

## Effect of leaching with magnetized water on three saline soils

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### Abstract

A column experiment was conducted to investigate the efficiency of magnetized water on leaching individual ions from saline soils. The study involved three different saline soils ranging between 38.14-85.91 dS.m<sup>-1</sup> leached with magnetized water (MW) or non-magnetized well water (WW). Treatments in triplicate were arranged and successive effluents were collected and analyzed. Results showed that EC decreased to 2.99–3.29 dS.m<sup>-1</sup> mostly during the first two volumes and was greater under MW treatment. Higher amount of Na<sup>+</sup> was leached under the first three volumes, but later the decrease was small. Amount of Na<sup>+</sup> leached was higher from S1 followed by S2 then S3. Sodium (Na<sup>+</sup>) decreased from 718.58, 549.03 and 419.85 mmol<sub>c</sub> L<sup>-1</sup> for S1, S2 and S3, respectively to less than 50 mmol<sub>c</sub> L<sup>-1</sup> at PV5. Calcium (Ca<sup>+2</sup>) and magnesium (Mg<sup>+2</sup>) concentrations decreased then followed by increase at the last pore volume. Most of chloride (Cl<sup>-</sup>) removal from the soil was during PV1, indicating that the source of Cl<sup>-</sup> was highly soluble salts. Magnetic water treatment proved to be efficient in leaching salts.

Key words: Leaching, Magnetized Water, Saline Soil.

## Introduction

Salts accumulate in the root zone by two processes, the upward movement of shallow saline water table and salt left in the soil due to insufficient leaching (1). Saline soils increased in central and Southern parts of Iraq due to the rise of saline ground water, and the use of poor-quality irrigation water (2). These salts affect the properties of the soil and the growth of the plant. To battle against salts that accumulate in the root zone, the soil must be adequately leached.

The available water for leaching is limited and contains various dissolved salts in it.

## Materials and Methods

Three surface soil samples (0-30 cm) were brought from Sawadah (Lat. 32°38'33.78" N, Long. 45°53' 39.96"E, Alt. 16 m above sea level (a.s.l) in Wasit province-Iraq about 167km South-East of Baghdad. The soils had initial EC of ( $S_1=85.91 \text{ dS.m}^{-1}$ ,  $S_2=53.92 \text{ dS.m}^{-1}$  and  $S_3=38.14 \text{ dS.m}^{-1}$ ). Some characteristics of those soils were shown in

Using magnetic treatment (MT) thought to be effective in dissolving and leaching salts from the soil (3-5). Magnetized water applied to salty soil breaks down the salt crystals twice as fast as un-magnetized water allowing the salt to be leached from the soil (6). A number of studies on effect of MT have been carried out in different locations of the world (7-10). But information on effect of MT on leaching of individual ions during the leaching process is lacking. The present study was carried out to study the role of MT in leaching of individual ions from soils having different salinity level

the Table 1.

Polyvinyl chloride PVC columns of 45cm long and 7.5cm internal diameter were filled uniformly with 1,200g of the three different dried soils that had been sieved through a 2mm screen. The bottom of each column was drilled and a filter paper was fitted. The columns positioned vertically in a wooden stand.

**Table 1. Some physical and chemical properties of soil.**

Characteristics	S1	S2	S3
pH	7.79	7.64	7.59
EC (dS.m <sup>-1</sup> )	85.91	53.92	38.14
Na <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	718.58	549.03	419.85
K <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	1.51	1.19	0.96
Ca <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	30.80	32.80	32.00
Mg <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	28.80	16.80	16.0
Cl <sup>-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	218.00	143.00	96.00
CO <sub>3</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	20.00	13.00	10.00
SO <sub>4</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	541.69	443.82	348.41
SAR (mmol <sub>c</sub> L <sup>-1</sup> )	131.63	110.25	102.43
Sand (g.kg <sup>-1</sup> )	196.50	181.50	171.50
Silt (g.kg <sup>-1</sup> )	475.00	455.00	340.00
Clay (g.kg <sup>-1</sup> )	328.50	363.50	488.50
Soil texture	Silty clay loam	Silty clay loam	Clay

Mmole<sub>c</sub>. L<sup>-1</sup> means millimole charge per liter

Leaching experiment was conducted under saturation condition. The study was conducted using two water treatments, magnetic water (MW) and well water (WW) and in three replicates (i.e., 2 water treatment × 3 soils × 3 Rep. = 18).

250 ml of water was added to each column daily at 9:30 a.m. and the effluents were collected after 24 h. The WW is either magnetized before or used without any treatment.

Five pore volumes of effluents were collected then analyzed daily for pH, EC, soluble anions (HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, CO<sub>3</sub><sup>2-</sup> and SO<sub>4</sub><sup>2-</sup>) and cations (Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup>). After the completion of leaching processes, the soil columns were allowed to air dried and analyzed for pH, EC, soluble ions according to (11).

## Results and Discussion

The chemical composition of the water used for saturation of soil columns were presented in Table 2. The values of pH, EC and soluble ions changed after magnetization of water, all values decreased except for Mg<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup>, the reduction also confirmed by other researchers (12-14).

Table 3 shows the pH data of water drained at each pore volume. PV2 showed higher pH values, and with other pore volumes there was little difference among the soils and water treatments. The data also shows that a higher amount of salts was leached in PV1, the rate however, slowed down gradually with the increasing of pore volumes (15 and 16). Greater amount of salt leached from MW treatment followed by WW treatment, which indicated by higher EC values (Table 3), this result agreed with (17 and 18). But

**Table 2. Water analysis before magnetization (WW) and after magnetization (MW)**

Characteristics	WW	MW
pH	7.14	6.98
EC (dS.m <sup>-1</sup> )	1.56	0.86
Na <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	2.10	1.49
K <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	0.07	0.05
Ca <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	3.30	2.10
Mg <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	5.90	7.40
Cl <sup>-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	0.60	0.50
CO <sub>3</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	1.00	0.80
HCO <sub>3</sub> <sup>-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	4.00	6.00
SO <sub>4</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	5.77	3.74

Mmol<sub>c</sub>.L<sup>-1</sup> means millimole charge per lite

**Table 3. pH and EC of leachates.**

EC (dS.m <sup>-1</sup> )						
T	Soil	PV1	PV2	PV3	PV4	PV5
	S1	139.67	116.97	28.07	5.65	4.96
WW	S2	127.26	68.26	15.87	5.64	4.69
	S3	103.39	40.46	17.42	5.89	5.42
	S1	140.31	116.52	28.04	5.65	4.96
MW	S2	131.23	69.75	16.76	6.14	4.70
	S3	107.44	40.46	17.44	5.88	5.42
pH						
	S1	7.74	8.13	7.84	7.91	8.01
WW	S2	7.71	8.49	7.78	7.72	7.99
	S3	7.27	8.05	7.84	7.93	7.88
	S1	7.71	8.10	7.81	7.89	7.99
MW	S2	7.68	8.40	7.72	7.60	7.98
	S3	7.02	8.00	7.79	7.89	7.85

PV1, PV2, PV3, PV4 & PV5 mean pore volume of the soil

**Table 4. Cations leached from soil through the pore volumes.**

Ca <sup>2+</sup> (mmol/L)								Na <sup>+</sup> (mmol/L)					
T	Soil	PV1	PV2	PV3	PV4	PV5	Total	PV1*	PV2	PV3	PV4	PV5	Total
	S1	**	34.00	18.67	20.00	28.00	100.67	**	2,693.68	182.11	43.95	25.29	2,945.03
WW	S2	**	23.33	19.00	22.00	26.50	90.83	**	1,517.57	130.89	43.63	24.66	1,716.75
	S3	**	22.00	20.00	22.33	26.00	90.33	**	834.66	130.89	48.69	32.25	1,046.49
	S1	**	27.00	20.33	20.33	20.67	88.33	**	2,301.64	102.44	31.62	5.44	2,441.13
MW	S2	**	25.00	20.00	18.67	19.67	83.33	**	1,365.81	104.33	43.95	12.33	1,526.42
	S3	**	20.00	21.00	19.00	18.33	78.33	**	784.08	113.19	46.16	18.78	962.20
Mg <sup>2+</sup> (mmol/L)								K <sup>+</sup> (mmol/L)					
	S1	**	35.00	3.67	4.33	4.67	47.67	0.87	1.45	0.67	0.43	0.27	2.81
WW	S2	**	15.50	5.33	4.00	4.00	28.83	0.54	1.11	0.55	0.39	0.31	2.35
	S3	**	14.67	6.00	5.00	2.50	28.17	0.49	0.85	0.56	0.34	0.37	2.12
	S1	**	42.00	5.00	5.00	9.00	61.00	0.68	1.70	0.54	0.26	0.33	2.83
MW	S2	**	24.00	5.67	8.33	8.67	46.67	0.54	0.92	0.57	0.24	0.29	2.01
	S3	**	20.33	5.33	9.00	13.33	48.00	0.27	0.81	0.61	0.21	0.30	1.93

\*Not included in the total values; \*\*Very high concentration. Subscript (c) means **charge**

**Table 5. Anions leached from soil through the pore volumes.**

Cl <sup>-</sup> (mmol/L)								SO <sub>4</sub> <sup>2-</sup> (mmol/L)					
T	Soil	PV1	PV2	PV3	PV4	PV5	Total	PV1*	PV2	PV3	PV4	PV5	Total
	S1	110.00	21.67	9.17	8.33	7.92	47.08	**	2,727.63	186.21	55.71	46.51	3,016.06
WW	S2	73.67	18.33	8.67	8.17	8.33	43.50	**	1,521.93	139.00	57.32	42.90	1,761.15
	S3	54.33	19.00	9.08	8.92	8.50	45.50	**	836.68	138.50	61.85	47.42	1,084.45
	S1	160.33	11.33	6.83	6.58	6.42	31.17	**	2,344.85	114.14	45.03	23.68	2,527.69
MW	S2	68.67	8.67	7.00	6.42	6.42	28.50	**	1,391.23	114.24	57.30	28.00	1,590.77
	S3	42.00	9.67	6.92	6.42	6.50	29.50	**	800.88	123.01	59.29	36.51	1,019.70
CO <sub>3</sub> <sup>2-</sup> (mmol/L)								CO <sub>3</sub> <sup>-</sup> (mmol/L)					
	S1	**	0.67	0.00	0.80	0.13	1.60	**	14.17	9.73	3.87	3.67	31.43
WW	S2	**	1.00	0.00	0.73	0.33	2.07	**	16.25	8.10	3.80	3.90	32.05
	S3	**	1.17	0.67	0.87	0.60	3.30	**	15.33	9.20	4.73	4.60	33.87
	S1	**	1.17	0.00	0.40	0.53	2.10	**	15.00	7.33	5.20	4.80	32.33
MW	S2	**	1.50	0.60	0.80	0.73	3.63	**	14.33	8.73	6.67	5.80	35.53
	S3	**	1.67	0.80	0.80	0.67	3.93	**	13.00	9.40	7.87	7.07	37.33

\*Not included in the total values; \*\*Very high concentration.

after the second pore volume, there was hardly any difference. Among soils, the higher the initial EC, the greater the amount of salts leached. The data on leaching of different ions are presented in Tables 4 and 5. No values were measured for the first pore volume, because the concentrations of ions were very high, the leachate diluted 250 times for  $\text{Na}^+$  and no reading could be taken. The rest of ions also could not be measured. Among the cations under the two water treatments and all types of soils,  $\text{Na}^+$  was leached in higher quantity as compared with  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ . Higher amount of  $\text{Na}^+$  was leached under pore volumes (PV1, PV2 and PV3), but after PV3 the difference in decrease was small.

In case of water treatments, values of  $\text{Na}^+$  were higher in the leachate of WW treatment for all pore volumes. This may indicate that the higher amount of  $\text{Na}^+$  was leached in the PV1 under MW treatment (19), (unfortunately, the concentration of  $\text{Na}^+$  could not be determined). Amount of  $\text{Na}^+$  leached was higher from S1 followed by S2 then S3; this may be attributed to the higher initial salinity and texture.

$\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  concentrations showed similar trend, after PV2 both concentrations decreased then increased. The decrease could be attributed to the exchange between ( $\text{Ca}^{2+}$  +  $\text{Mg}^{2+}$ ) and exchangeable  $\text{Na}^+$  resulting in displacement of  $\text{Na}^+$  into the leachates. The displaced  $\text{Na}^+$  decreased sharply indicating slow release of  $\text{Na}^+$  from the soil. The concentrations of  $\text{Mg}^{2+}$  in the leachates from different water treatments were less than the

concentrations of  $\text{Ca}^{2+}$  and more than  $\text{K}^+$ , which present in small quantities. For anions, the  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and  $\text{HCO}_3^-$  showed trend similar to  $\text{Na}^+$  while  $\text{CO}_3^{2-}$  was present in small quantities in leachates.

Most of  $\text{Cl}^-$  was removed from the soils during PV1, indicating that the source of the  $\text{Cl}^-$  were highly soluble  $\text{NaCl}$  and  $\text{CaCl}_2$ . After PV5, concentration of  $\text{Cl}^-$  in leachate from the soil columns reached approximately  $8.2 \text{ mmol}_c \text{ L}^{-1}$  and  $6.5 \text{ mmol}_c \text{ L}^{-1}$  for WW and MW treatment, respectively. Concentration of  $\text{SO}_4^{2-}$  fell sharply to a minimum average value of about  $45.6 \text{ mmol}_c \text{ L}^{-1}$  and  $29.4 \text{ mmol}_c \text{ L}^{-1}$  for WW and MW treatments, respectively. A large initial concentration of  $\text{HCO}_3^-$  was found in PV2 and its decrease to more stable values after PV3. Considering the water treatments, generally the total amount of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  were less in the leachates of MW treatment. It may be attributed to that MW promotes leaching process in the initial stage of salt leaching, but as the leaching progresses, the salt concentrations decrease, this can be indicated by the darker color and more concentrated PV1 leachate of MW treatment compared to WW treatment. This may also indicate that less water requirement is needed under this treatment.

Among soil types, generally more cations and anions were leached from the highest initial soil salinity S1=  $85.91 \text{ dS.m}^{-1}$  followed by S2=  $53.92 \text{ dS.m}^{-1}$  then S3=  $38.14 \text{ dS.m}^{-1}$ .

Table 6 shows the analysis of soluble ions in soil after saturation with five pore volumes.

The hypothetical combination revealed that the initial soils before the leaching process were mainly sulfatic and chloridic ( $\text{Na}_2\text{SO}_4$  the dominant salt followed by  $\text{NaCl}$ ). After saturation with five pore volumes, the dominant salts were  $\text{CaSO}_4$  which indicates replacement of soil exchangeable  $\text{Na}^+$  by  $\text{Ca}^{2+}$ . The effect of exchange reactions becomes prominent after two pore volumes.

Generally, greater amounts of soluble ions were leached through the soil columns (Tables 1-6). After five pore volumes, concentrations of soluble  $\text{Na}^+$  decreased sharply to reach a value below  $2.74 \text{ mmol}_c \text{ L}^{-1}$

<sup>1</sup> for WW treatment and  $3.16 \text{ mmol}_c \text{ L}^{-1}$  for MW treatment.

$\text{Ca}^{2+}$  concentrations decreased to the half and there was also a noticeable decrease in  $\text{Mg}^{2+}$  concentrations. For anions after PV1,  $\text{SO}_4^{2-}$  was the dominant ion followed by  $\text{Cl}^-$  and least quantity of  $\text{HCO}_3^-$  was observed in all soils and water treatments. This confirms that the dominant initial salts in soil were sulfate and chlorides. Among different water treatments, except for  $\text{Ca}^{2+}$ , generally highest quantities of cations and anions were found under WW treatment.

**Table 6. Analysis of soluble ions in the soils after leaching.**

	WW			MW		
Soils	S1	S2	S3	S1	S2	S3
pH	7.19	7.23	7.43	7.25	7.34	7.39
EC ( $\text{dS.m}^{-1}$ )	3.04	3.11	3.29	3.02	2.99	2.99
Ca ( $\text{mmol}_c \text{ L}^{-1}$ )	14.10	13.93	13.30	16.17	16.22	15.33
Mg ( $\text{mmol}_c \text{ L}^{-1}$ )	5.40	4.34	4.26	1.50	0.61	1.22
Na ( $\text{mmol}_c \text{ L}^{-1}$ )	2.74	2.20	1.35	2.14	2.26	3.16
K ( $\text{mmol}_c \text{ L}^{-1}$ )	0.48	0.44	0.44	0.44	0.41	0.40
Cl ( $\text{mmol}_c \text{ L}^{-1}$ )	3.33	4.00	3.17	3.00	3.67	4.00
$\text{CO}_3$ ( $\text{mmol}_c \text{ L}^{-1}$ )	0.00	0.00	0.00	0.00	0.00	0.00
$\text{HCO}_3$ ( $\text{mmol}_c \text{ L}$ )	1.56	1.50	1.44	1.50	1.61	1.50
$\text{SO}_4$ ( $\text{mmol}_c \text{ L}^{-1}$ )	17.83	15.42	14.73	15.75	14.23	14.62

## Conclusions

It can be concluded from the above results that most salts were leached in PV1 and were higher from MW treatment, but after PV2 there was hardly any difference between water treatments. The EC decreased from 85.91, 53.92 and 38.14 dS.m<sup>-1</sup> for S1, S2 and S3 respectively to a range between 2.99-3.29 dS.m<sup>-1</sup>. The PV5 was adequate to decrease the Na<sup>+</sup> values from 718.58, 549.03 and 419.85 mmolc.L<sup>-1</sup> for S1, S2 and S3 respectively to less than 50 mmolc.L<sup>-1</sup>. MW treatment proved to be efficient in leaching salts and helps in exchangeable Ca<sup>2+</sup> build-up in soil and overcome the deleterious effect of Na<sup>+</sup>. The above results should be taken in consideration in reclamation of salt affected soils.

## References

- 1- Stephen, R. G. 2002. Irrigation water salinity and crop production, Publication 8066 by the regents of university of California, division of Agriculture and natural resources. USA.
- 2- AlZubaidy, A. H. 1989. Soil Salinity. Biet-Al-Hekma. University of Bagdad. Ministry of higher Education and Scientific Research. Iraq. (in Arabic).
- 3 - Bruns, S. A; V. I..Klassen and Konshina, A.K.1966.Change in the extinction of light by water after treatment in a magnetic field, Kolloidn. Zh., 28:153-155.
- 4 - Busch, K.W; M. A. Busch; D.H. Parker; R.E. Darling and McAtee, J. L. Jr1986. Studies of water treatment device that uses magnetic fields. Corrosion,42 (4): 211-221.
- 5- Tkatchenko, U. 1997. Hydromagnetic aeroionizers in the system of spray, Method of irrigation of agricultural crops, Hydromagnetic systems and their role in creating micro – climate. Chapter from Prof. Tkatchenkos book, Practical magnetology. Dubai,UAE.
- 6- Mostafazadeh-Fard, B.; M. Heidarpour; A. Aghakhani and Feizi, M.2008. Effects of leaching on soil desalinization for wheat crop in an arid region, Plant, Soil and Environment, 54 (1):20-29.
- 7- Duffy, E. A.1977. Investigation of magnetic water treatment devices, Ph.D. Dissertation, Clemson University.
- 8- Hasson, D. and D. Bramson.1985. Effectiveness of magnetic water treatment in suppressing CaCO<sub>3</sub> scaledeposition, Ind. Eng. Chem. Process Des. Dev., 24:588-592.
- 9- Miraslav, C. and D. Mors long-term effect of electromagnetic radiation on solution and suspended collides. Longmuir. 14 (4): 783-787.
- 10- Selim, M. M. 2008. Application of magnetic technologies in correcting underground brackish water for irrigation in the arid and semi-arid ecosystem. The 3<sup>rd</sup> International Conference on Water Resources and Arid Environments.
- 11- Page, L.; R. H. Miller and Kenney, D. R., 1982. Methods of analysis: Part 2— Chemical and Microbiological Properties, 2<sup>nd</sup>ed. Wisconsin, USA.
- 12- Chechel, P. S. and G. V. Annenkova. 1972. Influence of magnetic treatment on solubility of calcium sulphate, Coke Chem. USSR8: 60-61.



- 13- Al-Juthari, H. A. 2006. Effect of irrigation water quality, magnetic water and potassium fertilizer levels on some chemical properties of soil, growth and yield of corn, M.Sc. Thesis. College of Agriculture. University of Baghdad. Iraq. (In Arabic).
- 14- Maheshwari, B. L. and H. S. Grewal. 2009. Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity, *Agric. Water Manage.*, 96: 1229-1236.
- 15- Martynova, I.; E. F. Tebenekhin and Gusev. B. T. 1967. Conditions and mechanism of deposition of the solid calcium carbonate phase from aqueous [sic] solutions under the influence of a magnetic field, *Colloid J.*, 29: 512-514. USSR.
- 16- Kronenberg, K. J. 1985. Experimental evidence for effects of magnetic fields on moving water, *IEEE Trans. on Magnetics*, 21 (5): 2059-2061
- 17- Joshi, K. M. and P. V. Kamat. 1966. Effect of magnetic field on the physical properties of water. *J. Ind. Chem. Soc.*, 43: 620-622.
- 18- McNeely, M. 1994. Magnetic fuel treatment system designed to attack fuel-borne microbes, *Diesel Progress Engines and Drives*. Russia. pp. 16.
- 19 - Klassen, V. I. 1981. Magnetic treatment of water in mineral processing, in: *Developments in Mineral Processing: Part B—Mineral Processing*, Elsevier, NY, 1077-1097.