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Long-Term Effects of Municipal Wastewater Irrigation on Some Properties of a Semiarid Region Soil of Iran

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Abstract
To investigate the effect of long-term irrigation of wheat farms on the soil properties, a field study was carried out in Varamin Station located in southern Tehran, Iran. The soil samples were collected from the area with 29 years using wastewater irrigation and comparing the results with soil properties extracted from the previous control profile of the pedological study in 1981. Some soil properties of the samples such as electrical conductivity (EC), soil reaction (pH), organic carbon (OC), bulk density (pb), and saturate hydraulic conductivity (Ks) were measured for comparison. The obtained paired data were analyzed with T-test. The results showed that using wastewater significantly increased the soil organic carbon and bulk density in depth of 0-20 centimeters ($p<0.05$). Saturated hydraulic conductivity in depth of 0-20 centimeters and soil reaction in both depths of 0-20 and 20-40 centimeters significantly decreased ($p<0.05$). The reason may be due to filling of colloidal particles suspended in wastewater within the soil porosity. Wastewater quality and, possibly soil properties, appear to play an important role in the effect of using wastewater irrigation on the soil physical properties.

***Keywords**: irrigation; municipal wastewater; physical properties; irrigation*

I. Introduction

Arid and semiarid regions are characterized by exceeding of the evapotranspiration rate rather than precipitation during most of the years. Therefore, agriculture in these regions depends on supplementary irrigation to enable crop growth production. At the same time, one of the main environmental problems in these regions is the shortage of freshwater expected to become more severe in the future due to the growing demand of different segments for water. Decay of water resources, as well as drought and climate change make the problem more severe and critical. In these regions, one of the challenges facing agricultural practice, which needs a large amount of water, is finding new water resources for irrigation.

In recent years, one of the alternatives of supplying water resources could be reuse of treated domestic swage (effluent) for irrigation (Lado and Ben-Hur, 2009). Irrigation with municipal wastewater could change soil properties that play an important role on the amount and availability of nutrients present in the applied wastewater (Magesan *et al*. 1998). In particular, soil physical properties such as texture, structure, porosity, and hydraulic conductivity will influence soil water content and aeration, which in effect control the type and rate of soil microbial activity and chemical reactions (Magesan, 2001). A growing demand of water for the irrigation of agricultural lands has increased the reuse of treated and/or untreated municipal wastewater. Wastewater has been widely used for agricultural irrigation in China and in countries located in arid and semi-arid area as reported by Chen *et al*. (2004). Wastewater irrigation provides water, nitrogen, phosphorus as well as organic matter to the soil (Siebe,1998). All these factors will have beneficial effects on soil microbiology.

Wastewater from municipal origin is rich in organic matter and contains considerable amounts of macro and micronutrients (Tabariand and Salehi, 2009). However, there are some challenges about salt, heavy metal, and surfactants that can accumulate in the soil (Siebe and Cifuentes, 1995). The effects of industrial and municipal wastewater on agricultural soils have been documented, mostly with regard to heavy metal concentration (Domlngues *et al*., 2004; Yang, 2002). The reduction in soil hydraulic conductivity not only affects downward movement through a soil profile, but can also affect water movement across the soil profile (Coppola *et al*., 2004).

Many studies have investigated various soil physical and chemical properties in the area irrigated with wastewater. Several authors have studied the effects of effluent irrigation on the soil chemical and physical properties (Dawes and Goonetilleke, 2006; Heidarpour *et al*., 2007), including soil hydraulic properties (Vinten *et al*., 1983; Cook *et al*., 1994; Tarchitzky *et al*., 1999; Magesan *et al*., 1998, 2001; 2002; Lado *et al*., 2005; Gloaguen *et al*., 2006; Gharaibeh *et al*., 2007; Bhardwaj *et al*., 2008; Mandal *et al*., 2008).

Among the potential risks associated with irrigation with treated wastewater are degradation of aggregate stability, leading to decreases in soil hydraulic conductivity and compaction decrease in soil aeration increase in runoff and finally increase in soil erosion (Tarchitzky and Golobati, 1999). Despite the diversity in the origin of wastewater, it has been established that 40 to 50 % of the dissolved organic matter (DOM) in Israel's high load organic matter (OM)

wastewater were humic matters. (~25% fluvic acids, ~ 11% humic acids, and ~7.5% hymathomenanice acids)(Rebhum and Manka, 1971). Suspended solids present in wastewater may fill pore spaces and physically block water conducting pores, thereby leading to a sharp decrease in soil hydraulic conductivity (K)(Vinters,1983). Filling of the pores occurs mostly in the upper soil layer (Siegrist, 1987).

Opposite findings have been reported concerning the effects of dissolved organic matter on the soil structural stability. It was suggested that organic substances have been considered as cementing agents that improve aggregate stability (Goldberg *et al*., 1988). Humic substances, however, have been observed to have dual effects as aggregating and disaggregating agents (Oades, 1984). Some studies have indicated that duality effects may be related to the concentration of humic substances. At low concentrations (<0.05-0.10 g kg-1), humic substances stabilize the aggregates, while at higher concentrations, they have a dispersive effect (Piccolo *et al*., 1996).

Another soil property that can be affected by effluent irrigation, and be influenced by soil structural behavior and hydraulic properties is soil organic matter content: An increase in organic matter content in the soil increased the aggregate stability (Lado *et al*., 2004b), and prevented the decrease of saturated hydraulic conductivity (Ks) during leaching of the soil with deionized water (Lado *et al*., 2004a), and seal formation under rainfall (Lado *et al*., 2004b). Jueschke *et al*. (2008) studied the effect of irrigation with secondary effluents on soil organic matter content in four locations in the semiarid region of Israel. The effect of effluent irrigation on the organic matter content in the topsoil (0–20-cm layer) was inconsistent among the various studied sites. Similar results were obtained by Gharaibeh *et al*. (2007), who found inconsistent effects of effluent irrigation on organic matter content in a clay topsoil (0–0.3 m) near Ar-Ramtha (Jordan).

In the present study, the long-term influence of using municipal wastewater as irrigation water on soil properties was studied and soil properties in 2010 were compared with the same results of control profile in pedological studies (1981), using *T*-test.

II. Materials and Methods

Site description

The soil samples (Typic Haplogypsids, Soil Survey Staff, 2003) were collected from the surface horizon (0-20cm) and subsurface horizon(20-40cm) of a 100 ha of wheat farms under 29 years municipal wastewater irrigation located 5 km south of Tehran, Iran(35° 37' N, 51° 23' E) with an Soil samples were air-dried and sieved using a 2mm-mesh stainless steel sieve. Physical and chemical properties of the soil were determined by the methods used in pedological studies (1981). Soil ECe and pH were measured in saturation extract with Swiss made metrohm instruments.

Statistical analysis

The paired data of measured soil parameters including soil electrical conductivity (ECe), soil reaction (pH), organic carbon (OC), bulk density (pb), saturated hydraulic

elevation of 1005 m above sea level. The climate of the studied site is semiarid with mild cold winters and a seven-month dry season (mid-April to mid-November). The average annual rainfall and the average annual temperature are 232 mm and 13.3°C, respectively. The highest rainfall appeared in March and the lowest in August. The warmest month occurred in August and the coldest in January.

Soil samples analysis

Organic carbon was determined by wet oxidation Walkley and Black's rapid titration method. Saturated hydraulic conductivity was measured by the standard method (Gupta and Dakshinamurthi, 1989). Bulk density was measured by cloud and paraffin.

conductivity (Ks) in year 2010 and data extracted from control profile in pedological studies (1981), were compared with *T*-test.

III. Results and discussion

Soil reaction, organic carbon, saturated hydraulic conductivity, and bulk density are shown in Fig. 1 to 3 respectively. Soil properties were based on paired data in 1981 and 2010 in 0-20 and 20-40 centimeter depth and their comparison was based on the student-*t* values were shown in Table 1.

Table 1. Comparison of soil properties based on *T*-Test in 1981 and 2010

Properties		1981	2010	*t*-value	1981	2010	
	df	Depth(Cm)	Depth(Cm)		Depth(Cm)	Depth(Cm)	*t*-value
		0-20	0-20		20-40	20-40	
PH	18	7.9	7.8	2.7*	8.2	7.9	6.9**
EC(ds m^{-1})	18	1.6	1.7	0.5 ns	1.0	1.6	2.5*
Organic Carbon (%)	18	0.6	1.1	6.5**	0.3	0.7	9.2**
Saturated hydraulic(mm h^{-1})	18	29.4	13.5	6.1**	26.3	31.5	0.9 ns
Bulk density(mg cm^{-3})	18	1.3	1.4	2.9*	1.3	1.3	0.0 ns

Soil reaction (pH)

Soil reactions significantly decreased from 1981 to 2010 in all depths (0-20 and 20-40 cm) ($p<0.05$). Soil reaction in topsoil (0-20cm) and subsoil (20-40cm) were 7.9 and 8.2 in 1981, where these values were 7.8 and 7.9 in 2010, respectively (Fig. 1).

The reason for decreasing of soil pH may be due to the decomposition of organic matter and production of organic acids in soils irrigated with wastewater (Vaseghi *et al*., 2005). This suggestion was supported by the finding of Vaseghi *et al*. (2005) and Khai *et al*. (2008). In the soil treated with wastewater, addition of organic matter in topsoil is more than subsoil. The wastewater from municipal origin is rich in organic matter and also contains appreciable amounts of macro and micronutrients (Gupta *et al*, 1998). Other researchers found that soil pH decreased with wastewater irrigation due to the oxidation of organic compounds and nitrification of ammonium (Mohammad and Mazahreh, 2003).

Electrical conductivity (EC)

Electrical conductivity of topsoil did not show any significant difference from 1981 to 2010 ($p<0.05$), where these values for subsoil changed from 1 ds m-1 to 1.6 ds m-1, respectively ($p<0.05$) (Fig. 1). Accumulation of soluble salt, heavy metal, and surfactants in the soil as a result of using wastewater was reported by Siebe and Cifuentes, 1995.

Tabari and Salehi (2008) reported the electrical conductivity (EC) of municipal wastewater ranged from 1.78 to 2.12 dS m-1 with the greatest value detected in August. Mohammad and Mazahreh (2003) stated that increase in EC for the soil irrigated with wastewater compared to the soil irrigated with fresh water attributed to the original high level of total dissolved solid (TDS) of the wastewater. The highest value was observed with 10 years of wastewater irrigation tending to be higher with longer period of wastewater irrigation. In addition, soluble salts were accumulated more in the deeper soil layers due to leaching the soluble salts into deeper depth (Abu-Awwad, 1996).

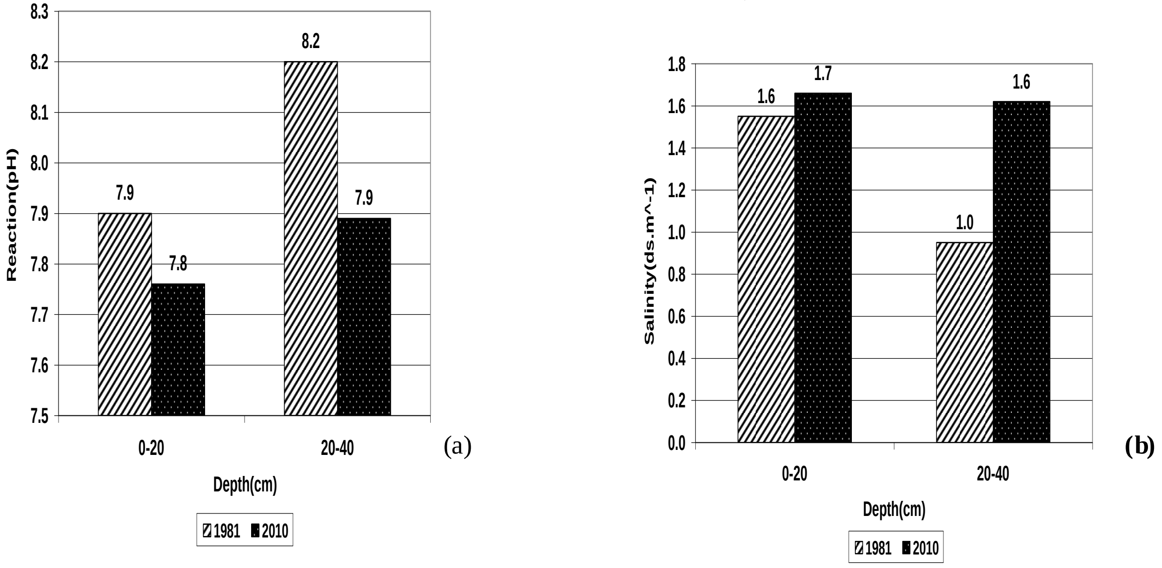


Fig. 1. Status of soil reaction (a) , and electrical conductivity (b) of topsoil and subsoil in 1981 and 2010

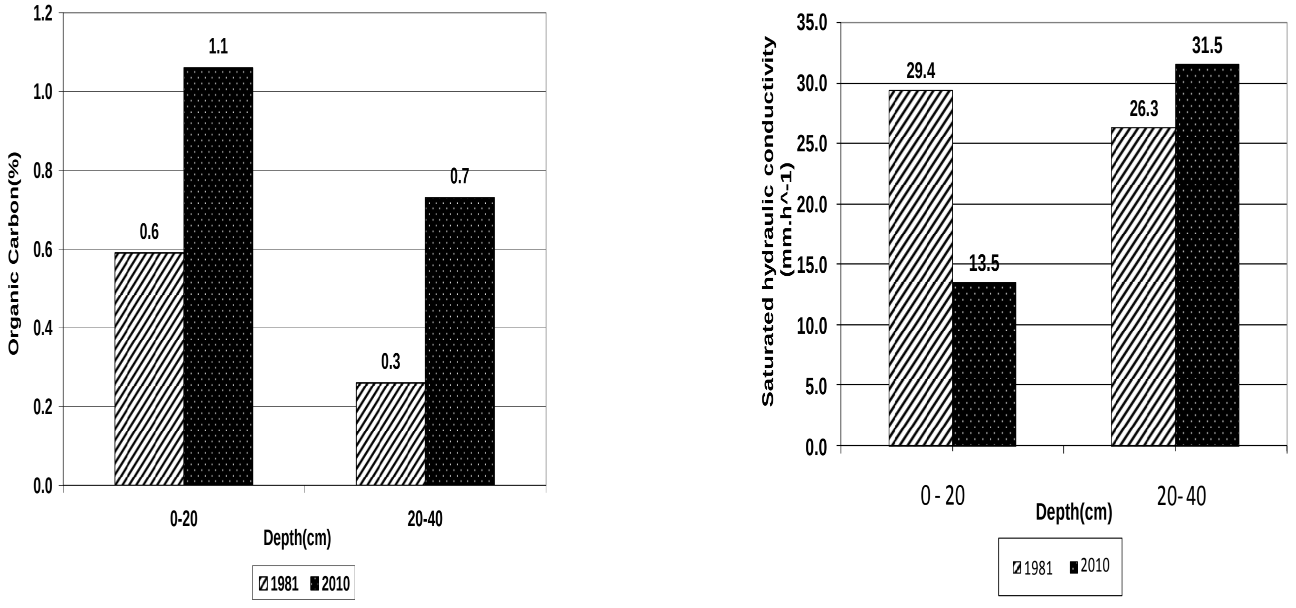
Organic carbon (OC)

According to Fig. 2, soil organic carbon significantly increased in all depths (0-20 and 20-40 cm) from 1981 to 2010 ($p<0.05$). In 1981, soil organic carbon in topsoil (0-20cm) and subsoil (20-40cm) were 0.6 and 0.3, where in 2010, these values were 1.1 and 0.7 percent, respectively. Wastewater irrigation provides water, nutrient, nitrogen, phosphorus, as well as organic matter to the soil (Siebe, 1998).

Soil organic carbon (SOC) is the most important indicator of soil quality playing a major role in nutrient cycling (Rattan, 2005). The addition of organic matter to the soil caused improving the physical, chemical, and biological characteristics of the soil so that a better nutrient absorption would accelerate the crop growth (Wang and Wang, 2005). Tabari and Salehi (2009) showed that SOC and $CaCO_3$ were greater in needles of the trees irrigated with municipal waste water compared to those irrigated with well water. Mohammadrusan *et al*. (2007) reported that soil organic matter content (OM) significantly increased with wastewater irrigation application and depending on the period of application ($p<0.05$). Organic content in the soil also increased as the number of irrigations increased, showing a benefit to the soil (Wang *et al*., 2007).

Saturated hydraulic conductivity (K_s)

Topsoil saturated hydraulic conductivity in 1981 was 29.4 mmh-1, where this value in 2010 was 13.5 mmh-1 (Fig. 2b). Cook *et al*. (1994) reported the decrease of hydraulic conductivity in soil due to wastewater irrigation. Lado (2009) showed the direct and indirect effects of wastewater irrigation on soil hydraulic properties are closely related to both wastewater and soil properties. The reduction in soil hydraulic conductivity not only affects water infiltration through the soil profile, but can also affects water movement across the landscape (Coppolaand *et al*., 2004). Suspended solids present in wastewater may accumulate and physically block water-conducting pores, thereby leading to a sharp decrease in soil hydraulic conductivity (Vinters, 1983). Blocking of the pores occurs mostly in the upper soil layer (Siegrist, 1987).



(a) **(b)**

Fig. 2. Soil organic carbon (a) and hydraulic conductivity (b) of topsoil and subsoil in 1981 and 2010

Bulk density (BD)

Soil bulk density of topsoil (0-20cm) increased from 1.3 g cm^{-3} to 1.4 g cm^{-3} during 1981 to 2010 (Fig. 3).

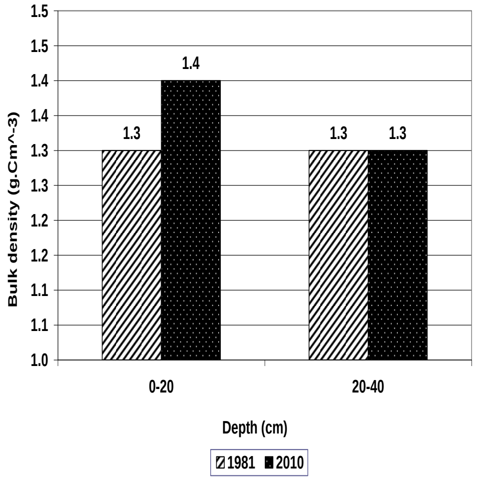


Fig. 3: Status of bulk density of topsoil and subsoil in 1981 and 2010

Blocking of the soil pores occurs mostly in the upper soil layer because irrigation with wastewater is degradation of aggregate stability, resulting in soil compaction, and decrease in soil aeration. Magesan, (2001) reported that B.D increased in the topsoil because suspended solids present in wastewater may accumulate and physically block water-conducting pores, thereby leading to increase in the B.D of topsoil.

IV. Conclusion

T-tests were performed to investigate the changes of soil properties under municipal wastewater irrigation. The results indicated that the use of untreated municipal wastewater significantly decreased saturated hydraulic conductivity and soil reaction of topsoil ($p<0.05$). Irrigation with wastewater also significantly increased the electrical conductivity of subsoil and bulk density of topsoil ($p<0.05$).

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