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Effects of Municipal Wastewater on Physical and Chemical Properties of Saline Soil

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ABSTRACT

A study was carried out to investigate the effects of municipal wastewater treatments on physical and chemical properties of saline soil. Recently, the amounts of wastewater are sharply increasing and the kinds of pollutants are also varied as the world wide industry is being developed incessantly. Soil samplings of 0-20 cm depth were from Segzi plain in Isfahan province (the center of Iran). The experiment was carried out at green house. The experiment consisted of 4 treatments including soil without irrigated (T1), soil irrigated with 100 ml of wastewater (T2), 200 ml of wastewater (T3) and 300ml of wastewater (T4) for everyday were taken as experimental unit. Soil reaction (pH), electrical conductivity (EC), organic matter (OM), total nitrogen (TN), phosphorus (P), potassium (K), sodium ions (Na), chloride ions (Cl), extractable iron (Fe), cadmium (Cd), zinc (Zn) and bulk density (BD) were determined. Soil irrigated with wastewater caused increase of EC, P, OM, TN, K, Na, Cl, Fe, Cd and Zn but it caused a decrease of soil pH. This result showed that soil irrigated with wastewater caused a decreased of BD.

Key Words: Bulk density, Cadmium, Lead, Nitrogen, Saline soil, Wastewater

INTRODUCTION

Water is a scarce commodity in the Middle East and North Africa (MENA) and its availability is declining to a crisis level. The reuse of wastewaters for purposes such as agricultural irrigation can reduces the amount of water that needs to be extracted from environmental water sources (Heydarpour *et al.* 2007). Water is a vital resource but a severely limited one in most countries (Mapandaa *et al.* 2005).

Due to its especial geographic condition, Iran is a dry and semi-dry zone in the world (Honarjoo *et al.* 2010). In arid and semi-arid regions, water resources of good quality are becoming scarcer and are being allocated with priority for urban water supply. Therefore, there is an increasing necessity to irrigate with water that already contains salts, such as saline groundwater, drainage water, and treated wastewater (Jalali *et al.* 2007).

Recently, the amounts of wastewater are sharply increasing and the kinds of pollutants are also varied as the world wide industry is being developed incessantly. With respect to both the quantity and composition, the textile processing wastewater is recorded as the most polluted sources among all industrial sectors (Chang *et al.* 2009).

Irrigation with treated municipal wastewater is considered an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies. In addition, wastewater is a valuable source of plant nutrients and organic matter needed for maintaining fertility and productivity levels of the soil (Rusan *et al.* 2007).

Najafi and Nasr (2009) investigated comparative the effects of wastewater on soil chemical properties in three irrigation methods. The results showed that the application of wastewater in DI (Drip Irrigation) caused an increase of EC, OM, SO_4, Ca, Na, Cl and a decrease of hydraulic conductivity, porosity, Pb and moisture point of soil DI and FW (Fresh Water) treatments.

Karami *et al.* (2007) investigated the effects of municipal sewage sludge on the concentration of Lead (Pb) and Cadmium (Cd) in soil and on yield of wheat. Their results showed that the application of sewage sludge cause increase of extractable cadmium and lead in soil.

Abedi-Koupai *et al.* (2006) investigated the effect of treated wastewater on soil chemical and physical properties in an arid region. Treated wastewater showed no effect on the increase of Fe, Cd, Ni, Cu and Zn during growing season. The irrigation system had a significant effect on infiltration rate, bulk density and total porosity.

Gloaguen *et al.* (2007) investigated soil solution chemistry of a Brazilian Oxisol irrigated with treated sewage effluent. Results about C and N chemistry showed mineralization of dissolved organic matter and rapid nitrification from ammoniac and organic nitrogen provided by effluent. The nitrate concentration decreased by plant uptake but also by leaching during the rainy season, pointing out a long-term risk of contamination of shallow groundwater environments.

The aim of this research was to assess the effects of urban wastewater on some properties of saline soil.

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MATERIALS AND METHODS

Site description, soil sample preparation

The experiment was carried out at green house in 2011. Soil samplings of 0-20 cm depth were from Segzi plain in Isfahan province in the center of Iran. Soil samples were air dried in a green house at a temperature between 25ºC and 30ºC and sifted through a 2-mm mesh sieve for preparation of soil samples (Mojiri *et al.* 2011). The experiment consisted of 4 treatments including soil without irrigated (T1), soil irrigated with 100 ml of wastewater (T2), soil irrigated with 200 ml of wastewater (T3) and soil irrigated with 300 ml of wastewater (T4) for everyday were taken as experimental unit. Soil samples were taken for testing, after 40 days.

Laboratory determinations

Soil reaction (pH), electrical conductivity (EC) and soluble cations were measured on 1:1 extract (Soil:Water). Sodium ion (Na) and potassium (K) were measured by Flamephotometry (Zarinkafsh 1993). Soil organic matter (OM) was determined as in Walkley and Black (ASA 1982). Chloride ion was measured by titration method with silver nitrate (Richards 1954). Total nitrogen (TN) was measured by Kjeldahl method, was measured (ASA 1982). Phosphorus was measured by Olsen method (Ludwick *et al.* 1974). Micronutrients and heavy metals in soil samples were carried out by DTPA in accordance the Standard Methods (APHA 1998). The Bulk density (BD) was estimated using paraffin method (Blake and Hartge, 1986).

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) was conducted using SPSS software.

RESULTS AND DISCUSSION

Wastewater properties, analysis of main soil, soil samples irrigation with 100 ml, 200 ml and 300 ml of wastewater for everyday and comparing the means for soil chemical characteristics before and after experiment are shown in Tables 1, 2 and 3, respectively.

Table 1. Analysis of wastewater

pH	EC (dS m^{-1})	BOD (ppm)	N (ppm)	P (me L^{-1})	Na (me L^{-1})	Cl (me L^{-1})	K (me L^{-1})	Fe (ppm)	Zn (ppm)	Cd (ppm)
6.88	1.21	30.0	26.3	15.03	9.2	6.9	27.99	0.22	0.016	0.09

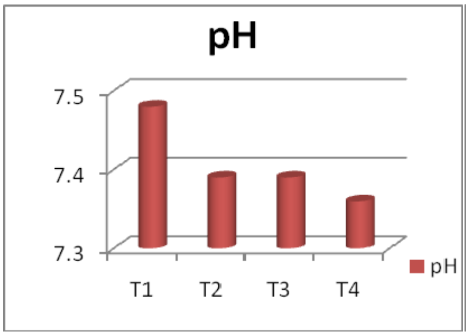
Table 2. Soil samples properties

pH	EC (dS m^{-1})	P (mg Kg^{-1})	OM (%)	N (%)	Na (me L^{-1})	Cl (me L^{-1})	K (me L^{-1})	Fe (ppm)	Cd (ppm)	Zn (ppm)	BD (g/cm^3)
Soil without irrigation with wastewater (Main Soil) (T1)											
7.48	60.00	20.00	0.49	0.09	1600.0	610.0	15.5	1.07	0.00	0.04	1.38
Soil irrigated with 100 ml of wastewater for everyday (T2)											
7.39	62.18	21.11	0.69	0.13	1780.0	632.1	16.7	1.15	0.00	0.05	1.38
Soil irrigated with 200 ml of wastewater for everyday (T3)											
7.39	63.07	22.02	0.77	0.16	1800.6	667.3	17.9	1.35	0.05	0.07	1.31
Soil irrigated with 300 ml of wastewater for everyday (T4)											
7.36	65.09	23.13	0.84	0.18	1826.0	692.0	18.3	1.35	0.08	0.07	1.31

Table 3. Comparing the means for soil chemical characteristic before and after experiment

Parameters	Treatments			
	T1	**T2**	**T3**	**T4**
pH	7.482a+	7.389b	7.393b	7.362d
EC	60.004a	62.177b	63.072c	65.092d
P	20.001a	21.106b	22.017c	23.131d
OM	0.494a	0.691b	0.773c	0.839d
N	0.092a	0.133b	0.156c	0.179d
Na	1600.05a	1780.03b	1800.64c	1826.05d
Cl	610.02a	632.07b	667.29c	692.04d
K	15.51a	16.68b	17.95c	18.26d
Fe	1.074a	1.154b	1.351c	1.354c
Zn	0.043a	0.054a	0.069c	0.072c
Cd	0.00a	0.00b	0.051c	0.084d
BD	1.38a	1.376a	1.314c	1.309c

+ Numbers followed by same letters are not significantly ($P<0.05$) different according to the DMR test



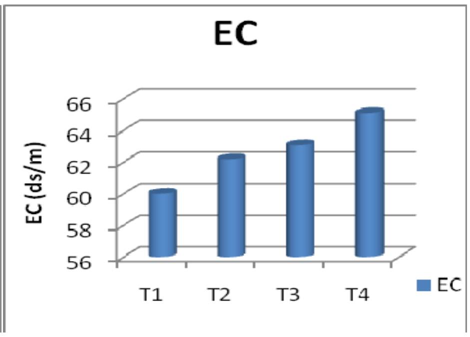
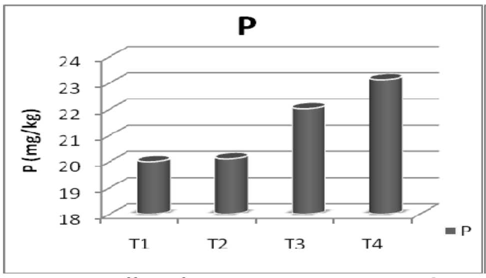


Figure 1. Effect of wastewater irrigation on soil pH **Figure 2.** Effect of wastewater irrigation on soil EC

Treatments 1, 2, 3 and 4 show the main soil, soil irrigated with 100 ml, 200 ml and 300 ml of wastewater, respectively



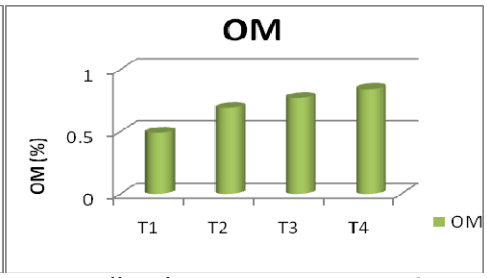
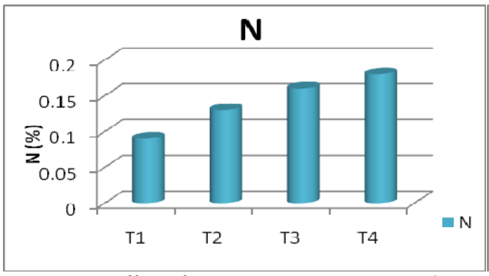


Figure 3. Effect of wastewater irrigation on Soil P **Figure 4.** Effect of wastewater irrigation on Soil OM



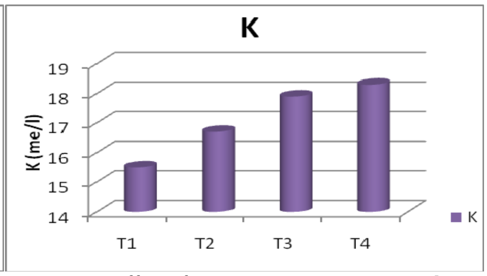


Figure 5. Effect of wastewater irrigation on Soil N **Figure 6.** Effect of wastewater irrigation on Soil K

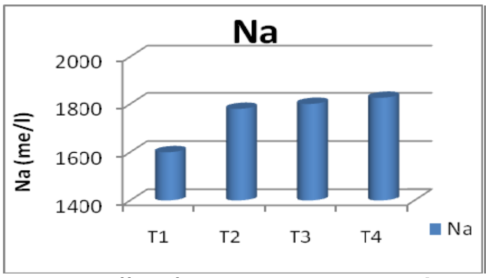


Figure 7. Effect of wastewater irrigation on Soil Na

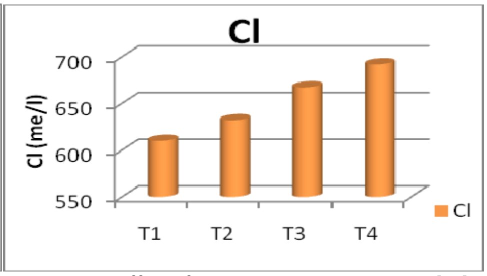


Figure 8. Effect of wastewater irrigation on Soil Cl

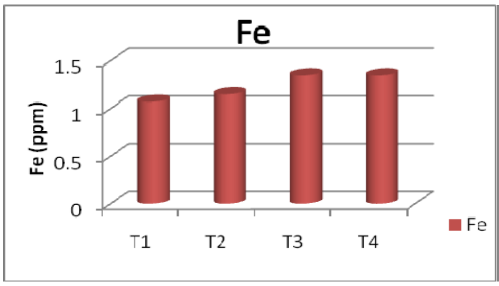


Figure 9. Effect of wastewater irrigation on Soil Fe

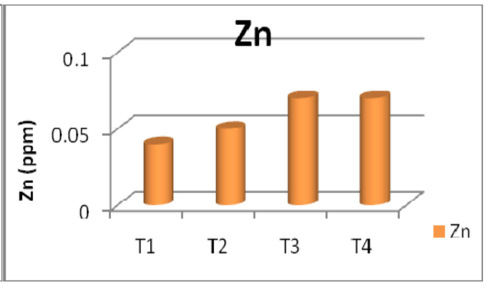


Figure 10. Effect of wastewater irrigation on Soil Zn

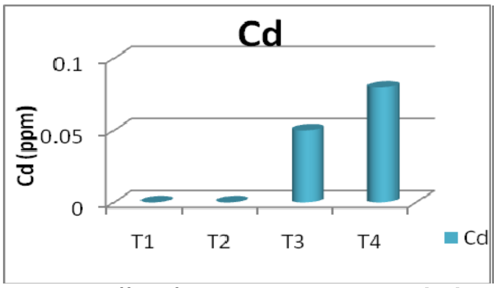


Figure 11. Effect of wastewater irrigation on Soil Cd

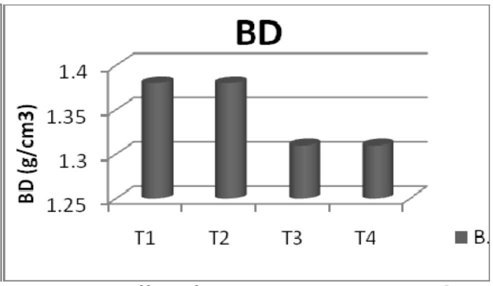


Figure 12. Effect of wastewater irrigation on Soil BD

Soil reaction (pH)

Irrigation with wastewater decreased soil pH (Table 3 and Fig. 1). The reason is likely due to the decomposition of organic matter and production of organic acid in soils irrigated with wastewater (Vaseghi *et al.* 2005). This is in line with findings of Vaseghi *et al.* (2005) and Khai *et al.* (2008).

Some investigations showed that the soil irrigation with wastewater increased soil pH (Rusan 2007, Rattan *et al.* 2005). Most these investigations described the long term impact of irrigation with sewage and wastewater effluents on soil properties while our study was short term. Soil irrigation with wastewater may cause at first a decrease of soil pH, but after a while it may cause an increase of soil pH.

Electrical conductivity (EC)

Electrical conductivity of soils irrigated with wastewater increased (Table 3 and Fig.2) because of higher EC of wastewater. This is in line with findings of Rusan *et al.* (2007), Jahantigh (2008). The higher concentration of cations such as Na and K in wastewater led to an increase in EC and exchangeable Na and K in soils irrigated with wastewater (Khai *et al.* 2008).

Phosphorus (P)

According to Table 3 and Fig. 3, soil irrigated with wastewater caused an increase of phosphorus. This is most likely due to the higher P content of wastewater.

Organic matter (OM)

Irrigation with wastewater increased OM content of soil (Table 3 and Fig. 4). This is most likely due to the higher OM content of wastewater. This is in line with findings of Debosz *et al.* (2002) and Khai *et al.* (2008).

Total nitrogen (TN)
According to Table 3 and Fig. 5, soil irrigated with wastewater caused an increase of total nitrogen. This is in line with findings of Rusan *et al.* (2007) and Khai *et al.* (2008). Increasing the total N of soil irrigated with wastewater can be attributed to N different forms in the wastewater.

Potassium (K)
According to Table 3 and Fig. 6, soil irrigated with wastewater caused an increase of potassium. This is most likely due to the higher K content of wastewater.

Sodium ions (Na)
According to Table 3 and Fig. 7, soil irrigated with wastewater caused an increase of sodium. This is in line with findings of Najafi and Nasr (2009). Increasing the Na of soil irrigated with wastewater can be attributed to minerals in the wastewater.

Chloride ions (Cl)
According to Table 3 and Fig. 8, soil irrigated with wastewater caused an increase of chloride. This is in line with findings of Najafi and Nasr (2009). Increasing the Cl of soil irrigated with wastewater can be attributed to minerals in the wastewater

Iron (Fe)
According to Table 3 and Fig. 9, soil irrigated with wastewater caused an increase of Fe. This is in line with findings of Vaseghi *et al.* (2005) and Abedi-Koupai (2006). The role of wastewater in reducing soil pH can be effective in increasing extractable Fe.

Zinc (Zn)
According to Table 3 and Fig. 10, soil irrigated with wastewater caused an increase of Zn. This is in line with findings of Vaseghi *et al.* (2005). The role of wastewater in reducing soil pH can be effective in increasing extractable Zn.

Cadmium (Cd)
According to Table 3 and Fig. 11, soil irrigated with wastewater caused an increase of cadmium. This is in line with findings of Mapanda *et al.* (2005). Cadmium is a ubiquitous non-essential element that possesses high toxicity and is easily accumulated from the environment by organisms (Rahimi and Nejatkhan 2010).

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).

Bulk density (BD)
According to Table 3 and Figure 12, soil irrigated with wastewater caused a decrease of BD. The role of wastewater in increasing soil OM can be effective in decreasing BD.

CONCLUSIONS

The reuse of wastewaters for purposes such as agricultural irrigation can reduces the amount of water that needs to be extracted from environmental water sources. Soil irrigated with wastewater caused increase of EC, P, OM, TN, K, Na, Cl, Fe, Cd and Zn but it caused a decrease of soil pH. This result showed that soil irrigated with wastewater caused a decreased of BD.

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