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Impact of irrigation with contaminated water on soil properties (Case Study: Border Land of Gharesoo River)

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ABSTRACT

The main purpose of this study was to evaluate the effects of irrigation with polluted water on soil properties in two water treatment as river water and well water during two years on Gharesoo River located in Dorodfaraman district, in 20 km south of Kermanshah. This study was performed in three soil layers 30, 60 & 90 cm with three replications in a randomized complete block design. Different soil properties including gradation curve, coefficients of uniformity (Cu) and curvature (Cc), saturation hydraulic conductivity (Ks) and other parameters such as bulk and practical density (ρ_b & ρ_a) and porosity (η) were determined. The results of statistical analysis showed that there was no uniform trend between various parameters. Using the polluted water caused a significant difference at 1% level on saturated hydraulic conductivity and uniformity coefficient at 5% level on curvature coefficient but on the other soil properties, no significant difference was found. Gradation curve of contaminated water had been transferred to the lower and right that this represented an increase of particles size. Also, the use of contaminated water increased uniformity and curvature coefficients then it improved these coefficients and the soil was more non-uniform. The results showed that irrigation with polluted water in loamy soil increased saturated hydraulic conductivity ratio but it decreased bulk and practical density significantly. It can be concluded that the use of polluted water increased the soil porosity.

1. Introduction

The total volume of water, world's saline water in the sea and oceans and fresh water in the rivers and lakes are estimated as 1.4 billion km^3, 97.50% and 2.50%, respectively (DSI. 2011). Nowadays, 70 % of total fresh global water is being used by agricultural sectors (Pedrero et al. 2010), and this value is about 95% in developing countries (FAOWATER. 2008). However, the use of wastewater for irrigation purposes in agriculture is only about 1% (World Water Assessment Program. 2009). Because of limited natural water resources in Mediterranean countries, arid and semi-arid regions of the world, the use of treated wastewater is a common habit (Pedrero et al. 2012).

The freshwater shortage in all over the world and especially in Middle East and in North of Africa is increasing and has been reached to critical levels (Jury et al., 2007). In arid condition, the municipal wastewater could be used as a fertilizer to improve soil permeability and porosity (Aggelides and Londra, 2000).

The long period uses of irrigation with wastewater can change the physical soil properties (Levy and Assouline. 2011). It can be mentioned that the use of available wastewater strategy for irrigation is useful, but it can create different challenges in agriculture as well (Hasan et al. 2014). Some nutrients can be provided in the soil by wastewater use in irrigation, however, this phenomenon can add extra hazardous elements such as heavy metal to the soil profile (Bahri. 1995; Pedrero et al. 2010; Belaida et al. 2012).

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Different causes such as population growth, industrialization improvement, discharge of industrial wastewater, household sewerage, agricultural and domestic run-off are considered for the deterioration of water quality in developing countries (Liu et al. 2012; Zhai et al. 2014). Changes in the water retention curve of five different soils of Sardinia especially changes in the pore size distributions and transition towards narrower pore spaces were reported because of the use of wastewater instead of fresh irrigation water (Coppola et al., 2004). Due to wastewater use for irrigation and pore spaces clogging, an additional Bio-growth and a significant decrease in saturated hydraulic conductivity in the surface layer of soil were reported in some studies (Beach et al., 2005; Bumgarner and McCray, 2007). Also, significant effects on soil infiltration values were reported using wastewater irrigation instead of fresh water (Abedi-Koupai et al. 2001). A 15.60 % reduction in soil permeability was observed by using of treated wastewater for corn irrigation during two years by Alizadeh et al. (2001).

The different soil physical properties under wastewater irrigation are depending on the amount of nutrient availability (Magesan. 2001). From the literature, the salinity and sodium amounts of the soil have been increased over long –term irrigation by treated wastewater (Lado and Ben-Hur. 2009; Morugan-Coronado et al. 2011). In poorly drained soil, an increase in salinity value could decrease different soil parameters such as aggregate stability and soil hydraulic conductivity (Mandal et al. 2008; Misra and Sivongxay. 2009).

In study of Magesan et al. (2000), no changes in unsaturated hydraulic conductivity after 5 years of irrigation with treated wastewater in two soil types was observed (et al., 2000). While, a 50% increase of the same parameter was reported with the half of irrigation period and the same water in two soil types located in New Zealand (Cook et al.1994). The fresh water shortage in different arid and semi-arid parts of the world and Iran leads to the increase in the use of wastewater for irrigation (Razzaghi et al. 2015).

The main objective of this study was to investigate the effects of long-term irrigation using contaminated water of Gharesoo River on soil properties. The results were analyzed as gradation curve, uniformity coefficient (C_u), curvature coefficient (C_c), bulk density (ρ_b), particle density (ρ_a), porosity (η), and saturated hydraulic conductivity (Ks). Finally, the results of this study were compared with well water as control treatment.

2. Materials and methods

2.1. Study site

The present investigation was conducted in Gomeshe village (34°14'33"N, 47°14'43"E) located in 20 km south of the city of Kermanshah in Dorodfaraman district (Fig.1 shows the site location). Kermanshah city is center of Kermanshah province that is located in the west of Iran. This district has the height of 1292 m above sea level, according to Domarton classification its climate is semi-arid, with the average annual temperature of 14.3 °C and average annual rainfall of nearly 445 mm.

Fig. 1. Location map showing the planted site of the present study.

2.2. Irrigation water

Gharesoo River is one of the Karkheh River Basin with the length of about 100 km. The main source of Gharesoo River is 50 km in the northwest of Kermanshah and comes from Ravansar spring. Different types of industrial wastes, agricultural hazardous toxins, Abshoran full of all kinds of germs, human waste and industrial waste are poured directly into the Gharesoo River in different locations that it contaminated ground and surface water, soil and good quality agricultural lands. Unfortunately, Kermanshah industrial city hasn't had wastewater treatment system yet, consequently many industrial units such as food industries, meat products, chemical units, color production, detergent production, carton, and metal parts factories add their sewage into the Gharesoo River directly. In this study, two irrigation treatments were used as Gharesoo River water and well water for comparison. In both treatments, water samples were tested before of irrigation start in May and after harvesting in October for two years (2013 & 2014). Physical and chemical properties of two water treatment were analyzed and compared to three international standards, including Food and Agriculture Organization (FAO), World Health Organization (WHO) and Environmental Protection Agency (EPA) as shown in Table 1. According to presented results in Table 1, well water almost had no particular problem in May and October during both years of investigation. Moreover, various parameters of river water only in a few cases partially were more than standard but almost all parameters of river water were higher than the standard in October. However, based on the average of water chemical properties of Gharesoo River in May and October it was higher than standard. Therefore, it can be concluded that the quality of Gharesoo River was low for irrigation.

2.3. Soil

Soil samples were collected in two irrigation treatments with three replications from three different soil layers (0-30, 30-60&60-90 cm) after harvesting in October (2013 & 2014). Thirty-six soil samples were collected, air-dried and then crushed and passed through a 2 mm sieve. The results are presented in Table 2. The soil pH values estimated by pH metery in the saturation extract as described by Thomas, 1996 (1:5 suspension). In the same suspension, electrical conductivity was also measured using conductivity meter. Soil organic carbon was estimated by Walkley-Black method (Walkley and Black, 1934), available phosphorous was determined by Olsen's method (Olsen et al., 1954) by using Spectrophotometer (VARIAN, Carry 100 Scan, Australia), available potassium and sodium estimated (ISRIC, 1986) by using flame photometer (JENWAY, PFP7, Australia). Concentrations of soluble Ca and Mg were measured by using the EDTA titration method (Schouwenburg. 1960). Cl was measured using the titration method with $AgNO_3$ (ISRIC, 1986). HCO_3 and CO_3^{2-} were measured using the titration with H_2SO_4 (ISRIC, 1986). Soil texture was determined by using Hydrometer 152H according to USDA, the results are shown in Table 3.

Both soil bulk density by Core method and soil particle density by Pycnometer method were determined (Roots of peace, 2008). Saturated hydraulic conductivity was measured by falling head method by using a cylinder that had internal diameter and length 7, 23 cm respectively. Finally, saturated hydraulic conductivity was determined by Darcy Equation (Eq.1).

$$k = \frac{2.3aL}{At} \log \frac{h_1}{h_2} \tag{1}$$

where k, a, L, A, h_1, h_2 and t are saturated hydraulic conductivity (cm/sec), cross section of burette pipe (cm^2), soil sample length (cm), cross-section of soil sample (cm^2), water head at the start of the experiment (cm), water head at the end of the experiment (cm) and water falling time from h_1 to h_2 (sec) respectively. Soil porosity was determined by Eq. 2.

$$n = (1 - \frac{\rho b}{\rho a}) \times 100 \tag{2}$$

where n, ρ_b, and ρ_a are soil porosity (%), soil bulk density (gr/cm^3) and soil particle density (gr/cm^3) respectively. Soil grading curve was drawn by a sieve with using sieves mesh numbers 4, 10, 20, 30, 60, 100, 170 and 200. Also, the uniformity coefficient and curvature coefficient were determined by Eqs.3 and 4.

$$Cu = \frac{D_{60}}{D_{10}} \tag{3}$$

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} \tag{4}$$

where Cu, Cc, D_{10}, D_{30}, and D_{60} are uniformity coefficient, curvature coefficient and diameter of sieves that 10, 30 and 60 percent of particles pass it respectively.

2.4. Experimental design

This study was conducted in a randomized complete block design (RCBD) with factorials experiment (irrigation water & soil) in two treatments (sewage river water and well water) with three replications during two years (2013 & 2014). For a comprehensive study of the results, the effect of year and replication in statistical analysis was calculated. Statistical analyses were performed using SAS 9.1 and MSTATC software. Also means comparison test conducted by Duncan's test at significantly different levels of 1% and 5%.

3. Results and discussion

The analysis of variance (Table 4) revealed that treatment effect of water quality was significant on saturated hydraulic conductivity and uniformity coefficient at 1% level, field capacity, welting point, and curvature coefficient at 5% level. The simultaneous effect of year and water quality treatments was significant on hydraulic conductivity and uniformity coefficient at 1%, field capacity and curvature coefficient 5% levels.

Moreover, the simultaneous effects of year, water quality and soil layer were significant only on hydraulic conductivity at 5% level. Also,

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different treatments had no any effect on particle density, bulk density, and soil porosity. The results showed that the coefficients of variation were in the acceptable range. The maximum and minimum values were found to be as 30.2 and 3.92 for hydraulic conductivity and particle density respectively (see Table 4).

Results of Duncan's mean comparison test at 5% level is shown for mechanical properties of different depths in Table 5. Hydraulic conductivity of soils irrigated with contaminated water was higher than well water, especially in the first layer significantly. Bulk density for contaminated water in the first layer increased and then decreased with soil depth. Although in the well water treatment the values of bulk density decreased with soil depth. Particle density was the least for two treatments in the surface layer. Porosity was the highest for both treatments in the surface layer. Uniformity and curvature coefficients for river water were more than well water in all three layers and curvature coefficient increased with soil depth for both treatments. The uniformity coefficient had no certain trend, firstly decreased and then increased with soil depth. The correlation between different parameters is shown in Table 6. Parameters correlated both positive and negative with each other. The correlation between bulk density and porosity, uniformity and curvature coefficient were significant at 1% level.

Table 1. Results of physicochemical experiments of irrigation treatments and comparison with International Standards.

Variable	Unit	Before irrigation (May)		After irrigation (October)		International Standards		
		Well	River	Well	River	FAO	WHO	EPA
Na	mg/l	27.7	13.15	32.6	162.00		69	69
Ca	″	102.9	126.7	108.2	210.6			200
Mg	″	62.4	37.8	54.1	112.3			25
K	″	7.4	1.9	8.5	15.8			
Al	″	0.00	0.08	0.00	1.03	5	5	1
Cl	″	23.38	20.02	21.54	62.48	142	106	100
B	″	0.03	>0.02	0.07	7.18	0.7	0.7	1
Hg	″	0.00	0.003	0.00	0.02			0.01
Fe	″	1.32	0.8	1.06	19.26	5	5	5
Cu	″	0.00	0.009	0.00	0.04	0.2	0.2	0.2
Zn	″	0.08	0.92	0.07	43.00	2	2	1
Cd	″	0.00	0.007	0.00	0.04	0.01	0.01	0.01
Ni	″	0.00	0.009	0.00	0.03	0.2	0.2	0.2
Cr	″	0.00	0.02	0.00	0.11	0.1	0.1	0.1
Pb	″	0.00	0.01	0.00	0.05	5	5	5
Mn	″	0.00	0.08	0.02	11.28	0.2	0.2	0.2
Co	″	0.00	0.007	0.00	0.06	0.05		0.05
As	″	0.00	>0.001	0.00	0.03	0.1	0.1	0.1
Se	″	0.00	0.01	0.00	0.00	0.02	0.02	0.02
NO_3	″	19.44	27.3	28.37	47.29	5	5	30
PO_4	″	3.82	6.7	6.25	28.54			10
TSS	″	11.2	123.8	0.00	123.8			5
TDS	″	376	501.6	368	763	450	450	
TOC	″	2.2	1.2	0.02	1.2			
TH	″	518	474.3	495	992			
SAR	-	3.04	1.45	3.61	12.74	3	3	
EC	ds/m	0.815	0.552	1.409	0.965	0.7	0.7	0.7
pH	-	7.25	6.56	7	7.59	6.5-8	6-8.5	6.5-8.4
Turbidity	NTU	31.6	32.4	0.9	32.4			2

Table 2. Results of soil chemical parameters at three layers for two irrigation treatments.

		River water			Well water		
Variable	Unit	0-30	30-60	60-90	0-30	30-60	60-90
Na	mg/l	323 ± 86.3	302.3 ± 58.3	349 ± 28.6	238.3 ± 67.8	288 ± 0.0	351 ± 46.7
Ca	″	8.6 ± 1.9	13 ± 6.7	17 ± 0.0	16.6 ± 10.2	18.8 ± 13.7	19.4 ± 8.3
Mg	″	15.6 ± 6.6	24 ± 11.6	13.2 ± 5.4	9 ± 9.8	9.12 ± 6.8	13.2 ± 9.4
Cl	″	13.0 ± 3.6	23.1 ± 10.2	6.7 ± 1.9	23.1 ± 7.5	13.3 ± 12.1	15.8 ± 4.1
K	″	98±5.17	94.6±6.23	91±0.0	103±7.07	101.3±6.23	94±6.48
P	″	0.01 ± 0.019	0.02 ± 0.016	0.03 ± 0.024	0.02 ± 0.0	0.01 ± 0.009	0.01 ± 0.009
N	%	0.18 ± 0.026	0.15 ± 0.03	0.15 ± 0.006	0.23 ± 0.019	0.12 ± 0.041	0.23 ± 0.061
$CaCO_3$	″	8.1 ± 4.6	11.8 ± 5.6	8 ± 3.2	12.7 ± 1.8	11.4 ± 0.31	13.8 ± 1.6
OM	″	3.7 ± 0.52	3 ± 0.57	2.9 ± 0.13	3.9 ± 1.2	2.5 ± 0.81	3.8 ± 0.2
OC	″	2.2 ± 0.3	1.9 ± 0.3	1.7 ± 0.07	2.7 ± 0.22	1.7 ± 0.46	2.2 ± 0.12
CO_3	mg/l	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HCO_3	″	24.4 ± 13.2	18.3 ± 10.9	33.6 ± 2.5	48.8 ± 4.3	33.6 ± 2.9	29.3 ± 8.7
TDS	″	104.2 ± 15.8	83.2 ± 15.7	73.7 ± 7.9	78.9 ± 3.0	56 ± 3.0	78.9 ± 8.0
EC	ds/m	0.16 ± 0.025	0.13 ± 0.024	0.12 ± 0.012	0.12 ± 0.005	0.09 ± 0.005	0.12 ± 0.012
pH	-	7.1 ± 0.09	7.2 ± 0.19	7.5 ± 0.16	7.3 ± 0.05	5.5 ± 0.12	7.4 ± 0.12
SAR	-	92.9 ± 41.9	70.3 ± 19.3	89.8 ± 17.4	66.6 ± 21.5	77.1 ± 0.0	86.9 ± 15.7

Table 3. Properties of soil texture.

Treatment	Layer	Sand (%)	Silt (%)	Clay (%)	Texture
River water	0-30	37	48	15	Loam
	30-60	29	41	30	Clay loam to loam
	60-90	29	45	26	Loam
Well water	0-30	45	45	10	Loam
	30-60	52	30	18	Loam
	60-90	41.5	40	18.5	Loam

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Table 4. Analysis of variance for the effect of irrigation treatments on soil properties.

Source	Df	Ks	ρb	Pa	N	Cu	Cc
Y	1	3718**	0.09^{ns}	0.0312^{ns}	80.9^{ns}	127.3**	0.211^{ns}
R(Y)	4	40.7	0.02	0.0071	48.2	7.186	0.075
A	1	3967**	0.06^{ns}	0.0005^{ns}	73.1^{ns}	120.9**	0.214*
Y*A	1	289.9**	0.06^{ns}	0.0005^{ns}	9.87^{ns}	10.22**	0.066*
R*A(Y)	4	74.2	0.03	0.0097	51.8	1.453	0.04
Error A	16	74.2	0.03	0.0097	51.8	1.453	0.04
B	2	39.9^{ns}	0.03^{ns}	0.0002^{ns}	38.2^{ns}	15.85**	0.061*
Y*B	2	323.5^{ns}	0.01^{ns}	0.0001^{ns}	13.5^{ns}	4.49**	0.031^{ns}
A*B	2	323.5^{ns}	0.01^{ns}	0.0001^{ns}	13.5^{ns}	4.48**	0.031^{ns}
Y*A*B	2	74.2*	0.03^{ns}	0.0097^{ns}	51.8^{ns}	1.453^{ns}	0.04^{ns}
Error B	2	39.9	0.05	0.0049	61.3	14.12	0.075
CV(%)	-	30.2	9.76	3.92	22.8	11.55	18.89

*Significant at 5% level, **Significant at 1% level and ^{ns}Nonsignificant
Y: Year, R: Replication, A: Water quality and B: Soil layer
Ks: Saturated hydraulic conductivity, ρb: Bulk density, ρa: Particle density, n: Porosity, Cu: Uniformity coefficient and Cc: Curvature coefficient

Table 5. Means comparison of soil properties under irrigation treatments.

Index	Ks (mm/h)	ρb (g/cm^3)	ρa (g/cm^3)	N (%)	Cu	Cc
A1	34.9a	1.70a	2.49a	31.7a	11.75b	1.15b
A2	22.0b	1.76a	2.54a	30.9a	9.11a	0.96a
A1*B1	37.4a	1.73ab	2.48e	30.3ab	12.0a	1.03a
A1*B2	31.0a	1.69ab	2.50cd	32.3ab	11.37a	1.2a
A1*B3	36.2a	1.68ab	2.49de	32.6ab	11.89a	1.22a
A2*B1	18.2a	1.59b	2.52bc	37.0a	8.08a	0.79a
A2*B2	27.2a	1.80ab	2.57a	29.9ab	7.83a	1.01a
A2*B3	20.6a	1.88a	2.54b	25.7b	11.43a	1.08a
Y1*A1*B1	39.5a	1.81a	2.51a	27.9a	12.93abc	1.02a
Y1*A1*B2	19.8a	1.67a	2.53a	34.1a	13. 5ab	1.22a
Y1*A1*B3	27.7a	1.63a	2.52a	35.3a	16.18a	1.36a
Y1*A2*B1	29.5a	1.54a	2.54a	39.5a	6.06e	0.74a
Y1*A2*B2	44. 8a	1.70a	2.60a	34.5a	6.95de	0.80a
Y1*A2*B3	37.0a	1.8a	2.56a	29.2a	10.64bcd	1.04a
Y2*A1*B1	35.4a	1.64a	2.44a	32.8a	11.06bcd	1.04a
Y2*A1*B2	42.3a	1.71a	2.47a	30.5a	9.29bcde	1.17a
Y2*A1*B3	44.7a	1.72a	2.46a	29.9a	7.60de	1.08a
Y2*A2*B1	6.9a	1.63a	2.49a	34.4a	10.1bcde	0.84a
Y2*A2*B2	9.5a	1.9a	2.54a	25.3a	8.7cde	1.22a
Y2*A2*B3	4.2a	1.96a	2.52a	22.3a	12.21abc	1.12a

In each column and for each group, the different letters represent significant differences ($p < 0.05$) Y1: First year, Y2: Second year, A1: River water, A2: Well water, B1: First layer, B2: Second layer and B3: Third layer

Table 6. Correlation between different parameters.

Index	Ks (mm/h)	ρb (g/cm3)	ρa (g/cm3)	Cu	Cc
ρb(g/cm3)	-0.145^{ns}				
ρa(g/cm3)	-0.051^{ns}	0.062^{ns}			
Cu	-0.191^{ns}	0.083^{ns}	-0.123^{ns}		
Cc	0.019^{ns}	0.25^{ns}	-0.065^{ns}	0.675**	
n (%)	0.117^{ns}	-0.944**	0.271^{ns}	-0.114^{ns}	-0.26^{ns}

3.1. Gradation and soil coefficients

Gradation curve of soils under different treatment shown in Fig. 2for all three soil layers. As fig. 2 showed the particles which passed through the 10 mesh sieve (2 mm) in the first layer was 19.4%, the second layer 21.1%, and the third layer 27.8% in the river water treatment. Additionally, these reduction values were respectively 12.1%, 13.6% and 57.8% on the 100 mesh sieve (0.15 mm) in the river water treatment respectively. Gradation curve of contaminated water compared to the control plates were transferred to the lower and right that this represented an increase of the particles size in the River water treatment.

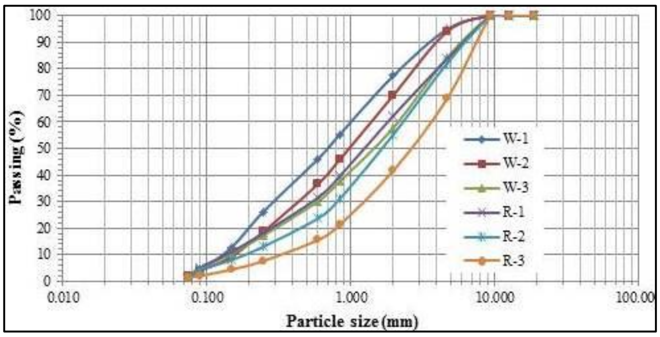

Fig. 2. The average two years of irrigation treatments at the three layers.

Statistical analysis of uniformity and curvature coefficients in River and Well water indicated that there was a significant difference at levels of 1% and 5% respectively. Uniformity and curvature coefficients for two irrigation treatments in three layers are shown in Fig. 3 and 4 respectively. The results showed that the uniformity coefficient increased in the first and second layers as 48.4%, and 45.3% and decreased in the third layer as 9.1% in the river water treatment. Curvature coefficient indicated an increase in the first and second layers as 29.6% and 18.3 % and decreased in the third layer as 2% in the river water. It can be concluded that irrigation with contaminated water improved uniformity and curvature coefficients and the soil was more non-uniform. Uniformity coefficients in both treatments were the lowest in the second layer and the highest in the third layer. Curvature coefficient in both treatments increased with soil depth. In a study, comparison with 1, 2, 3, 4 and 5 times irrigation with sewage and well water, the soil gradation curve in irrigation with sewage was in all cases lower than the irrigated soil with well water as reported by (Yazdani et al. 2015). Based on the present study and previous studies, it can be concluded that irrigation with sewage water increased the diameter of soil grains. Perhaps because of the presence of organic matter and solutes in the sewage water, which is tucked around the particles and increase their diameter.

3.2. Hydraulic conductivity

Statistical analysis showed a significant difference at the level of 1% between the saturated hydraulic conductivity of contaminated water and well water. According to irrigation water quality can be seen that total calcium and magnesium values of river water were more and sodium value was less than well water which could improve soil structure and increased its hydraulic conductivity. As shown in fig. 5 saturated hydraulic conductivity increased in the first, second and third layers as 105.8%, 14.2% and 75.9% in the contaminated water treatment respectively. Consequently, the use of contaminated water in a loamy soil increased saturated hydraulic conductivity. Saturated hydraulic conductivity was the highest in the first layer and the lowest in the second layer in the river water treatment and it was the highest in the second and the lowest in the first layers in the well water treatment. Results of previous reported studies shown that irrigation with treated and untreated wastewater reduced saturated and unsaturated hydraulic conductivity (Cook et al. 1994; Magesan et al. 2000; Alizadeh et al. 2001; Levy and Mamedov. 2002; Levy et al. 2003; Coppola et al. 2004; Goncalves et al. 2007; Uttam et al. 2008; Assouline and Narkis. 2011). This reduction observed in very sandy soils (Tarchouna et al. 2010). Also, an investigation reports shown that irrigation with treated wastewater had no effect on saturated hydraulic conductivity (Levy et al. 1999) or it increased after using treated wastewater by more than 10 years used (Mathan. 1994). Saturated hydraulic conductivity decreased in both freshwater and wastewater with depth that this reduction was the highest in the surface layer in wastewater treatment (Assouline and Narkis. 2011).

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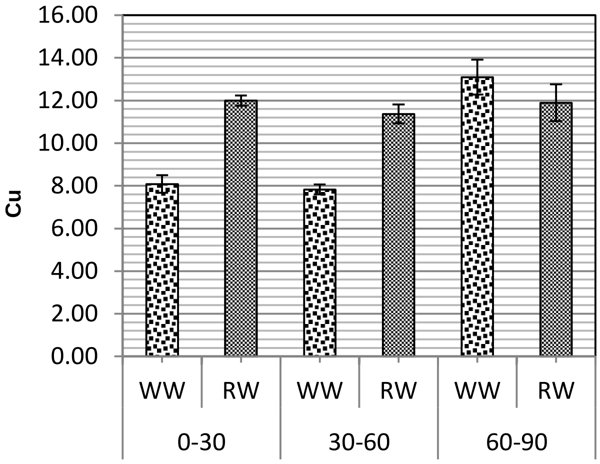

Fig. 3. The average value of uniformity coefficient at different depths under irrigation treatments.

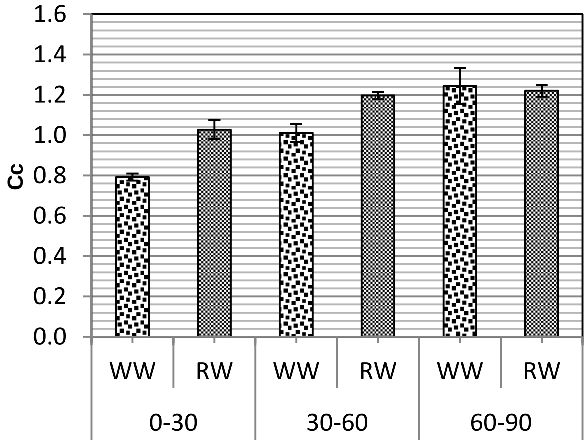

Fig. 4. The average value of curvature coefficient at different depths under irrigation treatments.

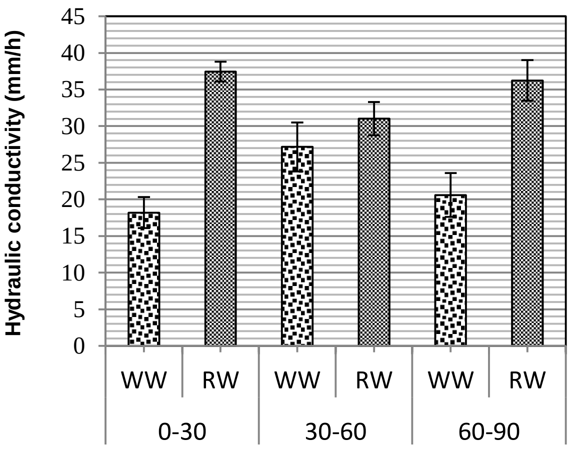

Fig. 5. The average hydraulic conductivity at different depths under irrigation treatments.

3.3. Soil porosity

The results showed that soil porosity had no significant difference in two irrigation treatments. As shown in Fig. 6, the porosity decreased about 18.1% in the first layer and increased 8.1% and 26.5% in the second and third layers in river water treatment respectively. The porosity reduced with a steady trend with soil depth in well water but steadily increased in river water treatment. Previous studies showed that the use of municipal waste compost increased the soil porosity (Annabi et al. 2007). It also reported an increase in soil porosity with the use of compost in a sandy soil (Gelik et al. 2004; Tejada and Ginzales. 2008). Investigating and calculating porosity in a study indicated increased porosity with increasing irrigation frequencies using wastewater. This increase was 2.5, 10, 2.5, 9 and 16.6%, with increasing irrigation times with wastewater (Yazdani et al. 2015). The soil porosity may be reduced due to the collapse of the soil structure and the dispersion of soil particles so that the coarse clogs become smaller particles and fill up empty spaces.

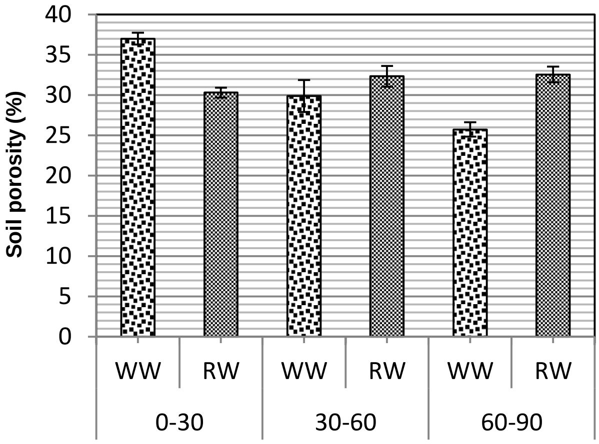

Fig. 6. Porosity at different depths under irrigation treatments.

3.4. Bulk and particle density of soil

According to Fig. 9 and 10 particle density decreased in three layers as 1.7%, 2.5%, and 2.1%, but bulk density decreased in the first and third soil layers as 2% and 0.7% respectively and increased in the second layer as4.5% in the treatment of river water compared to well water treatment.

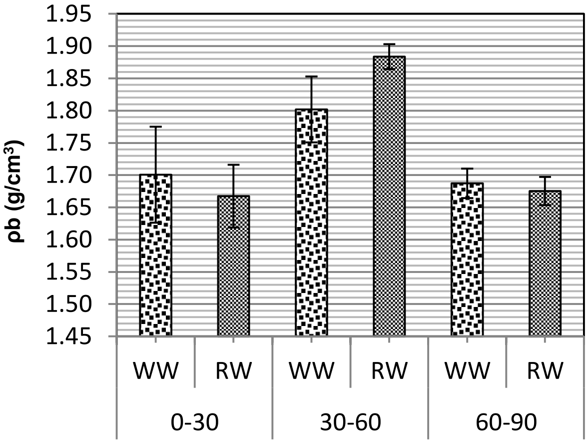

Fig. 9. The average of bulk density (ρb) at different depths under irrigation treatments.

According to previous researches, the use of municipal waste compost significantly reduced soil bulk density (Aggelides and Londra. 2000; Carter and Stewart. 1996; Zebarth et al. 1999). In a study using 40 tons of sewage sludge per hectare in a gypsum soil, bulk density decreased from 1.3 to 1.04 g/cm^3 (Navas et al. 1998). Significant reduction of particle density has been reported in a sandy clay soil compared to control (Marinari et al. 2000). A significant reduction in soil bulk density has been reported with the use of compost as an organic fertilizer (Tejada and Ginzales. 2008). According to previous studies irrigation with sewage affected the bulk density of soil and reduced its value, so by increasing 1, 2, 3, 4, and 5 times irrigation with sewage decreased by 2, 6/6, 4, 15/7 And 17.6% respectively also particle density of irrigation plots with sewage decreased as well. So that particle density in the irrigated land with 4 and 5 times the sewage has reached from 2.5 to 22.2 g/cm^3 (Yazdani et al. 2015). In the most domestic sewage, there are organic matters that have less weight than the grains of the soil particles, therefore, a decrease in bulk and particle density may be due to the addition of these grains lighter to the soil.

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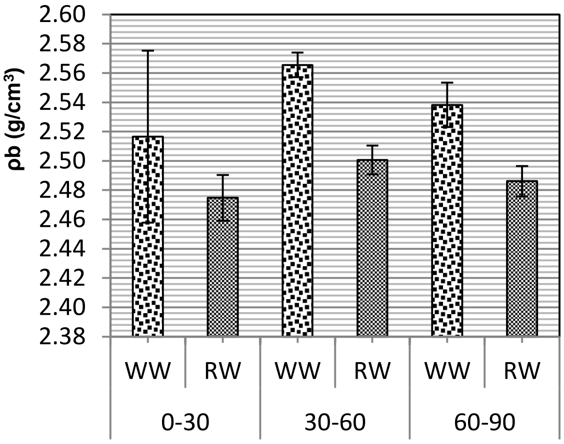

Fig.10. The average of particle density (ρa) at different depths under irrigation treatments.

4. Conclusions

The results of this research showed that the use of contaminated water which contains a different type of contaminants as domestic, industrial and agriculture could have positive or negative effects on different soil properties. The variance analysis showed that the use of contaminated water of Gharesoo River made a significant difference at the level of 1% on saturated hydraulic conductivity and uniformity coefficient at 5% level on curvature coefficient. But did not make a significant difference on the other parameters. Gradation curve of contaminated water compared to the control treatment was transferred to the lower and right that direction which represented an increase of particles size in the river water treatment. Moreover, the irrigation with contaminated water increased uniformity and curvature coefficients, it can be concluded that contaminated water improved those coefficients and the soil was more non-uniform. The studies also showed that irrigation with polluted water was increased the saturated hydraulic conductivity of the loamy soil significantly. In addition, polluted water treatment reduced bulk and particle density of the soil. Although soil porosity decreased in the first layer and increased in the next layers. In general, it can be concluded that the use of contaminated water increased soil porosity. It should be noted that the use of polluted water was affected most of the soil properties.

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