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Evaporation of magnetically treated water and NaCl solutions

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A b s t r a c t. This study was designed to evaluate the effects on evaporation of distilled water and tap water subjected to magnetic treatment for different periods of time. Evaporation of NaCl solutions magnetically treated was also studied. The magnetic treatment took place by circulation through a pipe with 125-mT magnets. The evaporation of distilled water, tap water and 0.026 M NaCl solution that had been magnetically treated for 60 min, were 5.07, 4.53 and 3.60 % less than their respective control. The dynamic magnetization of water and solutions generates a decrease in the evaporation whereby this method could provide a mechanism to economize water, principally applicable to agriculture.

K e y w o r d s: water, evaporation, magnetic treatment, magnetohydrodynamics, NaCl solutions

INTRODUCTION

When water passes through a magnetic field, its polar molecules align themselves in such a way that the physicochemical properties of the water change; increases in salt solubility (Carbonell *et al*., 1996), variation of viscosity (Ramos, 1994), pH (Srivastava *et al*., 1978), electrical conductivity (Díaz *et al.*, 2001), crystal shape (Coey *et al.*, 2000), particle size and compound precipitation (Barnothy, 1964) as consequences of the magnetic treatment of water have been reported. The effects of water magnetic devices in the prevention of the formation and removal of scale in pipes and boilers have been noticed (Busch *et al*., 1997). The limescale problem in hard water arises because the solubility of $CaCO_3$ decreases with increasing temperature (Strum *et al*., 1970). The aim of this study was to evaluate the effects that magnetohydrodynamic treatment of tap water, distilled water and NaCl solutions produce on evaporation.

The applications of magnetic treatment of seeds and water in Agriculture practice has been researched by many scientists; magnetohydrodynamic activation of natural water is used to change physical and chemical properties of the irrigation water, the application of the device allows intensified washing of saline soils, to decrease water consumption and to increase the crop yield by 15–20% (Bondarenko *et al*., 1996). Pietruszewski *et al*. (2001) have reported a positive influence of 35-mT alternating magnetic field in the germination of wheat grain.

MATERIALS AND METHODS

The experimental design was performed under laboratory conditions, at a mean room temperature of 20 ± 2°C. To evaluate the effect of magnetic treatment on evaporation four experiments, two repetitions of each, were carried out using distilled water (experiment 1), tap water (experiment 2), 0.026 M NaCl solution (experiment 3) and 0.052 M NaCl solution (experiment 4), summarized in Table 1. The 0.026 M and 0.052 M NaCl solutions, were obtained by dissolution of 1.5 and 3.0 g of NaCl in 1 l of distilled water.

The magnetic treatment of water and solutions took place by circulation, at 0.7 m s^{-1}, through a polyethylene pipe with six 125-mT magnets (Figs 1 and 2). The magnetic force lines are perpendicular to the direction of fluid flow according to the indications of Busch (1997). Prior to the beginning of the experiment, water and solutions were kept circulating for 30, 60 and 120 min for magnetization, and untreated samples served as control. Distilled water was kept circulating in the device without magnets, in the same experimental conditions, to serve as a blanc test.

The sample size in each experiment was 64 glasses corresponding to 16 per treatment and glasses were randomly distributed; this arrangement was based on a sequence of

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Table 1. Experimental design of magnetic treatment of samples. Different time of exposure to magnetic field (30, 60, and 120 min) of water and solutions provide different treatment T (T1-T12). C – Control (samples non exposed to magnetic field)

Experiment	Sample	Time of exposure (min)			
		0	30	60	120
1	Distilled water	C1	T1	T2	T3
2	Tap water	C2	T4	T5	T6
3	0.026 NaCl solution	C3	T7	T8	T9
4	0.052 NaCl solution	C4	T10	T11	T12

numbers mathematically generated and the edge effect was considered. The evaporation of water or solution was evaluated, each day, through the gravimetric method. The experiment finished when the differences of evaporation among treatments and their controls lost signification. Statistical analysis of data was performed using Anova, t-student, Kruskal-Wallis, Dunnet and Mann-Witney tests for comparison of treatments.

RESULTS AND DISCUSSION

Results presented in Table 2, show that evaporation of distilled water magnetically treated for 60 min (T2) is less

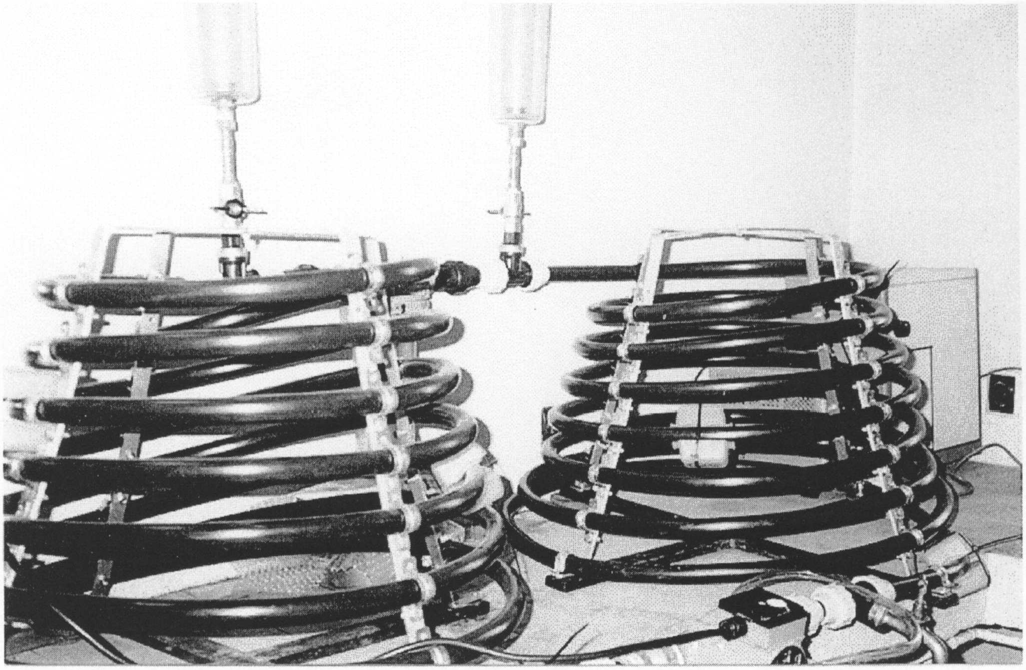

Fig. 1. Magnetic device to treatment of water. Water is magnetically treated by continous circulation in a double helix shipe pipe, with six magnetic batteries as the marked.

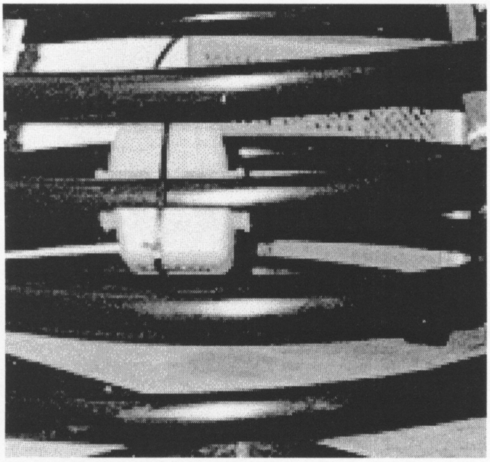

Fig. 2. Detail of magnetic battery placed in the pipe, each battery is composed of two 125 mT-magnets with north facing magnetic poles.

than control (C1); the maximum differences of evaporation of T2 related to control were 4.26% (2nd day, repetition 1) and 5.07 % (3th day, repetition 2). The statistical analysis of this data, using t-Student's test, reveals extremely significant differences.

Results of Table 3 show that evaporation of tap water magnetically treated for 60 min (T5) is 3.80 % (2nd day, repetition 1) and 3.86 % (4th day, repetition 2) less than the control, t-Student's test showed extremely significant differences.

Evaporation of 0.026 M NaCl dissolutions magnetically treated (T7-T9) related to control (C3), presented in Table 4, reveals that the evaporation of samples magnetically treated for 60 min was less than the untreated samples; the maximum differences between C3 and T8 were 3.60 % (4th day,

T a b l e 2. Evaporation of distilled water. Mean values ± SEM of evaporation of distilled water (g). T1– magnetization for 30 min; T2 – magnetization for 60 min; T3 – magnetization for 120 min; C1– control, untreated distilled water. SEM – Standard Error Medium

Mean (g) ± SEM	Repetition 1 Day			Repetition 2 Day			
	1	2	3	1	2	3	4
C1	4.60 ± 0.04	4.22 ±0.06	4.29 ±0.06	4.60 ±0.05	4.47 ±0.06	4.93 ±0.07	4.99 ±0.05
T1	4.82 ±0.05	4.15 ±0.08	4.21 ±0.12	4.72 ±0.04	4.50 ±0.05	4.89 ±0.05	4.92 ±0.04
T2	4.49 ±0.04	4.04 ±0.04	4.16 ±0.12	4.51 ±0.05	4.31 ±0.05	4.68 ±0.04	4.81 ±0.06
T3	4.64 ±0.05	4.18 ±0.06	4.26 ±0.05	4.66 ±0.06	4.46 ±0.06	4.98 ±0.08	4.76 ±0.04

T a b l e 3. Evaporation of tap water. Mean values ± SEM of evaporation of tap water (g). T4 – magnetization for 30 min; T5 – magnetization for 60 min; T6 – magnetization for 120 min; C2 – control, untreated tap water. SEM – Standard Error Medium

Mean (g) ± SEM	Repetition 1 Day				Repetition 2 Day			
	1	2	3	4	1	2	3	4
C2	5.02 ±0.04	5.26 ±0.07	5.59 ±0.06	6.05 ±0.06	4.86 ±0.04	4.60 ±0.05	4.82 ±0.06	5.18 ±0.04
T4	5.03 ±0.06	5.36 ±0.07	5.49 ±0.06	5.86 ±0.05	4.89 ±0.03	4.60 ±0.04	4.85 ±0.05	5.14 ±0.08
T5	4.98 ±0.04	5.06 ±0.05	5.48 ±0.05	5.96 ±0.05	4.75 ±0.03	4.47 ±0.04	4.67 ±0.03	4.98 ±0.04
T6	5.06 ±0.05	5.15 ±0.08	5.59 ±0.12	6.03 ±0.14	4.93 ±0.04	4.51 ±0.04	4.75 ±0.04	5.07 ±0.04

T a b l e 4. Evaporation of NaCl 0.026 M solution. Mean values ± SEM of evaporation of NaCl 0.026 M solution (g). T7 – magnetization for 30 min; T8 – magnetization for 60 min; T9 – magnetization for 120 min; C3 – control, untreated NaCl 0.026 M solution. SEM – Standard Error Medium

Mean (g) ± SEM	Repetition 1 Day				Repetition 2 Day			
	1	2	3	4	1	2	3	4
C3	3.52 ±0.04	3.59 ±0.04	3.53 ±0.04	3.61 ±0.05	3.50 ±0.03	3.52 ±0.03	3.48 ±0.04	3.40 ±0.03
T7	3.58 ±0.04	3.63 ±0.05	3.56 ±0.04	3.57 ±0.05	3.56 ±0.04	3.56 ±0.05	3.52 ±0.05	3.44 ±0.04
T8	3.46 ±0.03	3.49 ±0.03	3.45 ±0.03	3.48 ±0.03	3.49 ±0.03	3.46 ±0.05	3.39 ±0.04	3.37 ±0.03
T9	3.55 ±0.04	3.56 ±0.04	3.48 ±0.03	3.56 ±0.04	3.58 ±0.04	3.53 ±0.05	3.48 ±0.05	3.41 ±0.04

repetition 1) and 2.59 % (3rd day, repetition 2), the p value is $p < 0.05$, considered significant using Mann-Whitney test.

Results presented in Table 5, show that evaporation of 0.052 M NaCl solutions magnetically treated for 60 min (T11) is less than control (C4); the maximum differences of evaporation related to control were 2.37%. The statistical analysis reveals that the differences between treatments were not significant, probably due to the increase of salt in the solution.

By jointly analyzing the results of Tables 2–5 we can observe the lower evaporation values of distilled, tap water and NaCl solutions samples magnetically treated for 60 min,

T a b l e 5. Evaporation of NaCl 0.052 M solution. Mean values ± SEM of evaporation of NaCl 0.052 M solution. T10 – magnetization for 30 min; T11 – magnetization for 60 min; T12 – magnetization for 120 min; C4 – control, untreated NaCl 0.052 M solution. SEM – Standard Error Medium

Mean (g) ± SEM	Repetition 1 Day				Repetition 2 Day			
	1	2	3	4	1	2	3	4
C4	2.10 ±0.02	1.76 ±0.02	1.76 ±0.02	1.69 ±0.02	2.29 ±0.02	2.12 ±0.03	2.14 ±0.02	2.37 ±0.03
T10	2.08 ±0.03	1.78 ±0.02	1.78 ±0.02	1.72 ±0.02	2.26 ±0.02	2.13 ±0.02	2.10 ±0.02	2.35 ±0.03
T11	2.12 ±0.03	1.74 ±0.02	1.74 ±0.02	1.65 ±0.02	2.29 ±0.03	2.19 ±0.02	2.15 ±0.02	2.41 ±0.03
T12	2.20 ±0.04	1.73 ±0.04	1.79 ±0.03	1.73 ±0.02	2.31 ±0.03	2.17 ±0.03	2.16 ±0.02	2.41 ±0.03

vs. control. The greatest effect is obtained for distilled water but the effect of the magnetic treatment on the evaporation decreases when the amount of salts is increasing; then, evaporation of distilled water magnetically treated for 60 min is about 5% less than control and evaporation of 0.052 M NaCl solution magnetically treated for 60 min is 2.37% less than control.

Results obtained, when water was kept recirculating in the equipment without magnetic batteries (blanc test) with the same experimental design, showed identical evaporation to the control; then, we can reject the proposal that circulation has some effect on evaporation of water and we can conclude that the decrease found could be attributed to the magnetic treatment. The action mechanism of magnetic treatment on water is not well known to date, but the applications of magnetic treatment of water in Industry to prevent limescale has been used since last centuries. The first US patent for a water treatment system based on the use of a magnetic field corresponded to that developed by Porter in 1865 and Hay in 1873. Today many of these devices are commercially available since they are sometimes effective for scale control in water-using systems.

Changes in evaporation resulting from the magnetization of water may have important agricultural and environmental applications, and may even serve to save water and allow for more efficient use of water by biological systems. One of most important effects observed by Bondarenko *et al*. (1996) is the greater concentration of molecularly dissolved CO_2 in water, which affects moisture in soil, the solubility of fertiliziers and their uptake by plant cells. The CO_2 forms carbonic acid, which promotes the displacement of sodium from the soil – absorbing complex (SAC):

$$[\mathrm{SAC}]^{\mathrm{Na}^+}_{\mathrm{Na}^+} + \mathrm{H_2CO_3} \Leftrightarrow [\mathrm{SAC}]^{\mathrm{H}^+}_{\mathrm{H}^+} + \mathrm{Na_2CO_3}. \quad (1)$$

When carbonic acid interacts with insoluble soil carbonates, it converts this into soluble form, bicarbonates, which enter into an exchange reaction with SAC-sodium:

$$\mathrm{H_2CO_3} + \mathrm{CaCO_3} \Leftrightarrow \mathrm{Ca(HCO_3)_2} \quad (2)$$

$$[\mathrm{SAC}]^{\mathrm{Na}^+}_{\mathrm{Na}^+} + \mathrm{Ca(HCO_3)_2} \Leftrightarrow [\mathrm{SAC}]^{\mathrm{Ca}^{2+}}_{\mathrm{Ca}^{2+}} + 2\mathrm{NaHCO_3}. (3)$$

From these equations, sodium is displaced from SAC into the soil solution, which accelerates their leaching, and reduces water consumption.

The increase in the rate of germination when seeds are magnetically treated or irrigated with magnetized water may be explained by the improved availability of nutrients due to an increase in salt solubility (Martinez *et al*., 1999). According to this theory, Markov (1979) proposed a magnetic field in-water mechanism of biological action; changes in the properties of water induce a temporary stable state in which the exchange of energy with the environment is intensified; cell membranes become more permeable and the amount of free water in seeds increases. Enhanced germination, growth and yield in tomato cultivation (*Licopersicum esculentum* L.) were achieved when the water used for irrigation was magnetically treated leading to an improvement in the physical properties of the soil (Duarte, 1996).

CONCLUSIONS

1. The evaporation of distilled and tap water and NaCl solutions magnetically treated for 60 min is less than the evaporation of untreated samples.

2. The greatest differences of evaporation were obtained for distilled water. When the amount of salts was increasing (tap water and NaCl solutions) the differences of evaporation related to control decreased.

3. Magnetohydrodynamic treatment of water could provide a mechanism to economize water, and allow for more efficient use of water by biological systems, principally applicable to agriculture.

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