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Research Article

Effect of Magnetic Treatment on Surface Tension and Water Evaporation

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Abstract

In Tunisia, the availability of water resources is an important issue in agriculture, drinking water and industry. It is important to note that agriculture is the most water consuming activity. However, the scarcity of water resources, both in quality and quantity, and its geographical distribution are among the main factors limiting the development of Tunisian agriculture. It is clear that the magnetic device influences the characteristics of limestone. On the other hand, there is variation in the physico-chemical characteristics of water which improves productivity and crop performance. The performance of irrigation by magnetized water is greater than irrigation by raw water. In this context, we examine the effects of magnetic treatment of irrigation water on surface tension and evaporation. As a result, four apparatuses with different characteristics were used. The application of a magnetic field influenced the water parameters, decreasing its surface tension by up to 24 % and increasing its volume evaporated in relation to the raw water. Statistical analysis showed that our experimental results are significant.

Keywords: *Magnetic device, Water Evaporation, Surface Tension, Statistical analysis.*

1. Introduction

The degradation of water quality in Tunisia is mainly due to the overexploitation of groundwater, pollution and especially mismanagement in the different areas. Magnetic treatment methods can be used in the field of agriculture to alleviate salinity problems of irrigation. In recent years, the effects of magnetic fields on water have been of interest to physicists, chemists and biologists (Parsons *et al.,* 1997). Smirnov (2003) stated that water, as a conductor of electromagnetic waves, can receive signals emitted by magnetic forces and thus becomes the mediator between the source of magnetic field and the plant. These results are endorsed by Pang and Deng (2008) who added that the application of a magnetic field creates changes in the physical and chemical properties of water at microscopic and macroscopic scales. In addition, Cai *et al*. (2009) explained these changes by the formation of a large number of hydrogen bonds. Today, magnetic processing is of interest to several sectors of activity such as health, environment, industry, etc. In particular, we are targeting its applications in agriculture.

Some authors claim favorable effects of magnetism technology on the effects of water such as the removal of limestone deposits (Chibowski *et al*., 2003 and Alimi *et al*., 2006) in water pipes, improved germination rate and the stimulation of growth (Shabrangi *et al.*, 2009). It should be noted, however, that the application in agriculture of this magnetism technology can take place either by directly exposing organs of the plant (such as seeds) to the magnetic field (Florez *et al.,* 2007). Which is justified by the presence of Paramagnetic properties in the chloroplast, or via exposure of irrigation water to this magnetic field (Hozayn and Qados, 2010a)? This improvement can be attributed to the formation of new protein bands (Hozayn and Qados, 2010b). On the other hand, Çelik *et al.* (2008) and Shabrangi *et al.* (2009) reported that this physical treatment affects gene expression by increasing biological reactions such as protein synthesis.

Magnetic water treatment devices are environmentally friendly, competitively priced and no energy requirements (Hozyan and Qados, 2010a). However, little research is directed at improving the characteristics of the magnetic machine and optimizing the parameters for treatment against the salinity of irrigation water. Thus, magnetized water used for irrigation can improve water productivity (Maheshwari *et al.*, 2009), thus conserving water supply for the future in light of the expected global water shortage. Alkhazan and Saddik (2010), have

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shown that a magnetic field can physically and chemically affect water. The physical and chemical properties for samples were measured in addition to their bacterial content. In both cases of static and shaking, the magnitude of the magnetic flux is increased and the electrical conductivity (EC) is increased. Researchers observed that magnetized water helps in dissolving minerals and acids by a higher rate than unmagnetized water. This is in addition to dissolving oxygen and increasing the speed of chemical reactions (Moon and Chung, 2000).

Smirnov (2003) noticed that water can receive signals produced from magnetic forces that have a direct effect on living cells and their vital action. Clear inverse correlations between metallic pollutants concentrations and concentration-dependant magnetic characteristics are observed by Georgeaud *et al.* (1998) and Matasova *et al*. (2005). Krzemieniewski *et al.* (2004) revealed that the magnetization of tap water allows achieving its full oxygenation capacity.

The magnetized water used for irrigation can promote the development of the plant and increase its production (Dattatry and Vijaysinh, 2015). Taimourya *et al.* (2015) showed that the static magnetic field has positive effects such as stimulating growth and improving the production of cabbage (Brassica oleracea) of about 30 %. Elaoud A. et *al.* (2016) showed the effect of magnetic treatment on water quality and on the yield of the melon culture which increased by 39 % compared to the control (raw water).

Surface tension is one of properties of magnetic treatment water. Huo et *al.* (2011), found a decreasing tension coefficient on the surface of normal and deionized water, reaching a minimum value around 0.4 T - 0.7 T of magnetic treatment. Pang & Deng (2008) showed differences in surface tension of magnetic treatment water, based on the contact angle of a droplet on a smooth surface of copper and graphite. Finding that this angle is slightly lower than in the untreated water, which indicates a decrease in hydrophobicity. The above is in accordance with Otsuka and Ozeki (2006), results who observed that the contact angle of droplets of magnetized water was lower than that of untreated water, measured on a copper surface. Other authors (Amiri and Dadkhah, 2006 ; Cai et *al.*, 2009 ; Toledo et *al.*, 2013 and Hasaani et *al.*, 2015) have verified a reduction in surface tension under different experimental conditions. Also, Cai et *al.* (2009) pointed out that a magnetic field can decrease the surface tension while increasing the viscosity of water.

Evaporation is one of the physical parameters water influenced with magnetic device. Yun-Zhu et *al.* (2012), reported that under a strong magnetic field (more than 8 T), the evaporation rate increases significantly. This parameter depends on the surface of the liquid/gas interface, the change in the intensity of the hydrogen bonds and Van der Waals forces. Szcześ et *al.* (2011) point out an increase in the rate of evaporation of water after magnetization. Holysz et *al.* (2007) also observed this trend, but they make clear that the rate of evaporation of magnetic treatment is altered if it contains electrolytes in solution, in which case a high concentration may cause the opposite effect. This is because the thickness of the hydration layer around the ions affects this property. Wu et *al.* (2006) showed that the evaporation of pure water has increased in a static magnetic field (0.25, 0.36 and 0.55 T) compared to evaporation outside the magnetic field.

Nakagawa et *al.* (1999) examined the effect of magnetic field on water vaporization. The magnetic field enhances the water vaporization in air, but not in nitrogen. Furthe more, the magnitude of these effects depends on the field gradient product B dB/dx field and the maximum of the vaporization rate increment is asymmetric to the field axis.

Farhan L.R. et *al.* (2013) small increase in evaporation rates took place after using magnetic field. So, the magnetic field will increase the surface tension and lead to maximize the evaporation rate.

In this context, our subject arises in order to study the effect of magnetic fields on the physical and chemical parameters of water in order to bring about the improvement of the evaporation and tension surface.

2. Materials and methods

2.1 Generality

The study and analysis of the water was conducted at Laboratory of Natural Treatment Water - Water Research and Technologies Center - Borj Cedria, Tunisia.

The difference between the evaporated volume of the magnetized water and the evaporated volume of the not-magnetized water at a fixed temperature is ΔV (Eq .1).

$$\Delta V = Ve\ (M) - Ve\ (NM) \quad (1)$$

The experimental device is in complete random block to three repetitions. In each block contains 3 tests.

In this work, the magnetic devices (M1 = 3300 Gauss, M2 = 2900 Gauss, M3 = 5000 Gauss and Electromagnetic m = 900 Gauss) are mounted on experimental system in order to obtain magnetized water (Figure1).

We note Magnetized water (M) and Not-Magnetized water (NM).

Fig.1 Magnetic devices mounted on the experimental system

2.2 Measurement of surface tension

The experimenter carried out a large number of tests on surface tension of magnetized water. Magnetization condition mainly refers to intensity of magnetic field, magnetic course, temperature and water quality.

The method used to determine surface tension is the falling drop method. The drop which forms at the extremity of the burette (with 10 ml volume) is subjected to two opposing forces:

- Its weight increases during the development of the drop.
- The force of the surface tension which retains it in contact with the glass.

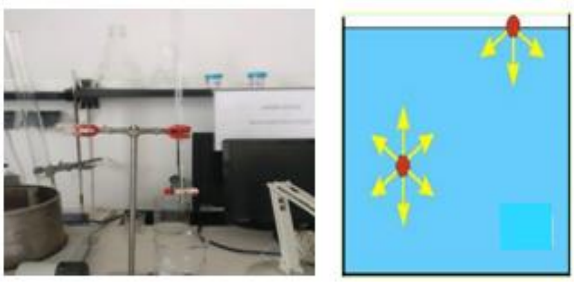

Fig. 2 Measurement of Surface Tension (ST)

2.3 Measurement of evaporation

Since the last century, many studies have focused on the effect of magnetic field on water, but the results of these studies were often contradictory. A large number of documents on the effect of the magnetic field on the physical and chemical properties of water were proposed. Most of the arguments are actually related to chemicals in water and not related to the properties of the water itself. Other studies investigated the effect of a magnetic field on the physical and chemical properties of pure water yielded inconsistent results (Cai et *al.*). In this Framework, we studied the influence of the magnetic field on the evaporation of water.

In order to better understand the physico-chemical modifications of the water following a magnetic treatment, an evaporation test was carried out. To do this, we need:

• Two graduated beaker of 80 ml
• An evaporation bath

Fig.3 Evaporation system

Evaporation of the samples, with temperatures between 50 °C and 100 °C for one hour were carried out on magnetized water and raw water to a volume of 80 ml. The difference of the evaporated volume [Magnetized (M) and Not-Magnetized water (NM) in ml]

2.4 Statistical Analysis

The results data were submitted to an analysis of variance at a 5 % significance level. The effects of the variables were studied by regression analysis. All statistical analyses were performed using the Excel specific program (Statistical). The analysis based on the coefficient of determination and the significance of regression coefficients. The significance of coefficients was estimated by t-test and p-values. The higher the level of the t-value and the lower the p-value, the more significant is the coefficient (Khuri *et al.*, 1987).

The sign of each coefficient suggests the direction of the relationship. The elimination of insignificant variables gives more accurate forecasts according to Sonmez and Rowings (Sonmez *et al.*, 1998). The R^2 have been widely used for model evaluation, these statistics are oversensitive to high extreme values and insensitive to additive and proportional differences between model predictions and measured data (Legates *et al.*, 1999).

3. Results and discussion

The objective of this study is to value the influence of the magnetic device on water (surface tension and evaporation).

The monitoring of the variation of the surface tension and evaporation of the water samples of the well, after magnetic treatment.

** Study of Tension surface*

This work shows the surface tension decrease in magnetized water and the evaporation increase during magnetic tracing. This variation depends on the temperature of water and intensity of magnetic device.

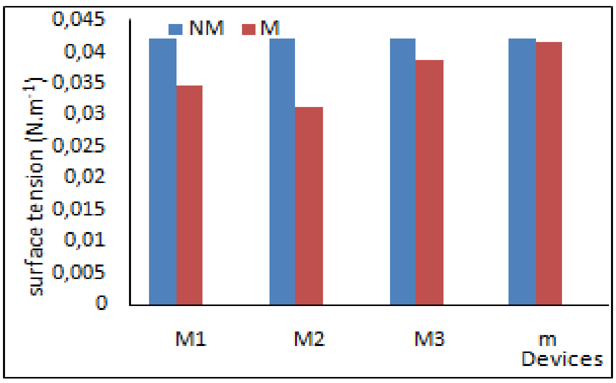

Fig.4 Effect of magnetic treatment of water on Surface Tension (ST)

The magnetic treatment of the water leads to a significant reduction in the surface tension.

In this context, it is noted that M2 shows a greater effect than other magnetic devices. The water treated with M2 illustrates a reduction of 24 % in the surface tension compared to the untreated water.

The electromagnetic (m) verified a very small variation in the surface tension of the water.

This confirms that change a 68.9 % (between M2 and m) in magnetic field intensity results a variation of 23 % in surface tension.

Toledo *et al.* (2013) have verified that a magnetic field increases the surface tension.

** Study of Evaporation*

This section examines the effect of magnetic treatment on evaporation of water. The results of the tests in the figure below shows that for one hour:

- For 50°, 80° and 100°C, all the devices favored evaporation of the water compared to the control.

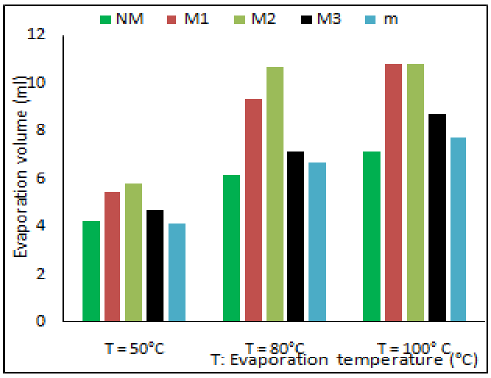

Fig.5 Effect of magnetic water treatment with different temperatures and devices

The magnetic device M2 records the highest evaporated volume. Figure 5 illustrate a difference of the evaporated volumes recorded between the quantity of water magnetized (M) with the apparatus M2 and the water not magnetized (NM) at T = 50°C : ΔV = 6 - 4 = 2 ml. Respectively for a temperature T = 80°C : ΔV = 4.5 ml.

This experiment shows the effect of temperature on the evaporation of magnetized water.

Table1 Effect of the magnetic treatment on evaporation volumes (ml) with two intensities and temperatures

Temperature/ Devise	M1 (3300 G)			M2 (2900G)		
50°C	5.4	5.3	5.4	5.8	5.8	5.8
80°C	9.4	9.4	9.3	10.7	10.6	10.7

For 50°C: M2 records the highest evaporated volume of 6.9 % with respect to M1 and 80°C with an evaporated volume difference of 12.1 %.

The evaporated volume is influenced by the intensity of the magnetic field and the temperature.

** Relation between tension surface and evaporation*

The lowest value of the surface tension was recorded with the M2 apparatus by a 24 % decrease compared to the control. For water evaporation, M2 showed a high evaporated volume at all temperatures

This gives us a relation between the surface tension and the evaporation. Indeed, when the surface tension decreases the evaporated volume increases

The results of this study of the effect of magnetic devices on water are consistent with Farhan L.R. et *al.* (2013) small increasing in evaporation rates were take place for using magnetic field if compared with the absence of magnetic field. Because? the magnetic devise will increase the surface tension and lead to maximize the evaporation rate.

Our results are in line with Yun-Zhu et *al.* (2012), when he showed that under a strong magnetic field, the evaporation rate increases significantly. This parameter depends on the change in the intensity of the hydrogen bonds and on the surface of the liquid/gas interface.

** Statistical analysis*

We observe the high significance of results of Evaporation with a regression R (0.83) (Table 2).

To test the significance of the regression analysis of variance (F-test) is performed according to the standard procedure.

If the calculated F value is greater than the F critical value, there is a real relation between dependent and independent variables. This test follows an F-distribution with degree of freedom (d.o.f) ν=2, so that the critical region will consist of a value exceeding 0.00079148. The calculated F-value (F=13.7277562) is greater than the critical F-value (0.00079148). As the Fisher F-value observed is much greater than the critical value F, which confirms the high significance of the testing of evaporation of magnetized or not-magnetized water (Table 3).

Using table 4, the model of Evaporation (Ev) is written (Eq.2):

$$Ev = -0{,}173 + 0{,}085\,T + 3.748\,10^{-4}\,I \qquad (2)$$

(T : Temperature and I : Intensity of magnetic)
The probability (Tab 4) can help us to state that temperature is the most influential parameter in the process (P = 0.00036<<0.05).

The calculated F-value for Surface Tension (F=1.2) is greater than the critical F-value (0.3) which confirms the significance of the testing of Surface Tension of water with regression R (0.54), (Table 5 and 6). The model of the surface tension (ST) extracted of the table 7 is written (Eq.3):

$$ST = 0.04 - 1.24\,10^{-6}\,I \qquad (3)$$

(ST : Surface Tension and I : Intensity of magnetic)

Table 2 Statistical regression of Evaporation (Ev)

Statistical regression	
Multiple determination coefficient	0.83
Coefficient of determination R^2	0.69
Standard Error	1.39
Observations	15

Table 3 Analysis of variance of Evaporation (Ev)

	Degree of freedom	Sum of squares	Average of squares	F	Critical value of F
Regression	2	53.3585439	26.679272	13.7277562	0.00079148
Residues	12	23.3214561	1.94345467		
Total	14	76.68			

Table 4 Analysis of coefficients and probabilities of Evaporation (Ev)

	Coefficients	Standard Error	Statistical t	Probability
Constant	-0.17278615	1.47119598	-0.11744604	0.90844947
Variable T	0.08573684	0.01751746	4.89436606	0.00036944
Variable I	0.00037485	0.00020034	1.87101396	0.08591821

Table 5 Statistical regression of Surface Tension (ST)

Statistical regression	
Multiple determination coefficient	0.54
Coefficient of determination R^2	0.29
Standard Error	0.0044
Observations	5

Table 6 Analysis of variance of Surface Tension (ST)

	Degree of freedom	Sum of squares	Average of squares	F	Critical value of F
Regression	1	2.4833E-05	2.4833E-05	1.22903397	0.34848076
Residues	3	6.0615E-05	2.0205E-05		
Total	4	8.5448E-05			

Table 7 Analysis of coefficients and probabilities of Surface Tension (ST)

	Coefficients	Standard Error	Statistical t	Probability
Constant	0.04065695	0.00335436	12.1206157	0.0012088
Variable I	-1.2404E-06	1.1189E-06	-1.10861805	0.34848076

Conclusion

The application of a magnetic field has influenced the physical parameters of the raw water by decreasing the surface tension and promoting evaporation. A 24 % decrease in surface tension causes an increase in the evaporated volume of 42 % at a temperature of 80 ° C. According to the statistical analysis, the effect of magnetic treatment on surface tension and evaporation depends mainly on the magnetic field intensity, temperature and physicochemical parameters of the raw water.

Statistical analysis showed a high significance and the results gave a regression R (0.83).

Some mechanisms of the effect of magnetization on the structure of water, soil and assimilation of the plant are still not well known.

Further analyzes could provide answers to the questions concerning the phenomena which favor the efficiency of magnetic treatment and the improvement of the yield of the plant.

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