International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

The Electromagnetic Memory of Water at Kinetic Condition

Redouane Mghaiouini[1,2*], Aniss Elaoud[3] , Toufik Garmim[2], M.E.Belghiti[5] , Eric Valette[6],Charles Henri Faure[6] Mahmoud Hozayn[4], Mohamade Monkade[2] and Abdeslam El Bouari[1]

[1]Department of chemistry, physical chemistry laboratory applied materials, Faculty of Sciences-Ben M'sik, Hassan II University, Casablanca, Morocco
[2]Department of Physic condensed Matter Laboratory, Faculty of Sciences, Chouaib Doukkali University, El-jadida, Morocco
[3]University of Carthage, Laboratory of Environmental Sciences and Technologies, Higher Institute of Sciences and Technology of Environment, Tunisia
[4]Agronomy Dept., Agric. and Biol. Div., National Research Centre, El-Bohoth St., 12622 Dokki, Cairo, Egypt
[5]Laboratory of Nernest Technology, 163 Willington Street, Sherbrook, J1H5C Quebec, Canada
[6]Planet Horizons Technologies Ecoparc de Daval A9 3960 Sierre, Switzerland

Received 10 Nov 2019, Accepted 12 Jan 2020, Available online 16 Jan 2020, **Vol.10, No.1 (Jan/Feb 2020)**

Abstract

This work presents an experimental study to investigate the effect of the electromagnetic on the tap water properties of water. The water flows through a closed loop with a speed of 0.18m/s, while the pH, TDS, and hardness represent its properties. For magnetized water using the aqua 4D device. the conductivity, TDS, salinity, temperature, absorbance at 631 nm and the turbidity of magnetized water increase respectively by 3.66%, 4%, 4.4%, 0.76%, 21.64%, and 62.6% compared to those of tap water, while density, resistivity, transmission and pH decrease by 2%, 4.1%, 1.32%, and 3.32% respectively.

Keywords: *Electromagnetic treatment, magnetic water, aqua 4D, magnetization time, physicochemical parameters, Memory*

1. Introduction

Magnetic water treatment involves simply passing water through a magnetic field using a magnetic treatment device (Aqua 4D) that would have affected the chemical, physical and bacteriological quality of the water.

Currently, hundreds of experiments are being carried out on the magnetic treatment of water with a considerable percentage of success, although the most beneficial applications of magnetic water treatment include the improvement of scale reduction in pipes and improved crop yield with reduced water use (Alimi *et al.*2009).

The first patent on a device for the treatment of water by a magnetic field was deposited in Belgium dates back to (Vermeiren *et al.*1953). After beginning to reduce scale formation in steam boilers, the magnetic water treatment has found several applications in the majority of thermal and industrial processes. Magnetic processing is currently used in the fight against precipitation, in the production of concrete and in the enrichment of useful minerals, as well as for the intensification of the processes of filtration and purification of water, etc. These devices allegedly use magnetic fields to alter the molecular composition of various constituents of water, such as calcium and iron, into other, more "inert" forms. The claimed result is a reduction or elimination of water contaminants (Vermeiren *et al.*1953).

Nevertheless, several scientific papers have been published in which the observed effects of the magnetic field on water were reported In particular those of (Baker *et al.*1996) examined the effect of the magnetic field on the chemical reactions affecting their kinetics and their yield (Zaidi et al .1996). Determine a complete concept and mechanism of magnetic field efficiencies on water. When water is subjected to a magnetic field it becomes more biologically active. (Molouk *et al.*2014) as it turns out to be more energetic and more able to flow. (Tai et al .2008,Smirov *et al.*2003) found that water can receive signals produced by magnetic forces, which have a direct effect on living cells and their vital action Magnetic treatment of water improved its hydration ability, which in turns enhanced the concrete strength (Fu et al .1994) the cement paste, and mortar (Alimi *et al.*2009,Wang *et al.*1997). (Colic et al .1998), on the effect of memory and magnetized water, should be noted. (Fathi *et al.*1998) noted that magnetic field processing increased the amount of precipitated calcium

*Corresponding author's ORCID ID: 0000-0003-3854-8437
DOI: https://doi.org/10.14741/ijcet/v.10.1.3

carbonate and that efficiencies depended on pH of water, speed, and magnetization time. Higashitani *et al.*1993 found that in the sodium carbonate solution treated at the magnetic field (0.3T) for 10 min under rest conditions, (Lungader *et al.*1995) (confirmed that the magnetic field affected both Ca^{2+} and HCO_3. It is generally accepted that) in solutions treated with magnetic fields there is more aragonite than calcite precipitates (Kob *et al.*2001, Chung *et al.*2010, Cefalas *et al.*2010, Chibowski *et al.*2003). The experiences of (Silva *et al.*2015) have shown that divalent cations are sensitive to the magnetic field only monovalent and also to divalent and monovalent anions. (Wang *et al.*2012) argued that the effects observed could be explained by the cluster transformation mechanism. (Guo *et al.*2011) Concluded that cluster transformation took place through molecular dynamics simulations. (Murad *et al.*2006) has shown that clusters of water are also weakened by the magnetic field. (Toledo *et al.*2008) confirm that the magnetic field affects the intercluster and intracluster hydrogen laisons of water. The ions remained oriented (memory effect) at the nanoballs of gas dispersed in the solution (Colic *et al.*1999). (Vialetto *et al.*2017) have published an article on a new floating object magnetic transport medium that could have significant industrial applications. (Koshordize *et al.*2014) studied the decrease in the electrokinetic potential of colloidal particles that passes through a magnetic field. (Nakagawa *et al.*1999, Kitazawa *et al.*2001,Guo *et al.*2012,Wang *et al.*2012,Rashid *et al.*2013,Seyfi *et al.*2017,Amor *et al.*2017) have reported an increase in the rate of water evaporation caused by MF. (Ghauri *et al.*2006) also observed an increase in viscosity (0.001-0.002mPa) after MF cross-processing in the temperature range of 298 to 323K, which was explained by changes in hydrogen bonding. Similarly, (Cai *et al.*2009) observed in water after constant flow (1 m / s) through a magnetic field (max 0.5 T), reduced surface tension and increased viscosity at 298 K. (Cefalas *et al.*2008, cefalas *et al.*2010) examined the effect of MF via its influence on the individual molecular rotors of water. They postulated that even a weak external MF causes a coherent macroscopic antisymmetric state, derived from two-level molecular water rotors. It is also worth mentioning the controversial previous findings of (Ostuka *et al.*2006) who showed the change of wetting contact angle on the platinum plate of water exposed to a magnetic field for 20 min (memory effect).

The purpose of this paper is to experimentally study closed-loop water flow and the effect of Aqua 4D on the physicochemical parameters of tap water such as pH, conductivity, TDS, salinity, temperature, density, transmission, turbidity, and absorbance. The aim is also to demonstrate the effect of time on the properties of magnetized water (memory effect).

2. Materials and methods

Definition of the Aqua 4D device and their characterization Aqua-4D (Fig.1) is a physical water treatment technology, based on the quantum and the electrodynamics' physics.

To follow the effects of the magnetic devices on the water, a laboratory pilot was realized. It consists of magnetic devices, pump, probes linked to a recorder connected to a computer for the instantaneous monitoring of physicochemical parameters of water such as magnetic field. The experimental tests consist a pumped the sample to the other beaker by passing through the magnetic apparatus.

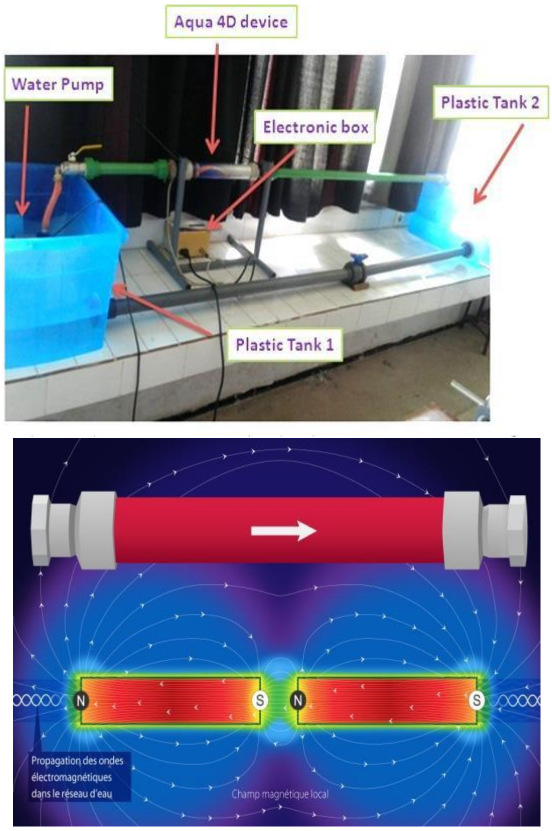

Fig.1: Equipments of aqua-4D and Electromagnetic field generator

The instrumentation system is chosen to measure pH, total dissolved solids (TDS), conductivity, salinity, absorbance, transmission, turbidity, temperature, and density

pH balance

The pH is measured with an Adwa AD1000 pH meter as shown in Fig.2.the technical characteristics of which are as follows:

Fig.2: pH meter measurement of magnetic water

Conductivity, TDS meter and salinity meter

Fig.3: Measuring the Conductivity, salinity and TDS of magnetic water by conductivity

Density

The magnetic water was placed in a 250 ml volumetric flask. Then, its mass was measured using sensitive balance type EXPLORER® PRECISION as shown in Fig.4.

Fig.4: Measuring the mass of magnetic water by sensitive balance

The density of magnetic water can be defined as $\rho = mV$ where, m is mass and v is volume

Thermocouple

The temperature of the magnetized water is measured by a PHYWE digital thermocouple mark as shown in Fig.3, which consists of a pair of different metals, e.g. iron and constantan. If the two contact points have different temperatures, the difference between the contact potentials can be measured as the thermal potential.

Fig.5: Temperature measurement of magnetic water

MULTITESTS for transmission measurement, absorbance and turbidity

MULTITESTS is a multi parameter photometer as shown in Fig.4, manufactured by AQUALABO GROUP for the analysis of more than 40 parameters (Transmission, Absorbance, turbidity, NO3, NH4, PO4, Fe, Ni, COD ...). Compatible with liquid reagents such as water.

Fig.6 Spectrophotometer for measuring transmission, absorbance and turbidity of magnetic water

Chemical Molecule Figure of water with and without electromagnetic field

A substance is said to be magnetized when its constituent molecules or structural elements can be aligned in a definite direction by the influence of an external magnetic field. In a liquid or in a gas, this can only happen molecule that process and odd number of electrons. Water, H_2O, contains 10 electrons, so it is not attracted to or oriented by a magnet Fig. (9).

In fact, water, like most molecules, is diamagnetic; it is actually repelled by a magnet, although so weakly those sensitive instruments are needed to observe this effect. The Fig. 7 shows structural group of water molecules. Fig.(8) shows water molecules which consisted of one oxygen molecule and two hydrogen molecules bonded as an isolated triangle with its upper angle is 105º. Generally, when water is subjected to a magnetic field, the water molecules will arrange in one direction as shown in Fig. (8). This mode of arrangement is caused by relaxation bonds, then the bond angle decreases to less than 105º (Chibowski *et al.*1995), leading to a decrease in the consolidation degree between water molecules, and increase in size of molecules. For these reasons, the viscosity of magnetic water is less than viscosity of normal water. This change in water molecules composite causes a change in permeability pressure, surface tension, pH and electric conduction (Chibowski *et al.*1995).

The figures below show the theoretical arrangements of the hydrogen bonds before and after the treatment with the electromagnetic field.

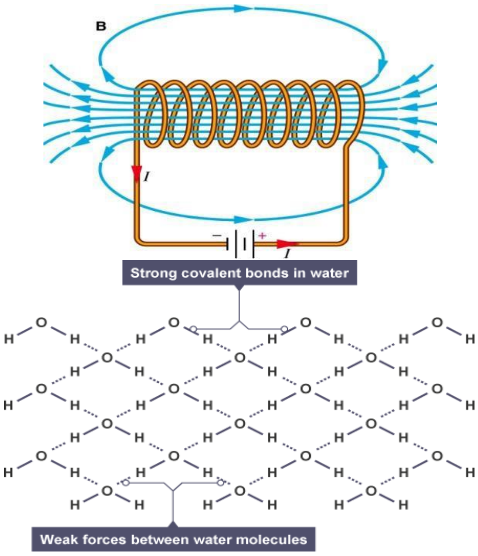

Fig.7: Solenoid magnetic field lines of Aqua-4D and Structural groups of water

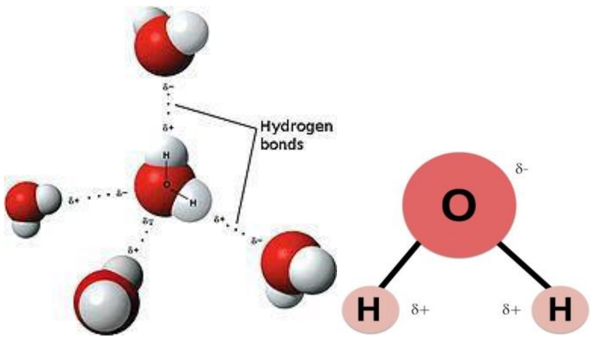

Fig.8: Water molecule and hydrogen bonds

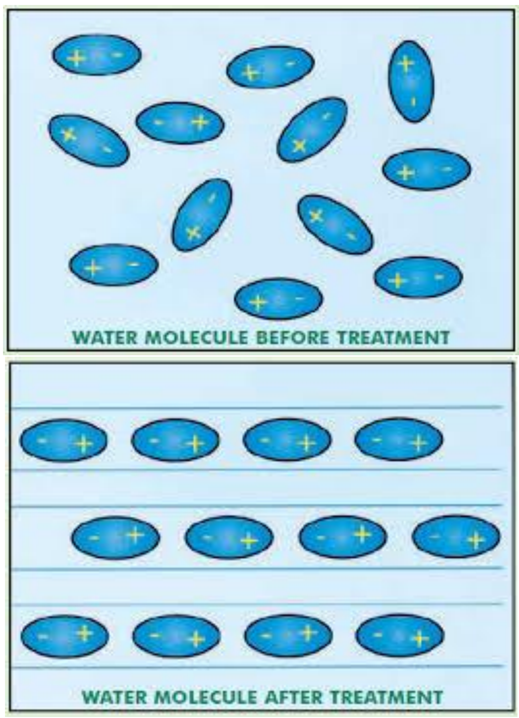

Fig.9: Water Molecules Before and After Magnetic Treatment

3. Results and discussion

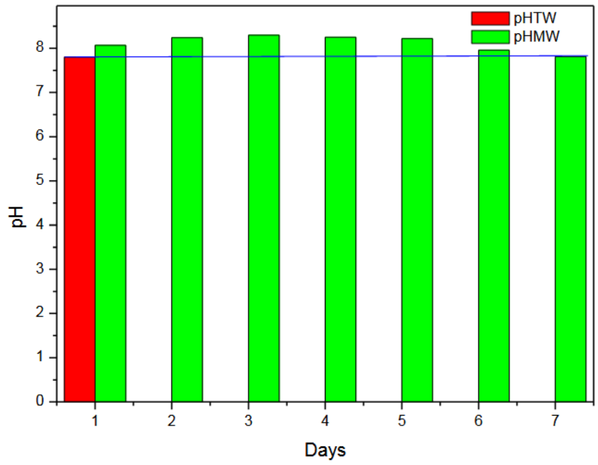

Fig.10: pH of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 10 illustrates the pH values of the magnetized tap water versus time after circulation of water in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the pH value is 7.8. We deduce that; during the 20 minutes of magnetization, the pH of the water was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Figure 10 show a decrease of 3.32% in the value pH in 7 days to return to the initial value of the tap water before magnetization.

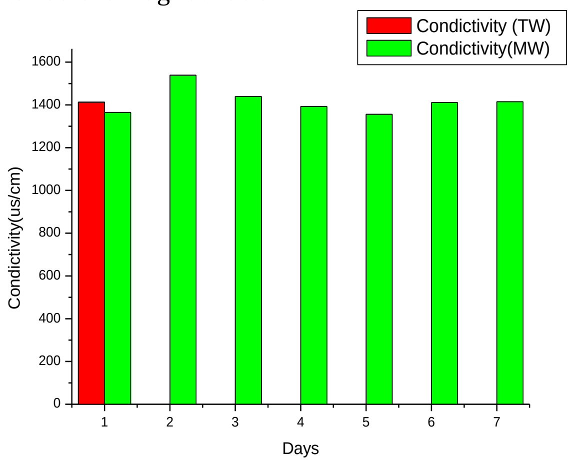

Fig.11: Conductivity of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 11 illustrates the conductivity values of the magnetized tap water versus time after a circulation of water in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation, the conductivity value is 1413 µS / cm. We deduce that; During the 20 minutes of magnetization, the water conductivity was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured daily in Figure 11 show a 3.66% increase in the value of the water conductivity in 7 days to return to the initial value of the tap water before magnetization.

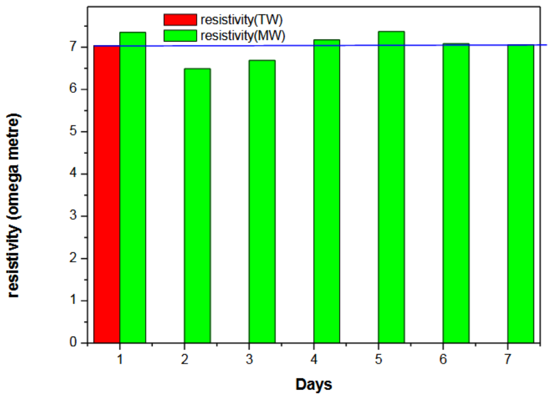

Fig.12: Resistivity of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Fig.12 illustrates the resistivity values of the magnetized tap water over time after water circulation in a closed loop for a period of 20 min at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the resistivity value is 7.04Ώ m. We deduce that; During the 20 minute magnetization, the water resistivity was affected by recirculation through the Aqua 4 D instrument. The averages of the values measured daily in Figure 12 show a 4.1% decrease in the value resistivity in 7 days to return to the initial value of the tap water before magnetization.

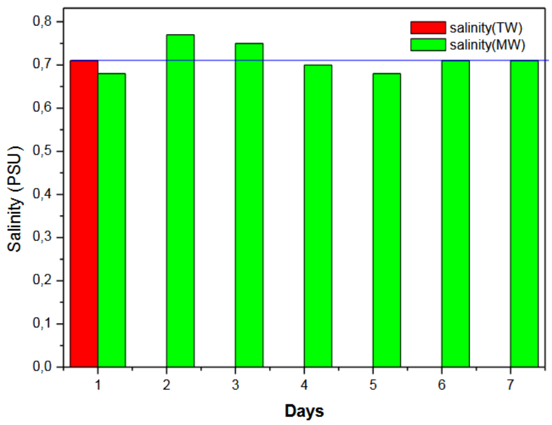

Fig.13: Salinity of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 13 illustrates the values of the salinity of the magnetized tap water with respect to time after water circulation in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the salinity value is 0.71 PSU. We deduce that; during the 20 minutes of magnetization, the salinity of the water was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured each day in Figure 13 show a 4.4% increase in the value of salinity in 7 days to return to the initial value of the tap water before magnetization.

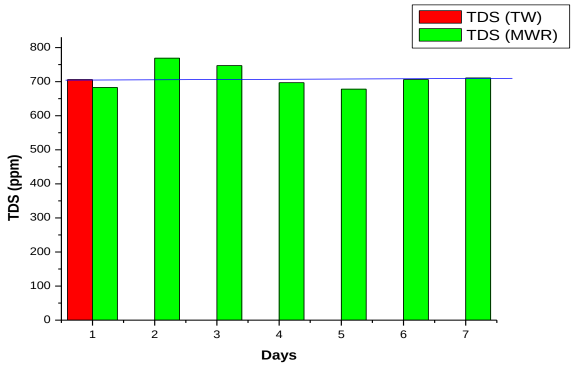

Fig.14: TDS of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Fig.14 illustrates the TDS values of the magnetized tap water versus time after water circulation in a closed loop for a period of 20 min at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the TDS value is 706 ppm. We deduce that; during the 20 minutes of magnetization, TDS of the water was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Figure 14 show a 4% increase in the value of TDS in 7 days to return to the initial value of the tap water before magnetization.

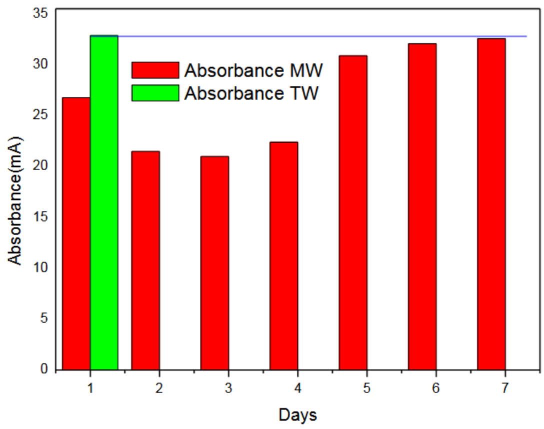

Fig.15: Absorbance of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Fig. 15 illustrates the values of the 631 nm absorbance of the magnetized tap water over time after water circulation in a closed loop for a period of 20 minutes at a rate of 0.18 m / sec across the device. Aqua 4D. Before circulation, the absorbance value at 631 nm is 32.9 mA. We deduce that; During the 20 minutes of magnetization, the absorbance at 631 nm of water was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Figure 15 show an increase of 21.64% of the absorbance value at 631 nm in 7 days to return to the initial value of the tap water before magnetization.

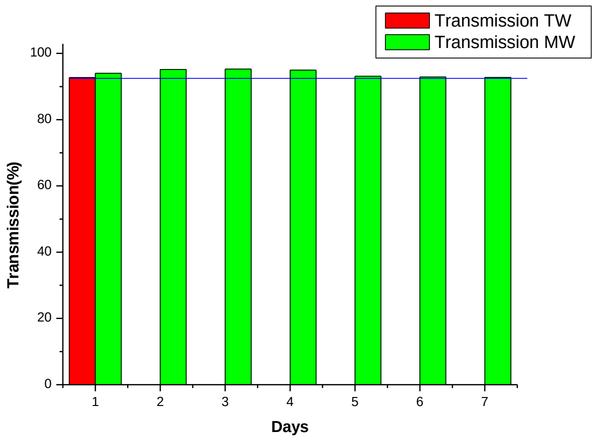

Fig.16: Transmission of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 16 illustrates the transmission values of the magnetized tap water over time after a circulation of water in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before traffic the value of the transmission is 92.72%. We deduce that; During the 20 minutes of magnetization, the water transmission was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Fig.16 show a decrease of 1.32% in the value. Transmission in 7 days to return to the initial value of the tap water before magnetization.

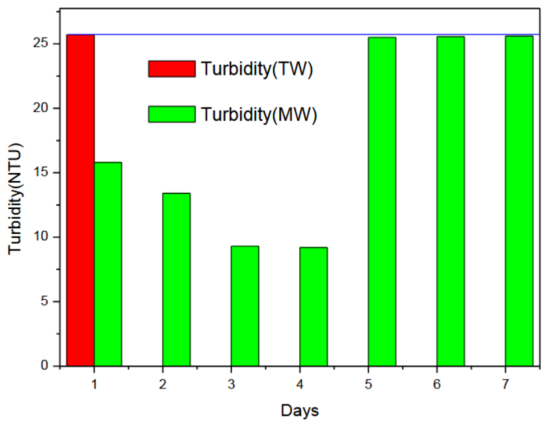

Fig.17: Turbidity of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Fig.17 illustrates the turbidity values of the treated water with respect to time after circulation of water in a closed loop during of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the turbidity value is 25.7 NTU. We deduce that; during the 20 minutes of magnetization, the turbidity of the water was affected by the recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Fig.17 show a 62% increase in the value turbidity in 7 days to return to the initial value of the tap water before magnetization.

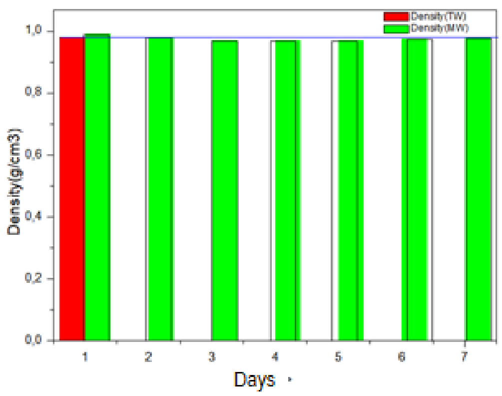

Fig.18: Density of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 18 illustrates the density values of the magnetized tap water versus time after a circulation of water in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the density value is 25.7g / cm3. We deduce that; During the 20 minutes of magnetization, the water density was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Figure 18 show a 2% decrease in the value of the water density in 7 days to return to the initial value of the tap water before magnetization.

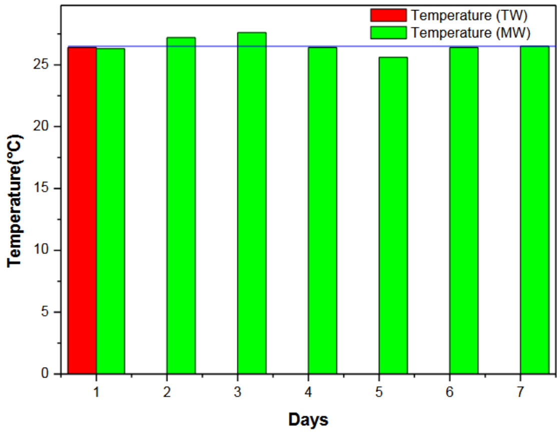

Fig.19: Temperature of magnetized tape water (Memory of Water) at v= 0.18m/s and magnetization time (t_m) = 20 min.

Figure 19 illustrates the temperature values of the magnetized tap water versus time after a circulation of water in a closed loop for a period of 20 minutes at a rate of 0.18 m / s through the Aqua 4D device. Before circulation the temperature value is 26.4 ° C. We deduce that; during the 20 minutes of magnetization, the water temperature was affected by recirculation through the Aqua 4 D apparatus. The averages of the values measured every day in Figure 19 show a 0.76% increase in the value. Temperature in 7 days to return to the initial value of the tap water before magnetization.

The question that arises here is when water retains the values of the physicochemical parameters (pH, salinity, TDS conductivity, absorbance, transmission, turbidity, temperature, density) obtained by the water passing through the electromagnetic field created by Aqua 4D during 20 min after the magnetized water is stored in a static state for seven days. This question illustrates the effect of the electromagnetic field on the memory of magnetized water. This paper answers the last question; 20 liters of water was magnetized for 20 minutes of recirculation in Aqua 4D, the magnetized water is stored and isolated from atmospheric air to eliminate the absorption effect of atmospheric gases by the stored water. The timer restarts and after each day a water sample is taken from the stored water and the values of the physicochemical parameters are measured each time. The total storage period is 7 days; Figures (10, 11, 12, 13, 14, 15, 16, 17, 18 and 19) illustrate the values of (pH, salinity, TDS conductivity, absorbance, transmission, turbidity, temperature, density) of the water stored in function of time. As illustrated in the figures, the water retains and retains the impact of the passage in the magnetic field, it is declared as retaining values of the physicochemical parameters of the magnetized water, and the memory of the water continues to forget the magnetic impact of these values over a period of 7 days.

This phenomenon defines the term (Water Memory) and can be defined as follows: the time at which the magnetized water remembers the impact of the magnetic field.

It can be seen that magnetized tap water samples slightly increase the rate of magnetism. And of memory effect. The magnetic field is maintained for 7 days, which indicates a memory effect. It can be found in the literature that the memory of a magnetic treatment can last up to 200 hours (Cefalas *et al.*2010). This effect can also be explained by quantum field theory (Cefalas *et al.*2010). According to Cefalas *et al.* (Cefalas *et al.*2010) the amplified magnetic mode is not disintegrated from the forbidden nature of the transition between the antisymmetric and symmetrical states and "remains trapped in the authentic volume of all the molecular rotors of water", which explains the memory effect of water.

The magnetic field can be understood from a macroscopic antisymmetric coherent state induced by an external magnetic field on a set of two-level rotors (state of coherence of the water). Individual molecular rotors are forced to rotate coherently by the external MF. The amplified magnetic mode does not disintegrate in the corresponding coherent symmetrical ground state, but it still remains in the coherent volume of the set of molecular rotors. The existence of water is antisymmetric. The coherent state explains the effects of the memory on the water (Cefalas *et al.*2010) by the memory of the water.

Conclusions

The tap water is magnetized for 20 min in a closed loop at a speed of 0.18m / s through the Aqua 4D device, after seven days it is concluded that:

1) The pH decreases by 3.32% over the seven days after magnetization.
2) The TDS increases by 4% over the seven days after magnetization.
3) Salinity increases by 4.4% over seven days after magnetization.
4) The temperature increases by 0.76% over the seven days after magnetization.
5) The density decreases by 2% over seven seven days after magnetization.
6) Conductivity increases by 3.66% over seven days after magnetization.
7) The absorbance at 631 nm increases by 21.64% over the seven days after magnetization.
8) Transmission decreases by 1.32% over seven days after magnetization.
9) Turbidity increases 62% over seven days after magnetization.
10) The resistivity decreases by 4.1% over the seven days after magnetization.
11) The water retains and retains the impact of crossing the magnetic field for seven days.
12) Water has a memory with physicochemical parameters measured for seven days as water memory indicator.

References

Alimi, F.,Tlili, M., Ben Amor, M.,Maurin, G., Gabrielli, C.(2009) Influence of magnetic field on calcium carbonate precipitation in the presence of foreign ions. Surf.Eng. Appl. Elect. 45, 56-62. DOI: 10.3103/S1068375509010104.

Vermeiren, T. (1953) Magnetic treatment device for liquids. US Patent 2652925.

Baker, J.S., Judd, S.J.(1996) Magnetic amelioration of scale formation. Water Res. 30, 247-
260. http://dx.doi.org/10.1016/0043-1354(95)00184-0

Zaidi, N.S., Sohaili, J., Muda, K., Sillanpää, M. (2014) Magnetic field application and its Potential in water and wastewater treatment systems. Sep. Purif. Rev. 43, 206-
240.https://doi.org/10.1080/15422119.2013.794148.

Molouk, M. K. A. & Amna, A. N. S. (2010) the effect of magnetic field on the physical chemical and microbiological properties of the lake water in Saudi Arabia. *Journal of Evolutionary Biology Research,* 2(1), pp. 7-14.

Tai, C., Chang, M., Shieh, R. & Chen, T.(2008) Magnetic effects on crystal growth rate of calcite in a constant-composition environment. *Journal of Crystal Growth,* Volume 310, pp. 3690-3697. DOI: 10.1016/j.jcrysgro.2008.05.024

Smirov, J. V.(2003) The effect of a specially modified electromagnetic field on the molecular structure of liquid water. In: *Biomagnetic Hydrology.* U.S.A: Global Quantec Inc., pp. 122-125.

Fu, W. & Wang, Z. (1994) The new technology of concrete engineering, Beijing: The publishing House of Chinese Architectural Industry.

Wang, Y., Babchin, A.J., Chernyi, L.T., Chow, R.S., Sawatzky, R.P.(1997) Rapid onset of Calcium carbonate crystallization under the influence of a magnetic field. Water Res. 31, 346–
350. https://doi.org/10.1016/S0043-1354(96)00243-6.

Colic, M., Morse, D.(1998) Effects of amplitude of the radiofrequency electromagnetic Radiation on aqueous suspensions and solutions. J. Colloid InterfaceSci. 200, 265–272. https://doi.org/10.1006/jcis.1997.5367.

Fathi, A.,Tlili, M.,Gabrieli, C., Maurin G., Ben Amor, M.(2006) Effect of magnetic water treatment on homogeneous and heterogeneous precipitation of calcium carbonate. Water Res. 40(10), 1941-1950. https://doi.org/10.1016/j.watres.2006.03.013.

Higashitani, K., Kage, A., Katamura, S., Imai, K., Hatade, S. (1993) Effects of magnetic field on formation of CaCO3 particles. J. Colloid Interface Sci. 156, 90–95. https://doi.org/10.1006/jcis.1993.1085.

Lungader Madsen, H.E.(1995) Influence of magnetic field on the precipitation of some Inorganic salts. J. Cryst. Growth, 152, 94–100. DOI: 10.3103/S1068375509010104.

Kobe,S., Drazic G., McGuiness, P. J., Strazisar, J.(2001) Control over nanocrystalization in turbulent flow in the presence of magnetic fields. J. Magn. Magn. Mater. 236, 71-76. DOI: 10.1016/S1463-0184(02)00035

Chibowski, E., Holysz, L., Szcześ, A. (2003) Time dependent changes in zeta potential of
Freshly precipitated calcium carbonate. Colloid. Surf. A, 222, 41-54.DOI: 10.1016/S0927-7757(03)00232-2

Chung, M.C., Tai, C.Y. (2010) Effect of the magnetic field on growth rate of aragonite and precipitation of CaCO3. Chem. Eng. J. 164, 1-9. DOI10.1016/j.cej.2010.07.018.

Cefalas, A.C., Sarantopoulou, E., Kollia, Z., Riziotis, C., Dražic, G., Kobe, S., Stražišar,J., Meden, A.(2010) Magnetic field trapping in coherent antisymmetric states of liquid water Molecular rotors. J. Comput. Theor.Nanosci. 7, 1800-1805. DOI: 10.1166/jctn.2010.1544.

Silva, B.,QueirozNeto, J.C., Petria, D.F.S.(2015) The effect of magnetic field on ion
hydration and sulfate scaleformation. Colloid. Surf. A., 465, 175–183. DOI10.1016/j.colsurfa.2014.10.054.

Wang, S.S.S., Chang, M.-C., Chang, H.-C., Chang, M.-H., Tai, C.Y.(2012) Growth behavior of aragonite under the influence of magnetic field, temperature, and impurity. Ind. Eng. Chem. Res. 51, 1041–1049. DOI: 10.1021/ie2016015.

Guo, B., Han H.-b., Chai F.(2011) Influence of magnetic field on microstructural and dynamic properties of sodium, magnesium and calcium ions. Trans. Nonferrous Met. Soc.China, 21, 494-498 https://doi.org/10.1016/S1003-6326(11)61631-2.

Murad, S. (2006) the role of magnetic fields on the membrane-based separation of aqueous electrolyte solutions. Chem. Phys. Lett., 417, 465-70. DOI: 10.1016/j.cplett.2005.10.069.

Toledo, E.J.L., Ramalho, T.C., Magriotis, Z.M. (2008) Influence of magnetic field on Physical-chemical properties of liquid water. Insights from experimental and theoretical Models. J. Mol. Struct. 888, 409-415. DOI: 1016/j.molstruc.2008.01.010.

Colic, M., Morse, D.(1999) The elusive mechanism of the magnetic 'memory' of water. Colloid. Surface. A. 154, 167–174. DOI:10.1016/S0927-7757(98)00894-2.

Vialetto, J., Hayakawa, M., Kavokine, N., Takinoue, M., Varanakkottu, S.N., Rudiuk, S., Anyfantakis, M., Morel, M., Baigl, D.(2017) Magnetic actuation of discrete liquid entities with a deformable paramagnetic liquid substrate. Angew. Chem. Int. Ed.52, 16565-16570. DOI: 10.1002/ange.201710668.

Koshoridze, S.I., Levin, Y.K. (2014) the influence of a magnetic field on the coagulation of nanosized colloid particles. Tech. Phys. Lett., 40, 716 -719. DOI: 10.1134/S1063785014080227. Nakagawa, J., Hirota, N., Kitazawa, K., Shoda, M.(1999) Magnetic field enhancement of Water vaporization. J. Appl. Phys. 86, 2923–2925. https://doi.org/10.1063/1.371144.

Kitazawa, K.,Ikezoe, Y.,Uetake, H.,Hirota, N.(2001) Magnetic field effects on water air and powders. Physica B, 294-295, 709-714. https://doi.org/10.1016/ S0921-4526(00) 00749-3.

Guo,Y-Z., Yin,D-C., Cao, H-L., Shi, J-Y., Zhang, C-Y., Liu, Y-M., Huang, H-H.,
Liu,Y.(2012) Evaporation rate of water as a function of a magnetic field and field gradient. Int J Mol Sci. 2012 Dec. 11; 13(12):16916-28. Doi: 10.3390/ijms131216916.

Wang, Y.,Guo, W-H., Qian,A-R., Shang, P.(2012) Evaporation rate of water as a function of a magnetic field and field gradient. Int. J. Mol. Sci. 13, 16916-16928. DOI: 10.3390/ijms131216916.

Rashid, F.L., Hassan, N.M., Jafar, A.M., Hashim, A. (2013) Increasing water evaporation rate by magnetic field. Int. Sci. Invest. J. 2, 61-68. https://doi.org/10.1016/j.cep.2017.06.009.

Seyfi, A., Afzalzadeha, R., Hajnorouzi, A.(2017) Increase in water evaporation rate with Increase in static magnetic field perpendicular to water-air interface, Chem. Eng. Process. 120, 195–200. https://doi.org/10.1016/ j.cep.2017.06.009.

Amor, H. B., Elaoud, A., Salah, N. B., Elmoueddeb, K.(2017) Effect of Magnetic Treatment on Surface Tension and Water Evaporation. International Journal of Advance Industrial Engineering. 5, 119-124. DOI: http://Dx.Doi.Org/10.14741/Ijae/5.3.4.

Ghauri, S.A., Ansari, M.S.(2006) Increase in water viscosity under the influence of magnetic field. J. Appl. Phys. 100, 066101-2. DOI: 10.1063/1.2347702.

Cai, R., Yang, H., He, J., Zhu, W.(2009) The effects of magnetic fields on water molecular hydrogen bonds, J. Mol. Struct. 938, 15-19. https://doi.org/10.1016/ j.molstruc. 2009.08.037.

Cefalas, A.C., Kobe, S., Dražic, G., Sarantopoulou, E., Kollia, Z., Stražišar, J., Meden, A.(2008) Nanocrystallization of CaCO3 at solid/liquid interfaces in magnetic field: a quantum approach. Appl. Surf. Sci. 254, 6715-6724. https://doi.org/10.1016/j.apsusc.2008.04.056.

Cefalas, A.C., Sarantopoulou, E., Kollia, Z., Riziotis, C., Dražic, G., Kobe, S., Stražišar, J., Meden, A.(2010) Magnetic field trapping in coherent antisymmetric states of liquid water
molecular rotors. J. Comput. Theor. Nanosci. 7, 1800-1805. DOI: 10.1166/jctn.2010.1544.

Otsuka, I.,Ozeki, S. (2006) Does magnetic treatment of water changes its properties. J. Phys. Chem., B, 110, 1509-1512. https://doi.org/10.1021/jp056198.

Chibowski, E., Hołysz, L. (1995) Changes in zeta potential of TiO2 and CaCO3 suspensions treated with radiofrequency electric field as measured with Zeta Plus instrument.Colloid. Surf. A 105, 211e220. https://doi.org/10.1016/0927-7757(95)03321-1.