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A Study on Physical and Hydraulic Properties in a Silt Loam Soil Influenced by Salinity and Turbidity of Irrigation Water

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Abstract – **Irrigation water quality affects soil physical and hydraulic properties. The present paper aims to investigate the effect of different salinity treatments in the presence of constant turbidity on the final infiltration rate of soil, saturated hydraulic conductivity, and total porosity of the soil. The salinity treatments were applied at five levels (S1=1,S2=2,S3=4, S4= 6, and S5=8 deci-Siemen/meter) with constant turbidity (T=200NTU). The treatments were examined at three different soil depths (0 to 15, 15 to 30 and 30 to 45 cm) with silt loam texture and three replications in a randomized complete block design. The final infiltration rate, saturated hydraulic conductivity, and total porosity of the soil were made respectively by Green-Ampt, constant head, and gravimetric methods. The results were analyzed in SPSS. Findings revealed that, compared to TS1 treatment, the soil final infiltration rate of TS2, TS3, TS4, and TS5 treatments respectively decreased 3, 11, 28.5, and 39percentages. Compared to TS1 treatment, the saturated hydraulic conductivity of TS2, TS3, TS4, and TS5 treatments respectively decreased 26, 41, 45, and 54 percentages. Comparison of saturated hydraulic conductivity of soil at various depths showed the increase of 47.5% and 55% respectively in the second and third depths than first depth. Compared to TS1 treatment, the soil total porosity of TS2, TS3, TS4, and TS5 treatments respectively decreased 2, 4, 4.4, and 6.5 percentages. Comparison of total porosity of the soil at various depths showed the increase of 2% and 5% respectively in the second and third depths than first depth.**

Keywords – **Total Porosity of the Soil, Water Turbidity, Final Infiltration, Saturated Hydraulic Conductivity.**

I. Introduction

Soil and water salinity is among the major problems standing in the way of agriculture development. For optimal use of saline water in agriculture, first of all the effect of salinity of water on the soil physical and chemical properties and plant function should be considered then, the proper management of these waters shall be applied (Feyzi et al., 2010).Turbidity is the first main physical property of water which occurs due to the suspended and colloidal solids in water. Clays are the most important colloids. Clays are negatively charged so, when the closeness of clays with the same charge leads to their rejection and prevent the deposition of these particles, even after a long time (Salamati, 2006). Infiltration is a physical property of the soil and an effective hydraulic parameter on surface irrigation. The process of water entering the soil surface vertically is known as infiltration. Water infiltration in the soil is of importance since non-infiltrated water not only causes loss of surface water but also reduces the product function. Indeed the type of irrigation system for a region is selected based on properties of water infiltration into the soil; thus, its evaluation is of importance that must be done (Alizade, 2005). Hydraulic conductivity indicates the soil's ability to transmit water. Hydraulic conductivity depends on their shape, continuity and pore size distribution in the soil (Baybordi, 2005). Porosity is a measure of the pore space in the soil; porosity is defined quantitatively as is the ratio of pore volume to its total volume (Alizade, 2007). Large amounts of sodium in the soil leads to the aggregate fragmentation, particle inflation, and chemical distribution that eventually reduce soil infiltration to the water and air (Emdad et al., 2003; Mamedov & Levy, 2001; Tedeschi & Menenti, 2002). The increase in irrigation water turbidity resulting in reduction of final infiltration rate of soil, saturated hydraulic conductivity, and soil total porosity; this is due to the suspended and colloidal solids in water and its replacement in the small soil pores (Salamati, 2006). This research aims to investigate the effect of constant turbidity and different levels of irrigation water salinity on the final infiltration rate, saturated hydraulic conductivity, and total porosity of the soil.

II. Methodology

In 2011, students of Shahid Chamran university of Ahvaz, faculty of water sciences engineering conducted a research based on measuring and recognizing the infiltration changes, saturated hydraulic conductivity, and total porosity of the soildue to the apply different quality of irrigation water (salinity and turbidity).

Achieving this aim, five treatments of irrigation water were examined at three different soil depths (0 to 15, 15 to 30 and 30 to 45 cm) with three replications in a randomized complete block design. In this regard, 15 polycop pipes, 10 cm in diameter and 70 cm in height were prepared. End of pipes were blocked by tiffany (a kind of cloth that allows water to pass through but prevent the passage of soil particles). Then, the soil was passed through a 2 mm sieve and pour into the pipes at a height of

55 cm. The treatments of water quality were applies at five salinity levels included S1=1,S2=2,S3=4, S4= 6, and S5=8 deci-Siemen/meterwith turbidity of 200NTU (Nephelometric turbidity units). Salinity treatments and turbidity treatment were achieved respectively by adding NaCl and clay. In order to achieve the water turbidity of NTU 200, one liter of water was added to the clay and stirred until it dissolved. Then, the sample was placed in a three-minute rest so heavy particles are deposited. Samples were taken from the solution (without deposited material)and the turbidity was measured by turbidity meter. The process was repeated for several samples and at last the expected turbidity was achieved. In order to prepare one liter of water and soil solution with 200 NTU turbidity, we need 350 mg of soil. However, increasing salinity resulted in increasing this rate since the sodium in water leads to the suspended particles distributionso, the deposition of these substances occurred in a time shorter than expected. The product of polycop pipes cross-section area at five centimeters depth of irrigation water, equivalent to 7/392 cubic centimeters, resulted in the volume of irrigation water of samples. The samples irrigation was done with the same volume of water within two months (with seven days irrigation interval regarding the wheat irrigation interval, the dominant plant). Soil infiltration in the first depth (0 to 15 cm)was measured by Green-Ampt method that was suggested based on capillary tubes behavior (Baybordi, 2005). Base infiltration rate estimated from the following equation:

$$I_b = ct_b^n \qquad (1)$$

In this regard I_b was considered as base infiltration rate(cm.h^{-1}), t_b is base infiltration time (min), and c and n are infiltration equation coefficients(Alizade, 2005).

Soil saturated hydraulic conductivity was estimated by constant head method and based on Darcy's law:

$$K = \frac{V \times L}{A \times h \times t} \qquad (2)$$

In this regard K was considered as saturated hydraulic conductivity (cm.day^{-1}), V is volume of water output from samples (cm^3), L is length of soil sample (cm), A is the cross section of sample (cm^2), h is the difference in water level between the input and output (cm), and t is duration of water withdrawal from the sample (day) (Alizade, 2007).

Total porosity of the soil was estimated by gravimetric method:

$$n = \frac{V_f}{V_t} \times 100 = \frac{V_a + V_w}{V_s + V_a + V_w} \times 100 \qquad (3)$$

In this regard, n was considered as total porosity of the soil (percentage),V_s is solids volume (cm^3), V_w is the water volume (cm^3), V_a is the air volume (cm^3), V_f is soil pores volume (cm^3), V_t is the total volume of the soil (cm^3)(Alizade, 2005).

III. Results and Discussion

Physical and chemical properties of the soil and also chemical properties of the irrigation water are shown in tables 1 and 2.

Table 1: Physical and Chemical Properties of the Soil

Parameters	Amounts
Sand (%)	42/2
Silt (%)	30/6
Clay (%)	26/5
Porosity (%)	43/7
pH	7/6
EC (dS m^{-1})	13/2
Na^+ (meq l^{-1})	61/1
Ca^{+2} (meq l^{-1})	29
Mg^{+2}(meq l^{-1})	54
SAR (meq l^{-1})$^{-0.5}$	9/5
ESP (%)	42/4
Cl^- (meq l^{-1})	95
HCO_3^- (meq l^{-1})	6/7

Table 2: Chemical Properties of the Irrigation water

Irrigation water Treatments[a]					Parameters
TS_5	TS_4	TS_3	TS_2	TS_1	
8	8	8	7/9	8	pH
8	6	4	2	1	EC (dS m^{-1})
89	61	32	13/5	9/5	Cl^- (meq l^{-1})
61/7	57/5	30/5	15/2	7/1	Na^+ (meq l^{-1})
5	4/8	4/2	3/7	1/6	Ca^{+2} (meq l^{-1})
2/4	1/9	3	2/3	0/1	Mg^{+2}(meq l^{-1})
3	2/5	2	2/33	1/5	HCO_3^- (meq l^{-1})
22/8	22/2	11/4	6/2	5/5	SAR (meq l^{-1})$^{-0.5}$

[a] T = turbidity (200 NTU); S = salinity

Based on table 1 and soil texture triangle, the soil had a silt loam textureand based on classification of saline soils and also the U.S. soil salinity laboratory method (ESP>15% and EC>4 dS.m^{-1})the soil was a saline-sodic one(Alizade, 2005b).Furthermore, according to Table 2 and based on the classification of irrigation water quality by Wilcox Diagram, the qualitative treatments of the irrigation water (TS_1 ،TS_2 ،TS_3 ،TS_4 وTS_5) were arranged respectively in the classes of C_3S_1 ،C_3S_1 ،C_4S_2 ،C_4S_3 وC_4S_3.

3.1. The effect of Irrigation Water Quality (Turbidity and Different Salinity Levels) on the Final Infiltration Rate of Soil

Statistical analyze showed the noticeable effect of irrigation water quality (p<0.01) on the final infiltration rate of the soil (table 3).Figure 1 shows this effect based in Duncan test. The diagrams are the mean of three replications.

Table 3: variance analysis of final infiltration rate of soil (mm/hr)

Significance	Degree Recognition F	Quadratic Mean	Degrees of Freedom	Index
0/00	26/953**	0/726	4	Water Quality
		0/027	10	Error
			15	Total

**Significance at the one percent probability level

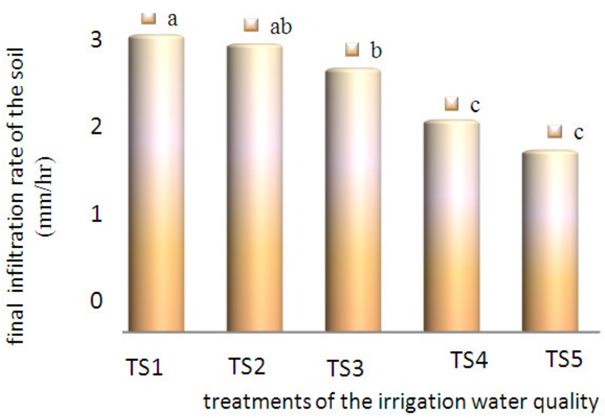

Fig.1. The effect of irrigation water quality on the final infiltration rate of the soil (columns with the common letters don' have significance difference at the one percent probability level)

As the figure 1 shows, the salinity increase in the presence of constant turbidity of 200NTU, leads to the reduction of final infiltration rate of the soil. According to the table 2, sodium adsorption ratio (SAR) of the TS2, TS3, TS4, and TS5 irrigation treatments showed respectively 12%, 52%, 75/4%, and 76% increase than TS1 treatment. On the other hand, the saline-sodic soil was the sample then, the effect of sodium ions in the soil increased. Thedegradation properties of sodium in the soil is the cause of infiltration reduction resulted from the use of saline and sodic water. Changes in the surface layer of soil, surface crust formation, and chemical dispersion of soil all lead to the infiltration reduction resulted from the use of saline and sodic water with different qualities (Rhoades, 1999; Frenkel et al., 1987; Suarez, 2006). The irrigation water turbidity is also effective in soil infiltration reduction; this can be due to the suspended and colloidal solids in the irrigation water and their settlement in the soil pores (Basirpour et al., 1998; Fuchs et al., 1997; Salamati, 2006).

3.2. The Effect of Irrigation Water Quality (Turbidity and Different Levels of Salinity) and the Soil Depth on the Saturated Hydraulic Conductivity

Statistical analyze showed the noticeable effect of irrigation water quality and soil depth (P<0/01) on the saturated hydraulic conductivity (table 4). Figure 2 shows this effect based in Duncan test. The diagrams are the mean of three replications.

Table 4: Variance analysis of saturated hydraulic conductivity (cm/day)

Significance	Degree Recognition F	Quadratic Mean	Degrees of freedom	Index
0/00	895/255**	4/886	4	Water Quality
0/00	2011/797**	10/981	2	Depth
0/00	51/158**	0/279	8	Water Quality*Depth
		0/005	28	Error
			44	Total

** Significance at the one percent probability level

As the figure 2 revealed, the salinity increase in the presence of constant turbidity of 200NTU, leads to the reduction of saturated hydraulic conductivity and the increase in the depth resulted in the increase of saturated hydraulic conductivity too. The increase in exchangeable sodium percentage (ESP) resulted in the saturated hydraulic conductivity reduction. The effect of sodium ions on inflation and dispersion of clay particles in the soil and also the clogging of soil pores leads to the saturated hydraulic conductivity reduction. The effect of sodium ions on the surface layer leads to the largest decrease of saturated hydraulic conductivity in the surface layer than lower depths (Goncalves,et al., 2007; Kumar Mandalet al., 2008). On the other hand the suspended and colloidal solids in the irrigation water results in soil pores clogging and consequently the saturated hydraulic conductivity reduction (Salamati, 2006; Sepaskhah & Sokoot, 2010; Viviani & Lovino, 2004).

3.3. The Effect of Irrigation Water Quality (Turbidity and Different Levels of Salinity) and the Soil Depth on the Total Porosity

Statistical analyze showed the noticeable effect of irrigation water quality and soil depth (P<0/01) on the total porosity (table 5). Figure 3 shows this effect based in Duncan test. The diagrams are the mean of three replications.

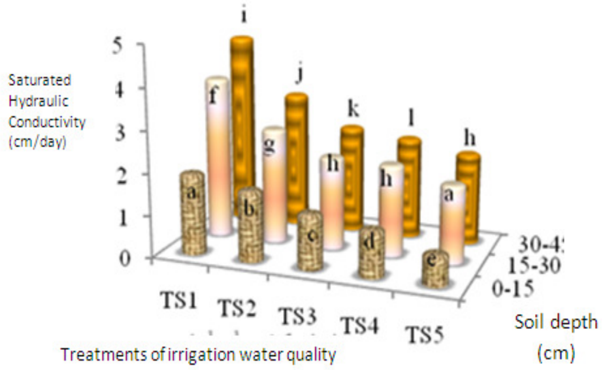

Fig.2. The effect of irrigation water quality on the saturated hydraulic conductivity at the different levels of soil depth (columns with the common letters don' have significance difference at the one percent probability level)

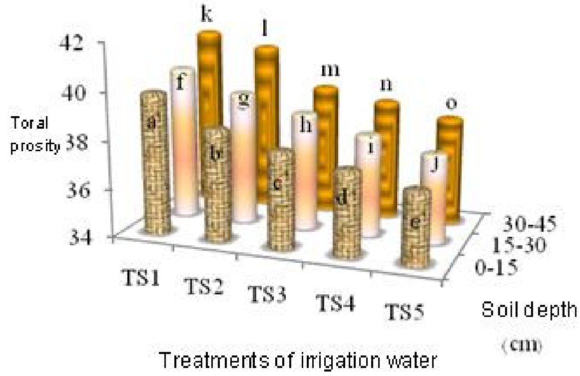

Fig.3. The effect of irrigation water quality on the total porosity at the different levels of soil depth (columns with the common letters don' have significance difference at the one percent probability level)

Table 5: Variance analyze of total porosity (percentage)

Significance	Degree Recognition F	Quadratic Mean	Degrees of freedom	Index
0/00	20749/727**	10/375	4	Water Quality
0/00	24751/560**	12/376	2	Depth
0/00	400/477**	0/2	8	Water Quality*Depth
		0/188	28	Error
			44	Total

** Significance at the one percent probability level

As figure 3 shows, salinity increase leads to the total porosity reduction and the depth increase also leads to the increase of total porosity. High sodium level in irrigation water results in chemical distribution in the soil and by creating a surface crust and cracks and reducing soil pores it also reduce the soil porosity (Ayers & Schoneman, 1993; Goncalves et al., 2010; Siddique Shakir et al., 2002). On the other hand, the colloidal solids in the irrigation water fill the cracks and reduce the pores and consequently results in total porosity reduction; this effect is noticeable in the surface layer (Salamati, 2006).

IV. Conclusion

Salinity increase in the presence of constant turbidity leads to the final infiltration rate of soil reduction. This is due to the inflation and dispersion of soil particles resulted from sodium ion and also the all soil pores with suspended and colloidal solids in irrigation water.

Salinity increase in the presence of constant turbidity leads to reduction of saturated hydraulic conductivity's coefficient. It can be due to the presence of sodium ion in the treatments of irrigation water which causes the fragmentation and degradation of soil structure. On the other hand, the suspended and colloidal solids in irrigation water cause soil pores reduction. Comparing the examined depths also showed that the minimum and maximum amount of hydraulic conductivity respectively belongs to the first and third depth. This is due to the sodium ion effect which exists in the surface layer of the soil and also the pores filling by the colloidal solids. Salinity increase in the presence of constant turbidity leads to reduction of total porosity. This can be due to the sodium ion effect on the inflation and distribution of soil that results in the reduction of pores. The pores filling by the colloidal solids also lead to the pores reduction.

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