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Effects of Magnetized Water on Soil Sulphate Ions in Trickle Irrigation

Behrouz Mostafazadeh-Fard [1+], Mojtaba Khoshravesh [2], Sayed-Farhad Mousavi [3] and Ali-Reza Kiani [4]

[1] Professor, Water Engineering Department, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran
[2] Graduate Student, Water Engineering Department, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran; E-mail: khoshravesh_m24@yahoo.com
[3] Professor, Water Engineering Department, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran ; E-mail : mousavi@cc.iut.ac.ir
[4] Researcher, Gorgan Agricultural and Natural Resources Research Center, Gorgan, 41996-13475, Iran; E-mail: akiani71@yahoo.com

Abstract. To reclaim soil and water, and to reduce soil salinity, magnetized water can be used. Magnetized water is obtained by passing of water through the permanent magnets or through the electro magnets installed in/on a feed pipeline. To investigate the effects of magnetized water and irrigation water salinity on sulphate ions of soil a field trickle irrigation experiment with complete randomized block design was performed at Gorgan Agricultural and Natural Resources Research Center, Gorgan province, Iran. The results showed that at all soil depths below the emitter, the mean soil sulphate ions for the magnetized irrigation water treatment are less than the non-magnetized irrigation water treatment and the differences were significant at 5% level. For the magnetized irrigation water treatment, soil sulphate ions decreased on average up to 37.3% ($p<0.01$). The use of magnetized water to reduce soil sulphate ions in order to reclaim salt affected soils is recommended for trickle irrigation.

Keywords: magnetized water, soil reclamation, trickle irrigation

1. Introduction

Continuous use of saline water for crop production enhances soil salinization. High contents of soluble salts accumulated in the soil can significantly decrease the value and productivity of agricultural lands. Using poor quality irrigation water with high salinity is one of the main problems in agriculture of Iran and many countries in the world (Mostafazadeh-Fard et al. 2008). To reclaim soil and water, and to reduce soil salinity, magnetized water can be used (Kney and Parsons 2006). Magnetized water is obtained by passing of water through the permanent magnets or through the electro magnets installed in/on a feed pipeline (Higashitani et al. 1993). The permanent ceramic magnets or electro magnets are installed around the incoming water pipe. According to the Ampere's law, when the electricity passes into a wire, a magnetized field will be created around it. Up to now, different devices have been produced to magnetize water. In spite of variety of structures and shapes for these devices, their performing mechanism is almost the same. When a fluid passes through the magnetized field, its structure and some physical characteristic such as density, salt solution capacity, and deposition ratio of solid particles will be changed (Higashitani et al. 1993). In a water sample containing $CaCO_3$, as the calcium and carbonate ions enter into the area that are influenced by the magnets, they are pushed in opposite directions, due to their opposite charges. As all of the calcium ions are pushed in one direction and all of the carbonate anions are pushed in the opposite direction, they tend to collide. When

[+] Corresponding author. Tel.: (+98)3113913430; fax: (+98)3113912254).
E-mail address: behrouz@cc.iut.ac.ir

these collisions occur, the ions stick together forming a solid form of $CaCO_3$ called aragonite. Because these microscopic crystals are forced to form while moving in the water, they do not have an opportunity to attach themselves to the pipeline. In other words, the acting of inspiration force on the fluid and because of the polarity of water, anions and cations vibrate and get close together and finally stick. Therefore, the electrical charge of suspended particles decreases and stay in the form of snowball phenomenon and suspend in water.

The changes caused by the magnetic influence depend on many factors, such as strength of the magnetic field, direction of applied magnetized field, duration of magnetic exposure, flow rate of the solution, additives present in the system, and the pH (Chibowski et al. 2005). The magnetized water has been studied by many researches (e.g. Inaba et al. 2004 and Ghauri and Ansari 2006). An experimental study showed that a relatively weak magnetic influence (field) increased the viscosity of water, which was interpreted by the stronger hydrogen bonds under the magnetic field (Ghauri and Ansari 2006).

Two theories have been developed to address magnetic field effects on calcium carbonate precipitation: 1- a direct effect on dissolved ions and 2- a magnetic effect on particulates. The first theory postulates a direct effect on dissolved ions. Examples of ionic response to a magnetic field have been reported by Higashitani et al. (1993) who investigated the characteristics of calcium carbonate crystals formed after mixing magnetically treated, quiescent-filtered solutions of calcium chloride and sodium carbonate. The second mechanism postulates a magnetic effect on particulates present in water rather than on dissolved ions and, further, that changes in the surface charge of particles influence the rate of nucleation and precipitation of calcium carbonate (Barrett and Parsons, 1998).

Higashitani and Oshitani (1996) investigated the effect of magnetic fields on the stability of non-magnetic colloid particles, and suggested that colloidal stability is influenced by magnetic fields through alteration of the structure of water molecules and ions either adsorbed on the particle surface, or in the medium. Bogatin et al. (1999) showed that the important components for effective magnetic treatment are flow rate through the apparatus and certain chemical parameters of water, namely, carbonate water hardness of more than 50 mg/L and concentration of hydrogenous ions in water at pH >7.2. Mostafazadeh-Fard et al. (2011) investigated effects of magnetized water and irrigation water salinity on soil moisture distribution in trickle irrigation. They showed that the mean soil moisture contents at different soil depths below the emitter for the magnetized irrigation water treatment were more than the non-magnetized irrigation water treatment and the differences were significant at 5% level.

The distribution pattern of soil water and salts resulting from trickle irrigation is quite different from those resulting from the conventional irrigation methods (Wang et al. 2006; Elmaloglou and Malamos 2006 and Elmaloglou and Diamantopoulos 2007).

The magnetized water has been studied by many researches. However, to date, there is no study about the effects of magnetized water on sulphate ions ($SO4^{-2}$) of soil in trickle irrigation. The objective of this study was to investigate the effects of magnetized water and irrigation water salinity on sulphate ions of soil in trickle irrigation.

2. Materials and Methods

An experimental field belonging to Gorgan Agricultural and Natural Resources Research Center, Gorgan province, Iran, was used to collect field data during summer of 2009. Gorgan (36°45′N, 54°25′E) with elevation of about 5.5 m above mean sea level is located in northern part of Iran with annual rainfall of 527.4 mm, annual evapotranspiration demand of 1321.1 mm, average annual temperature of 17.6 ^{o}C and mean annual humidity of 71%.

A trickle irrigation experiment with complete randomized block design was used. The trickle irrigation system had two sub-units and each sub unit had nine laterals, spaced 1 m apart, with diameter of 16 mm and length of 30 m which received water from a sub-main pipe with diameter of 64 mm. Each lateral had 30 emitters, spaced 1 m apart. The control valves were installed at the beginning of each sub-unit and the sub-units were spaced 2 m apart. An electro pump supplied water to the laterals from the water source at desired pressure of 1 atmosphere. The in-line, long-path, emitters with trade name of Typhoon with discharge of 4 l/h, operating at a pressure of 1 atmosphere, were used. All pipes used in the system were polyethylene.

Totally 10 irrigations (the irrigation number, called IN) with irrigation intervals of 10 days were applied. The amount of applied irrigation water was based on the initial soil moisture content and soil moisture deficit before irrigation and the applied water was such that soil reached to the field capacity.

Two main treatments of magnetic (I1) and non-magnetic irrigation water (I2) and three sub-treatments of irrigation water salts including well water as control (S_1), 200 ppm calcium carbonate (S_2), and 400 ppm calcium carbonate (S_3) were used. To determine soil chemical parameters such as sulphate ions and their distributions around the emitters, three soil samples were taken from each soil layer (0-20, 20-40, 40 60 cm) 24 hours after irrigation, for the first and tenth irrigation.

The following notations were used for the locations that the above parameters were determined: Y_1, at the emitter and on the soil surface. Y_2, at the emitter at depth of 20 cm. Y_3, at the emitter at depth of 40 cm. Y_4, at the emitter at depth of 60 cm. Y_5, at the soil surface and at distance of 25 cm from the emitter. Y_6, at distance of 25 cm from the emitter at depth of 20 cm. Y_7, at distance of 25 cm from the emitter at depth of 40 cm. Y_8, at distance of 25 cm from the emitter at depth of 60 cm. Y_9, at distance of 50 cm from the emitter at the soil surface. Y_{10}, at distance of 50 cm from the emitter at depth of 20 cm. Y_{11}, at distance of 50 cm from the emitter at depth of 40 cm. Y_{12}, at distance of 50 cm from the emitter at depth of 60 cm. There was no rainfall for the period that measurements were made and during the first and tenth irrigation. The field was irrigated for the first time with no crop cover. Chemical characteristics of the original irrigation water (well water) are given in Table 1. Soil physical characteristics before the start of the experiments are shown in Table 2.

Magnetic water can be obtained by passing of water through a magnet installed on the sub-main pipe. To magnetize water, two methods were used simultaneously to have better magnetizing influence. In the first method, an electro magnet with the trade name of Big Magnet Water was installed around the sub-main pipe before the entrance of water to the laterals to produce electrical current. For the electro magnet, two sections of the sub-main pipe each with a length of about 0.5 m and distance of about 0.5 m from each other were wrapped by electrical wire and the wires were connected to the electro magnet box that received its power from the city electrical power supply. In the second method, the permanent magnets (ceramic magnets) with the trade name of Saba Poul were installed around the sub-main pipe before the entrance of water to the laterals. The electro magnet was installed before the permanent magnets.

3. Results and Discussion

Analysis of variance presented in Table 3 shows that the effect of magnetized irrigation water on soil sulphate ions at all depths below the emitter was significant at 1% level. Also, at all soil depths below the emitter, the mean soil sulphate ions for the magnetized irrigation water treatment was less than the non-magnetized irrigation water treatment and the differences were significant at 5% level (Table 4). The interaction effect of magnetized irrigation water with irrigation water salinity on soil sulphate ions at the most locations of the emitter were significant at 1% level (Table 3). Fig. 1 shows the comparison of soil sulphate ions at the mean distance of 25 cm from the emitter at different soil depths after the tenth irrigation for different treatments. This figure shows that irrigation with the magnetized irrigation water caused lower soil sulphate ions as compared to the non-magnetized irrigation water for different irrigation water salinities. The overall results showed that magnetized irrigation water treatments as compared to the non-magnetized irrigation water treatments caused on average up to 37.3% decrease in soil sulphate ions ($p<0.01$).

4. Conclusions

When water passes through the magnetized field, its structure and some physical characteristics will be changed. To investigate the effects of magnetized water and irrigation water salinity on sulphate ions of soil a field trickle irrigation experiment was performed. The results showed that for the magnetized irrigation water treatment, soil sulphate ions decreased significantly. The reduction of soil sulphate ions reduce the chance of calcium sulphate precipitations in soil and increase the chance of salts leaching from the soil profile which the results would be better soil conditions for plant growth.

5. References

[1] R. A. Barrett, and S. A. Parsons. The influence of magnetic fields on calcium carbonate precipitation. *Water Research.* 1998, **32** (3): 609-612.

[2] J. Bogatin, N. Ph. Bondarenko, E. Z. Gak, E. E. Rokhinson, I. P. Ananyev. Magnetic treatment of irrigation water: Experimental results and application conditions. *Environmental Science and Technology.* 1999, **33**: 1280-1285.

[3] E. Chibowski, A. Szcześ, L. Hołysz. Influence of Sodium Dodecyl Sulfate and Static Magnetic Field on the Properties of Freshly Precipitated Calcium Carbonate. *ACS Publications.* 2005, **21** (18): 8114-8122.

[4] S. T. Elmaloglou, and N. Malamos. A methodology for determining the surface and vertical components of the wetting front under a surface point source, with root water uptake and evaporation. *Irrigation and Drainage.* 2006, **55** (1): 99-111.

[5] S. Elmaloglou, and E. Diamantopoulos. Wetting front advance patterns and water losses by deep percolation under the root zone as influenced by pulsed drip irrigation. *Agricultural Water Management*. 2007, **90** (1-2): 160-163.

[6] S. A.. Ghauri, and M. S. Ansari. Increase of water viscosity under the influence of magnetic field. *Applied Physics.* 2006, Vol. **100**, 2 p.

[7] K. Higashitani, A. Kage, S. Katamura, K. Imai, S. Hatade. Effects of a magnetic field on the formation of $CaCO_3$ particles. *Colloid and Interface Science.* 1993, **156** (1): 90-95.

[8] K. Higashitani, and J. Oshitani. Measurements of magnetic effects on electrolyte solutions by atomic force microscope. *In: Proceedings of the Second International Meeting on Antiscale Magnetic Treatment, Cranfield University,* Bedfordshire, England. 1996, March.

[9] H. Inaba, T. Saitou, K. Tozaki, H. Hayashi. Effect of the magnetic field on the melting transition of H_2O and D_2O measured by a high resolution and supersensitive differential scanning calorimeter. *Applied Physics.* 2004, **96** (11): 6127- 6132.

[10] A. D. Kney, and S. A. Parsons. A spectrophotometer-based study of magnetic water treatment: Assessment of ionic vs. surface mechanisms. *Water Research*. 2006, **40** (3): 517-524.

[11] B. Mostafazadeh-Fard, M. Heidarpour, A. Aghakhani, M. Feizi. Effects of leaching on soil desalinization for wheat crop in an arid region. *Plant, Soil and Environment.* 2008, **54** (1): 20-29.

[12] B. Mostafazadeh-Fard, M. Khoshravesh, S. F. Mousavi, A. R. Kiani. Effects of Magnetized Water and Irrigation Water Salinity on Soil Moisture Distribution in Trickle Irrigation. *ASCE. Journal of Irrigation and Drainage Engineering, American Society of Civil Engineering.* 2011, Vol. **137**, Issue 6.

[13] F. X. Wang, Y. Kang. S. P. Liu. Effects of drip irrigation frequency on soil wetting pattern and potato growth in North *China Plain. Agricultural Water Management*. 2006, **79** (3): 248-264.

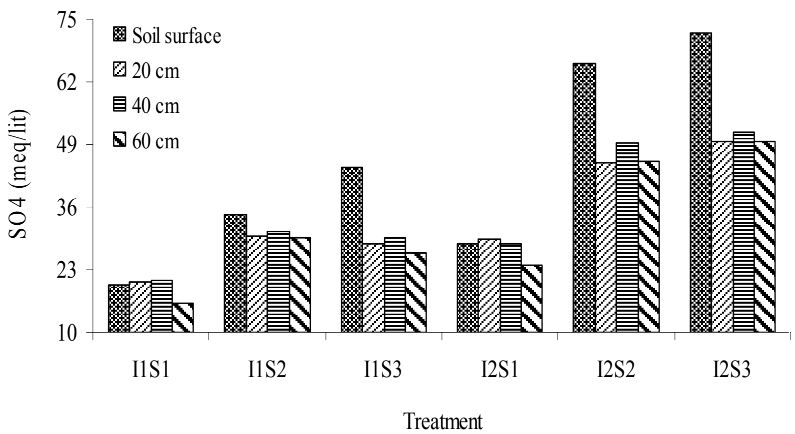

Fig. 1: The comparison of soil sulphate ions at distance of 25 cm from the emitter at different soil depths after the tenth irrigation for different treatments

Table 1: Chemical characteristic of water

EC (dS/m)	pH	Na (meq/lit)	HCO_3 (meq/lit)	Ca (meq/lit)	Mg (meq/lit)	SAR
0.66	7.6	1.8	3.2	3.2	2.4	1.08

Table 2: Some chemical characteristic of soil for the experimental field

Depth (cm)	EC (dS/m)	pH	Na (meq/lit)	Ca (meq/lit)	Mg (meq/lit)	SAR	ESP
0-20	7.5	7.4	18.1	10.2	13.1	5.3	6.15
20-40	8	7.3	18.5	12.1	10.4	5.51	6.43
40-60	8.2	7.5	18.7	15.7	9.7	5.24	6.08

Table 3: The analysis of variance for sulphate

Parameter	**Degrees of freedom**	**Mean squares**											
		Y_1	**Y_2**	**Y_3**	**Y_4**	**Y_5**	**Y_6**	**Y_7**	**Y_8**	**Y_9**	**Y_{10}**	**Y_{11}**	**Y_{12}**
I	1	2488^{**}	1596^{**}	1262^{**}	1719^{**}	2131.3^{**}	1327.3^{**}	1477.1^{**}	1415^{**}	3369^{**}	1370^{**}	1024^{**}	1544^{**}
Error	4	19.63	5.04	6.24	18.45	17.15	76.14	53.07	36.72	17.37	141.8	3.6	6.72
S	2	1769^{**}	730^{**}	368.2^{**}	690.1^{**}	1946.8^{**}	159.16^{ns}	407.8^{**}	487.3^{**}	1423^{**}	1262^{**}	649.7^{**}	952.9^{**}
S × I	2	162^{**}	55.5^{**}	32.8^{**}	93.4^{*}	98.37^{**}	78.14^{ns}	92.9^{ns}	83.82^{ns}	173.6^{**}	58.5^{ns}	25.16^{**}	54.55^{**}
Error	8	6.4	2.59	0.91	19.93	15.22	74.48	47.47	41.96	4.88	229.3	0.53	7.96
IN	1	1395^{**}	433^{**}	214.1^{**}	793.3^{**}	2275.2^{**}	16^{ns}	482.5^{*}	232.5^{*}	1754^{**}	223^{**}	116.6^{**}	2262^{**}
I ×IN	1	325^{**}	132^{**}	131.4^{**}	262.4^{**}	136.8^{**}	16.53^{ns}	170.7^{ns}	131.8^{ns}	390.1^{**}	52.08^{ns}	3.48^{*}	28.8^{ns}
S×IN	2	552^{**}	227^{**}	9.39^{**}	372.8^{**}	715.8^{**}	81.04^{ns}	319.4^{*}	64.21^{ns}	436.8^{**}	225^{*}	222^{**}	319.2^{**}
S × IN × I	2	101^{**}	52.43^{ns}	17.4^{ns}	76.64^{ns}	62.82^{ns}	31.73^{ns}	61.78^{ns}	37.28^{ns}	126.2^{**}	22.2^{ns}	15.7^{ns}	21.9^{ns}
Error	12	10.4	3.16	1.02	19.74	8.48	60.84	54.24	38.94	8.1	22.3	0.67	6.31

Note: ns, * and ** represent nonsignificant, significant at 5 percent level and significant at 1 percent level, respectively.

Table 4: The comparison of the sulphate

Treatment	**Sulphate**											
	Y_1	**Y_2**	**Y_3**	**Y_4**	**Y_5**	**Y_6**	**Y_7**	**Y_8**	**Y_9**	**Y_{10}**	**Y_{11}**	**Y_{12}**
I												
I_1	25.08 b	24.69 b	21.70 b	25.12 b	29.51 b	24.78 b	20.86 b	21.13 b	30.87 b	27.57 b	29.65 b	21.93 b
I_2	41.71 a	38.01 a	33.55 a	38.95 a	44.90 a	36.93 a	33.67 a	33.67 a	50.22 a	39.91 a	42.75 a	32.60 a
S												
S_1	21.15 c	23.92 c	22.50 c	23.28 b	23.89 c	26.75 a	20.68 b	20.10 b	28.75 c	25.80 b	26.64 c	19.64 c
S_2	33.60	30.65	26.86	36.31	38.45	32.15	29.34	30.25	42.66	35.43	37.70	27.83

	b	b	b	a	b	a	a	a	b	a	b	b
S_3	45.43 a	39.48 a	33.50 a	36.51 a	49.27 a	33.68 a	31.77 a	31.85 a	50.23 a	40 a	44.27 a	34.32 a
IN												
1st	27.17 b	27.88 b	25.18 b	27.34 b	29.25 b	30.19 a	23.60 b	24.86 b	33.57 b	31.25 b	28.27 b	25.46 b
10th	39.62 a	34.82 a	30.06 a	36.73 a	45.15 a	31.52 a	30.92 a	29.95 a	47.53 a	36.23 a	44.13 a	29.06 a

Each value in the table is an average of three replications.