and well water samples were taken out between early June and late November, 3 days per month and 3 times per day (morning, noon and evening). The pH of water was acidified by nitric acid (65%). The concentration of heavy metals was also determined by atomic absorption spectrophotometer.

SPSS (ver. 12.5) software was applied to analyze the information acquired during different stages of the present research. Initially, distribution of the data was performed using the Shapiro-Wilk's test. According to normality of data, comparison of heavy metals concentration of water (effluent and well water), leaf and similar depths of soil samples in two study areas were conducted by independent-sample t-test. Duncan Multiple range test was used for comparison of heavy metals content between different depths of soil in each irrigation area.

RESULTS

EC, pH and heavy metals concentration (Zn, Cu, Ni and Pb) in municipal effluent were significantly greater than those in well water ($p<0.01$) (Table 1). However, in both waters, pH and EC were in a normal range (Hach, 2002) and Pb and Ni contents were higher than the standard range. In municipal effluent, Zn concentration was greater than the standard range but Cu concentration was normal. In well water, Zn and Cu accumulation was lower than the standard range.

EC, pH, $CaCO_3$, C, SOC and heavy metals (Zn, Cu, Ni and Pb) were greater in soil (0-60 cm) irrigated by effluent (Table 2). Heavy metals were greater in effluent-irrigated area than in well-irrigated area (Fig. 2). In both treatments heavy metals were greater at superficial layer than at lower layers (Fig. 3). Only Ni in effluent-irrigated area and Pb in both irrigated areas were greater than the standard range (Table 2).

Zn and Cu elements were found in leaf samples, showing significantly greater in trees irrigated with effluent than well water. These did not reach to the harmful range for plant whereas their concentration was lower in leaf of trees irrigated with well water than the critical range (Table 3).

Table 1: Comparison of heavy metals (mean±SE) between municipal effluent and well water, using t-test

Source	pH	EC ($dS\ m^{-1}$)	Zn	Cu	Pb	Ni
			------------------------------- $mg\ L^{-1}$			------------------------------------
Municipal effluent	7.63±0.01^a	1.91±0.02^a	3.30±0.06^a	1.26±0.03^a	0.106±0.063^a	0.081±0.007^a
Well water	7.32±0.05^b	0.59±0.008^b	0.43±0.07^b	0.09±0.01^b	0.033±0.026^b	0.028±0.002^b
WHO[1]	6.5-8.5	3	3	1-2	0.01	0.02

Different superscripts in column are significantly different ($p<0.01$) (t-test), [1]World Health Orgnization (Hach, 2002)

Table 2: Comparison of soil properties (mean±SD) under the plantation of *Pinus eldarica* (depth of 0-60 cm) in two irrigated areas

Soil properties	Municipal effluent	Well water	p-value	Critical range
pH	8.090±0.05^a	7.790±0.129^b	<0.01	---------
EC ($dS\ m^{-1}$)	1.330±0.04^a	0.810±0.036^b	<0.01	---------
C (%)	0.695±0.033^a	0.521±0.050^b	<0.01	---------
Organic matter (%)	1.190±0.05^a	0.896±0.086^b	<0.01	---------
$CaCO_3$ (%)	18.940±0.73^a	16.070±0.51^b	<0.01	---------
Zn ($mg\ kg^{-1}$)	150.120±4.45^a	97.010±3.89^b	<0.01	10-500
Cu ($mg\ kg^{-1}$)	41.810±1.53^a	27.080±0.78^b	<0.01	5-400
Ni ($mg\ kg^{-1}$)	37.930±0.48^a	25.770±0.65^b	<0.01	30
Pb ($mg\ kg^{-1}$)	90.240±1.49^a	55.730±4.29^b	<0.01	40

Different superscripts in row are significantly different (t-test)

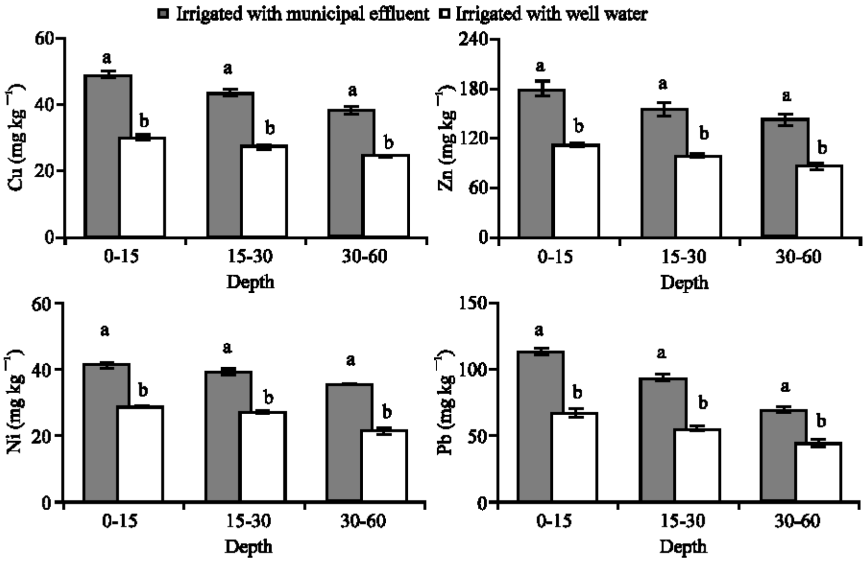

Fig. 2: Comparison of heavy metals in similar depths between soils irrigated with municipal effluent and well water, error bars are ± SE

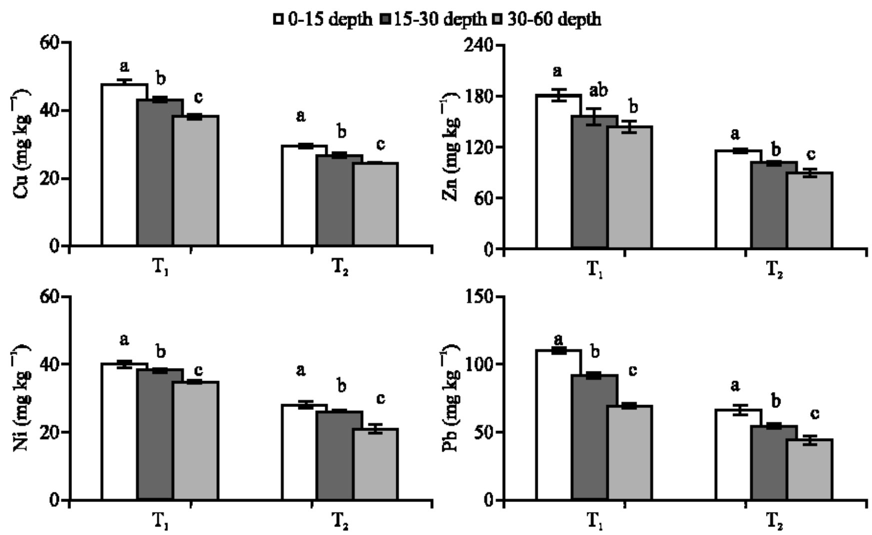

Fig. 3: Comparison of heavy metals among different depths of soil in each irrigated area, T_1: Soil irrigated by municipal effluent, T_2: Soils irrigated by well water, error bars are ± SE

Table 3: Accumulation (mean±SD) of heavy metals in leaf of *Pinus eldarica* irrigated with municipal effluent and well water, using t-test

Heavy metals	Municipal effluent	Well water	p-value	Critical range
Zn (mg kg^{-1})	14.06±1.19^{a}	9.06±1.87^{b}	<0.01	10-100
Cu (mg kg^{-1})	2.05±0.22^{a}	1.51±0.20^{b}	<0.05	2-20

Different superscripts in row are significantly different (t-test)

DISCUSSION

In this study, the accumulation of Zn, Cu, Ni and Pb in municipal effluent was greater than that in well water. The amount of Ni and Pb in municipal effluent and well water and Zn in municipal effluent was greater than those in standard level. The concentration Zn, Cu, Ni and Pb was higher in all depths of soil in effluent irrigated-area. As a matter of fact, high concentration of heavy metals in effluent leads to increase them in soil (Saber, 1986; Torabian and Baghori, 1997; Huerta *et al*., 2002; Mapanda *et al*., 2005; Singh and Bhati, 2005; Aghabarati, 2006). In this study, with effluent irrigation, concentration of Zn and Cu did not reach to harmful range, nevertheless Ni and Pb contents were greater than the standard (EPA, 2002). In general, effluent affects heavy metals accumulation of soil. This depends on various factors such as concentration of heavy metals of effluent, period of irrigation, soil properties (pH, texture, cation exchange capacity) (Hodji and Jalalian, 2004; Salehi *et al*., 2007). Generally, 10 to 50 years is needed so that the heavy metals levels reach to the standard levels (Smith *et al*., 1996). This is while that Ramirez-Fuentes *et al*. (2002) and Smith *et al*. (1996), respectively with studies of 4 and 17 years showed that heavy metals concentration in effluent-irrigated soil did not vary markedly during these periods.

The concentration of heavy metals decreases with soil depth in both areas. Low concentration of heavy metals in lower layers is due to their low mobility in soil (Afyoni *et al*., 1998). Because soil texture in both areas is loam-clay, as a result penetrability decreases and accumulation of these elements observed at upper layers (Aghabarati, 2006).

Although, the main problem of the effluent-irrigated plantations is due to the existence of heavy and toxic metals (Aucejo *et al*., 1996; Bozkurt and Yarilga, 2003; Singh and Bhati, 2005; Aghabarati, 2006; Paula *et al*., 2006) our results showed that irrigation with effluent did not lead to toxicity in leaf of *Pinus eldarica* trees. This may be due to their low dynamic and mobility in both soil and plant, whereas heavy metals (Ni and Pb) were likely accumulated in lower parts of the plant, such as root and stump (Baldantoni *et al*., 2004).

Generally, little quantity of micro elements in plants is not dangerous but is necessary; however, disturbance in plant nutrition may occur when absorption and accumulation of these elements increase in soil and plant (Woolhouse, 1983; Baker, 1987; Macnair, 1993). In our study micro elements of Zn and Cu existed in effluent were favored for *Pinus eldarica* trees.

Regarding to the results of this study, it can be recommended that based on an accurate and controlled management, effluents can be utilized for plantation projects in suburb and green belts of cities, provided their physical, chemical and microbial properties are not exceed the international standards. Pre-refining could reduce soil and plant contaminations. Hence, for long time, municipal effluent can be used for irrigation of suburb and urban green space.

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