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Effects of Urban Wastewater on Accumulation of Heavy Metals in Soil and Corn (*Zea mays* L.) with Sprinkler Irrigation Method

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Abstract: As a result of urbanization, urban wastewater has increased fast, so reusing urban wastewater has become a research topic for a long time. The aim of the study was to investigate the effects of urban wastewater on accumulation of heavy metals in soil and corn (*Zea mays* L.) with sprinkler irrigation method. Soil samplings of 0 to 10 cm depth were taken. Corn was transplanted in these soils. The experiment consisted of two treatments including soil irrigation with water by SI system (Sprinkler Irrigation) (T1) and soil irrigation with wastewater by SI system (T2). Soil properties such as soil reaction (pH), Electrical Conductivity (EC), Organic Matter (OM), Extractable Fe, Manganese (Mn), Nickel (Ni) and Cadmium (Cd) were measured. After 40 days, samples were taken for testing. In this study, the concentrations of extractable Fe, Mn, Cd and Ni (ppm) in soil under T1 treatment were 2.44, 1.76, 0.08 and 0.36 but they (ppm) in soil under T2 treatment were 2.56, 1.90, 0.11 and 0.45, respectively. In the corn under the treatments, the concentrations of extractable Fe, Mn, Cd and Ni (ppm) in shoots under T1 treatment were 1.112, 0.362, 0 and 0 but they (ppm) in shoots under T2 treatment were 2.217, 0.924, 0.011 and 0.016, respectively. These results showed that the urban wastewater caused increase of DTPA-extractable iron, manganese, cadmium and nickel in soil and corn with sprinkler irrigation method. Accumulation of these metals in shoots was more important than in roots in SI system.

Key words: Corn, heavy metals, soil, sprinkler irrigation, wastewater

INTRODUCTION

The rapid population growth in many municipalities in the arid eastern Iran continues to place increasing demands on limited fresh water supplies. Many cities and districts are struggling to balance water use among municipal, industrial, agricultural and recreational users. Treated or recycled wastewater appears to be the only water resource that is increasing as other sources are dwindling (Jahantigh, 2008). As a result of urbanization, urban wastewater has increased fast, so reusing urban wastewater has become a research topic for a long time. Also, the pollutant components should be removed (Burun *et al*., 2006).

Water shortages are becoming increasingly common in the arid and semi arid areas. Increased use of Reclaimed Wastewater (RWW), i.e., recycled water, is viewed as one of the approaches to maximize the existing water resource and stretch current urban water supplies. Wastewaters often contain significant concentrations of organic and inorganic nutrients for example nitrogen, phosphate, (Alshammary and Qian, 2008) micronutrients and heavy metals.

Municipal wastewater is a combination of the water and carried wastes removed from residential, institutional and commercial establishments together with infiltration of water, surface water and runoff water (Rusan *et al*., 2007).

Wastewater sludge produced by sewage treatment plants are represented as a good source of macro- and microelements and generally contain a high quality of organic matter. Their application in agriculture translates into improved soil fertility (Amin *et al*., 2009).

Wastewaters carry appreciable amounts of toxic heavy metals and concentrations of heavy metals in waste waters vary from city to city. Important sources of heavy metals in waste water are urban and industrial effluents. Heavy metals are extremely persistent in the environment; they are nonbiodegradable and nonthermodegradable and thus readily accumulate to toxic levels. Long-term use of waste waters on lands often results in the build-up of the elevated levels of heavy metals in soils (Tabari *et al*., 2008).

The effect of wastewater on soil, subsurface water and plants completely depend on the type of the wastewater and its content (Tabatabaei *et al*., 2007).

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Asagi *et al*. (2007) explained the application of sewage sludge may also have beneficial effects on soil physiochemical and biological properties. However, the application of sewage sludge to farmlands has received considerable attention since it not only contains nutrients for plants but also sometimes has a significant level of heavy, potentially toxic metals such as Zn, Cu, Pb and Cd; these pose a risk to human health through accumulation in the soil and food chain. It has also been reported that heavy metal concentrations in sewage sludge depend on regional characteristics.

The four basic methods of irrigation are: Subsurface irrigation ("subirrigation" which uses tile drain lines), surface or gravity irrigation, trickle irrigation (also called drip irrigation) and sprinkler irrigation. A sprinkler "throws" water through the air to simulate rainfall whereas the other three irrigation methods apply water directly to the soil, either on or below the surface (Scherer, 2010).

The aims of this research were to assess the effects of urban wastewater on accumulation of micronutrients and heavy metals soil and corn.

MATERIALS AND METHODS

Sample preparation: Soil samples of 0 to 10 cm depth were taken from Fereydoonshahr area in Isfahan province (center of Iran). Corn was transplanted in these soils. The experiment was carried out at green house in 2011. The experiment consisted of two treatments (with 3 replications) including soil irrigation with water by SI (Sprinkler Irrigation) (T1) and soil irrigation with wastewater by SI system (T2).

After 40 days, samples were taken for testing. The plant tissues were prepared for laboratory analysis by Wet Digestion method (Campbell and Plank, 1998). Soil samples were air dried in a green house at a temperature between 25 and 30°C and sifted through a 2 mm mesh sieve for preparation of soil samples (Mojiri *et al*., 2011).

Laboratory determinations: Soil Reaction (pH), Electrical Conductivity (EC) and soluble cations were measured on 1:1 extract (Soil: Water). Sodium ions (Na) and potassium ions (K) were measured by Flamephotometry (Zarinkafsh, 1993). Total Nitrogen (TN) was measured by Kjeldahl method (ASA, 1982). Micronutrients and heavy metals in soil and plant samples were carried out by DTPA in accordance the Standard Methods, analysis of wastewater was carried out in accordance the Standard Methods (APHA, 1998).

Statistical analysis: Descriptive statistical analysis including mean comparison using Duncan's Multiple Range Test (DMRT) (in 0.05 level) was conducted using SPSS software.

RESULTS AND DISCUSSION

Main soil, water and wastewater properties before experiment are shown in Table 1. The soil chemical characteristics in the two treatments can be compared in Table 2.

DTPA-extractable iron (Fe), Manganese (Mn), Cadmium (Cd) and Nickel (Ni) (ppm) equal to 2.47, 1.72, 0.08 and 0.37 were found in the main soil, respectively.

The quality of municipal wastewater and well water was assessed for irrigation with respect to their pH, EC and content of heavy metals (Table 1). Extractable Fe, Mn, Cd and Ni equal to 0.371, 0.082, 0.071 and 0.032 were found in the wastewater, respectively.

Minimum extractable Fe (ppm) equal to 2.44 was observed in T1 and maximum extractable Fe equal to 2.56 was found in T2. Minimum extractable Mn (ppm) equal to 1.76 was recorded in T1 and maximum extractable Mn equal to 1.90 was determined in T2. Minimum extractable Cd (ppm) equal to 0.08 was recorded in T1 and maximum extractable Cd equal to 0.11 was observed in T2. Minimum extractable Ni (ppm) equal to 0.36 was determined in T1 and maximum extractable Ni equal to 0.41 was determined in T2.

According to Table 2, soil irrigation with wastewater increased Fe, Mn, Cd and Ni. The role of wastewater in reducing soil pH can be effective in increasing of extractable Fe, Mn, Cd and Ni.

Table 1: Main soil, water and wastewater properties

	pH	EC (dS m^{-1})	N (ppm)	BOD_5 (ppm)	K (ppm)	Ca (me L^{-1})	Mg (me L^{-1})	Na (me L^{-1})	Fe (ppm)	Mn (ppm)	Cd (ppm)	Ni (ppm)
Soil	7.14	1.10	0.08	-	2.95	-	-	23.01	2.47	1.72	0.08	0.37
Water	7.04	0.26	0.00	-	0.02	2.10	1.17	0.40	0.001	0.00	0.00	0.00
Wastewater	6.90	1.20	30.12	26.21	25.41	3.91	2.99	7.87	0.371	0.082	0.071	0.032

Table 2: Comparing the means for soil chemical characteristics

Soil irrigation by SI system	pH	EC (dS m^{-1})	N (%)	Fe (ppm)	Mn (ppm)	Cd (ppm)	Ni (ppm)
T1 (With water)	7.13^{a}	1.17^{a}	0.11^{a}	2.44^{a}	1.76^{a}	0.08^{a}	0.36^{a}
T2 (With wastewater)	6.98^{b}	1.24^{b}	0.22^{b}	2.56^{b}	1.90^{b}	0.11^{b}	0.41^{b}

Values followed by same letters in each column are not significantly ($p<0.05$) different according to the DMR test

Effects of wastewater irrigation on accumulation of micronutrients and heavy metals in soil: These results showed that:

- Irrigation with wastewater increased extractable Fe. This is in line with findings of Rusan *et al.* (2007)
- Irrigation with wastewater increased extractable Mn. This is in line with findings of Rusan *et al.* (2007)
- Irrigation with wastewater increased extractable Cd. This is in line with findings of Mapanda *et al.* (2005)
- Irrigation with wastewater increased extractable Ni. This is in line with findings of Mapanda *et al.* (2005)

Accumulation of micronutrients and heavy metals from wastewater application could be caused directly by the wastewater composition or indirectly through increasing solubility of the indigenous insoluble soil heavy metals as a result of the chelation or acidification action of the applied wastewater (Rusan *et al.*, 2007).

Hussein (2009) Investigated impact of sewage sludge as organic manure on some soil properties, growth, yield and nutrient contents of cucumber crop. The results showed that the application of sewage sludge increased the cucumber leaf elemental contents grown in sandy and calcareous soils. The data revealed that macronutrients (N, P and K), micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Cd and Ni) content increased gradually with increasing levels of sludge application. Also, sewage sludge insignificantly increased the contents of Ca, Mg and Co of cucumber leaves grown in sandy soil. Also, the results in showed that the concentration of N, P, Ca, Mg, Fe, Mn, Cu, Zn, Cd and Ni in cucumber leaves grown in calcareous soil significantly increased with increasing sewage sludge application rates.

Some investigations showed that the irrigation with wastewater does not have effect on soil extractable concentration of cadmium and nickel (Rusan *et al.*, 2007; Vaseghi *et al.*, 2005). In these investigations the smaller effect of wastewater on the extractable cadmium and nickel may be due to the small amount of cadmium and nickel in the applied sewage sludge and wastewater.

Data on the extractable concentration of heavy metals in wheat plants in the four applied treatments can be seen in Table 3.

Minimum extractable concentration of Fe (ppm) in shoot, equal to 1.112, was determined in T1 and maximum extractable Fe equal to 2.217 was found in T2. Minimum extractable Mn (ppm) in shoot equal to 0.362 was recorded in T1 and maximum extractable Mn equal to 0.924 was related to T2. Minimum extractable Cd in root (ppm) equal to 0.00 was observed in T1 while maximum extractable Cd equal to 0.011 was noticed in T2. Minimum extractable Ni in shoot (ppm) equal to 0.00 was determined in T1 while maximum extractable Ni equal to 0.016 was found in T2.

Table 3: Comparing the accumulation of heavy metals in corn in the four applied treatments

Corn irrigation SI system	Fe (ppm)	Mn (ppm)	Cd (ppm)	Ni (ppm)
T1 (With water)				
Root	1.763^{a}	0.706^{a}	0.008^{a}	0.008^{a}
Shoot	1.112^{b}	0.362^{b}	0.00^{b}	0.00^{b}
T2 (With wastewater)				
Root	1.911^{c}	0.742^{c}	0.009^{a}	0.011^{c}
Shoot	2.217^{d}	0.924^{d}	0.011^{c}	0.016^{d}

Values followed by same letters in each column are not significantly ($p<0.05$) different according to the DMR test

Minimum extractable concentration of Fe (ppm) in root, equal to 1.763, was determined in T1 and maximum extractable Fe equal to 1.911 was found in T2. Minimum extractable Mn (ppm) in root equal to 0.706 was recorded in T1 and maximum extractable Mn equal to 0.742 was related to T2. Minimum extractable Cd in root (ppm) equal to 0.008 was observed in T1 while maximum extractable Cd equal to 0.009 was noticed in T2. Minimum extractable Ni in root (ppm) equal to 0.008 was determined in T1 while maximum extractable Ni equal to 0 .011 was found in T2.

According to Table 3, corn irrigation with wastewater increased Fe, Mn, Cd and Ni in roots and in shoots.

The effects of wastewater on accumulation of micronutrients and heavy metals in corn: These results showed that:

- Extractable Fe in corn irrigated with wastewater increased. This is in line with findings of Arora *et al.* (2008)
- Extractable Mn in corn irrigated with wastewater increased. This is in line with findings of Arora *et al.* (2008)
- Extractable Cd in corn irrigated with wastewater increased. This is in line with findings of Rusan *et al.* (2007)
- Extractable Ni in corn irrigated with wastewater increased. This is in line with findings of Jagtab *et al.* (2010)

Asgari *et al.* (2007) investigated the effects of treated municipal wastewater on growth parameters of corn in different irrigation conditions. Results indicated that, subsurface drip irrigation with wastewater in 30 cm depth as compared to other treatments (Treatment were: Furrow irrigation with drinking water network, surface drip irrigation with wastewater, subsurface drip irrigation with wastewater in 15 cm depth, subsurface drip irrigation with wastewater in 30 cm depth and furrow irrigation with wastewater) had higher growth parameters and had seen significant difference. Thus, drip irrigation with wastewater and furrow irrigation with wastewater, had lower growth parameters as compared to another treatments.

In many investigations accumulation of heavy metals in roots was more important than in shoots (Arora *et al*., 2008; Galavi *et al*., 2010). In these investigations irrigation methods were flooding irrigation, drip irrigation or etc but in this study irrigation method was sprinkler method. A sprinkler "throws" water through the air to simulate rainfall whereas the other irrigation methods apply water directly to the soil, either on or below the surface, as a result accumulation of heavy metals in upper issues of plant were more important than in the lower issues of plant.

Accumulation of micronutrients and heavy metals as a result of wastewater application could be caused directly by the wastewater composition or indirectly through increasing solubility of the indigenous insoluble soil heavy metals as a result of the chelation or acidification action of the applied wastewater (Rusan *et al*., 2007).

According to this study, the accumulation of heavy metals in shoot was more important than in root in SI system.

CONCLUSION

Municipal wastewater is a combination of the water and carried wastes removed from residential, institutional and commercial establishments together with infiltration of water, surface water and runoff water. The effect of urban wastewater on accumulation of heavy metals in soil and corn (*Zea mays* L.) with sprinkler irrigation (SI system) method has been investigated. The evidences provided by this experiment indicated that the urban wastewater caused increase of micronutrients and heavy metals in soil and corn with sprinkler irrigation method. Accumulation of heavy metals in shoots was more important than in roots in SI system.

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