Egypt.J.Chem. **Vol. 62**, No. 8. pp. 1467- 1481 (2019)

Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Effect of Magnetic Treatment of Potable Water in Looped and Dead End Water Networks

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POTABLE water was exposed to permanent magnetic field (PMF) with a magnetic flux density (B=1.45 T ± 0.05) to investigate its effect on some water parameters for different time intervals at open and dead end flow conditions at flow rate of 41.93 L/min and 52.16 L/min, respectively. Such as these parameters are; electrical conductivity (EC), total dissolved solids (TDS), pH and temperature. In the existence of this permanent magnetic field, so these pervious parameters were also studied as a function of water flow rate in case of the open loop system. The results showed that the PMF fluctuates the tested parameters of the outflow of this potable water at the previous flow conditions. The potable water is used in this study as a preliminary work before application on the salt water. These effects are owing to the hydrogen bond network. Theoretical approach of calculating inter-molecular interaction energy of H-bonded systems of water clusters under the effect of magnetic field is performed using DFT (Density Functional Theory) level with B3LYP function on Gaussian 09 Program.

Keywords: TDS, EC, Flow rate, Permanent magnetic field, Potable water.

Introduction

The magnetic field has a significant effect on the physical and chemical properties of water as well as potable or saline solutions. During the last years many researchers have been studied the effect of temporary and permanent magnetic field on the water properties [1-4]. The magnetic power has been one of the mysteries of life, where this power has an effective role in positioning the atoms and molecules not only in case of solid substance, but also in case of liquid phase [5-7]. The magnetic field is not only changing the physical and chemical properties of water but also has a very significant effect on the scale formation in aqueous saline solutions and as well as diminish the salt crystallization [8-11]. Many studies have been reported that the availability and applicability of the magnetic water treatment in different fields and this task has conventional devotion from the scientific community [12-15]. The previous studies reported that when water is exposed to a magnetic field, its molecules will arrange in one direction, in which this is the main purpose of changing the physical and chemical properties of water [16-18]. These studies proved that the magnetic field does not affect the constitution of water molecules but causes fluctuations only on the distribution and polarizability of oxygen and hydrogen atoms. It is found that the variation effects were correlated with the intensity of magnetic field and magnetization time. Although, the effect of all these factors has been reported

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Received 15/1/2019; Accepted 20/2/2019
DOI: 10.21608/EJCHEM.2019.7268.1595

but no correlation between them was established. There are a lot of circumstances difficult to dominate on them during doing water treatment by magnetic field, such as magnetic impurities. Thus, the practical experiments have been qualitative, it is very important to perform the theoretical calculations to overcome these problems. The computational developments make the theoretical calculations more precise. It is recognized that the water molecules are consisted of clusters or collections and the more stable cluster numbers are called magic numbers. These series of magic numbers offer fundamental information about the electronic and ionic structures of the cluster and consequently the water characteristics. It is possibly make partial or minor changes to the magic numbers, typically so as to improve them, we can get a lot of new uses available of water as another possibility. It is reported that, when larger water cluster smash creating smaller clusters [19]. The more stable water molecules are established to get new stable arrangements under the influence of an external magnetic field [20]. It is already proven that the magnetic field improved the clustering or collecting structure of the chain of hydrogen-bond and as well as the polarizability properties of water [21,22]. The relation between theoretical calculation and experimental measurement of some water parameters is discussed and it is found that the hydrogen bond networks are affected by the magnetic field [23]. In this paper, the study focused on the change in some water properties when subjected to permanent magnetic field. The electrical conductivity (EC), the total dissolved salts (TDS), pH and temperature were studied. It is well known that the TDS is directly proportional to the electrical conductivity (EC), and the following Eq. 1 is used for calculating the TDS as a function of EC:

$$TDS = K * EC \quad \text{Eq. (1)}$$

where, K is a constant that is equal to 0.67

Experimental

Materials

The experimental setup is constructed in the National Research Center, in which potable water (or tap water) was used for this objective. Both pump and valve (gate valve) causes the turbidity of flowing water to be increased. The specification of the used pump is mentioned in Fig. 1, knowing that the permanent water treatment (PWT) device is shown in Fig. 2. Table 1 represents the specification of PWT device, supplied kindly by mechanical design and production department, faculty of engineering, Cairo University as seen in Fig. 2.

Fig. 1. Specification of the used water pump [1 inch 0.75 hp suction pump]. Knowing that 52.16 L/min is the actual measured pump's flow rate when the height equals zero.

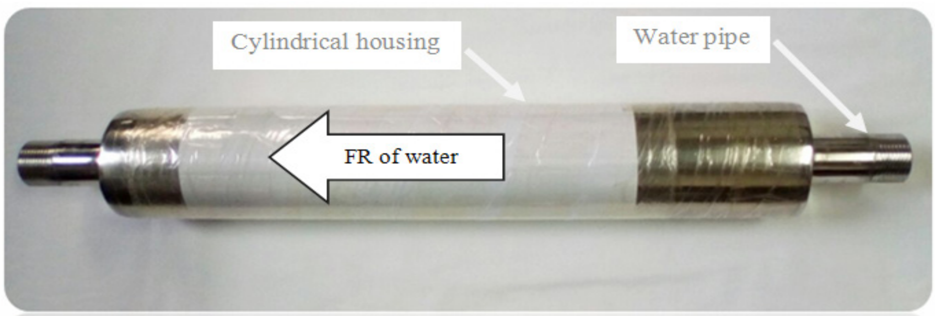


Fig. 2. The used magnet device for open and recirculating system.

TABLE 1. Specifications of potable water treatment device.

Device	Housing dimension D x L, (mm)	Pipe dimension D x L, (mm)	F. R, (m^3/h)	B, (T)	$T_{max,}$ (°C)	W, (kg)
1_{inch} thread	78.3 x 455	25 x 598.5	12	1.45-1.5	80	5

D = diameter, L = length, F. R = flow rate,B = magnetic flux density, T = tesla.

Magnetic exposure

The length of the used hose, being in contact with the used pump, is about 150 cm with diameter of about 2.5 cm. The PWT device was attached to another piece of plastic hose with the same pervious dimensions (diameter 2.5 cm, length 150 cm). In a series of experiments, PWT device was used. All water samples were tested in which the electrical conductivity (EC), total dissolved solids (TDS), pH and temperature were studied as a function of time in both of open and dead end loop. In addition, these water parameter were also studied as a function of water flow rate in case of an open loop. The schematic diagram for the experimental setup is shown in Fig. 3. Water treatment system experiments were repeated 3 times at the room temperature (23 ± 1 °C) in two cases: (a) Open loop (one through system), in which the inflow path is starting at the tap water and then passes to a small tank through a plastic hose. A pump is used to push the inflow from this tank to PWT device, as mentioned in Fig. 4a. Figure 4b represents the dead end loop (recirculating system), in which the inflow path is starting at the reservoir and ending at it, as shown in Fig. 4b.

Measurements

The samples of the examined water were placed in a glass beaker together with the electrode of the apparatus (Adwa instruments AD8000), in which it is used to determine the values of the previous water parameters for the inflow before entering the PWT device and for the outflow after coming out from it. Each experiment was repeated three times and the average was taken. For this purpose, the PWT device is used to generate a permanent magnetic field with a magnetic flux density (B = 1.45 T ± 0.05). The measurable parameters for in flow tap water can be mentioned below in Table 2.

Computational methodology

Hydrogen bond values of water molecule clusters were estimated using Density Functional Theory (DFT) level with (B3LYP) that can be considered as particularly accurate calculation of molecular magnetic properties [24-27]. Few works have investigated hydrogen-bonded clusters using DFT [28]. The influence of the external apparent magnetic field on the ground state PES (potential energy surface) was studied using single-point energy calculations for some water cluster structures as shown in Table 6, which have been designed using Avogadro open Bapel version 2.3.90. The methodology of using magnetic field has also been applied by other research groups [29,30]. The intensities of apparent magnetic field on different water clusters are in the range from 0 to 85 T. The energy of molecular interaction was calculated using the following Eq. 2:

$$\Delta E_{HB} = E_{(H2O)n} - n\, E_{(H2O)} \qquad \text{Eq. (2)}$$

where ΔE_{HB} is the intra cluster binding energy for the water molecule, $E(H_2O)_n$ is the energy of water cluster, n is the number of water molecules and $E(H_2O)$ is the energy for the water molecule.

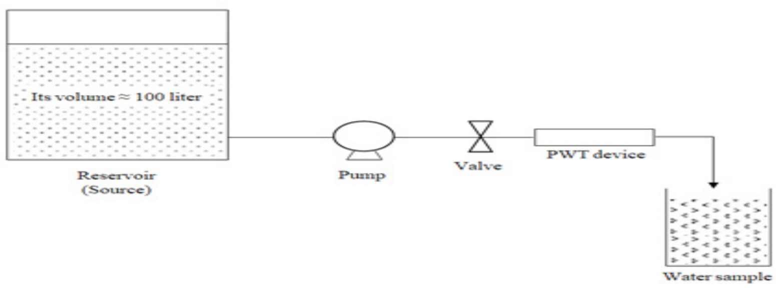


Fig. 3. The schematic diagram of permanent magnetic field PMT system.

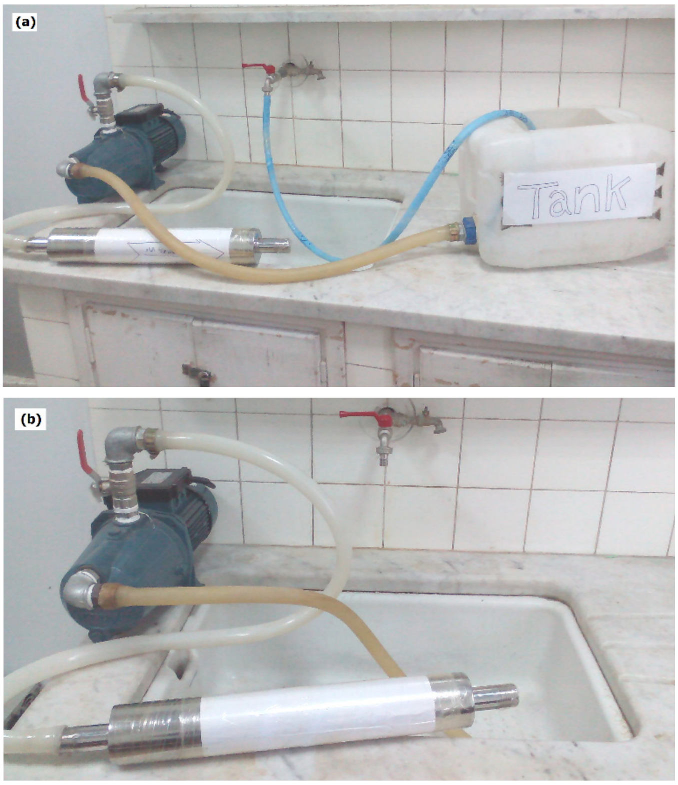


Fig. 4. Water treatment system; (a) Open loop (b) closed loop.

TABLE 2. The measurable parameters for in flow tap water.

T, °C	pH	EC, µS/cm	TDS, ppm
29.25	6.62	357	239.19

Results and Discussion

Water parameters in one through system (Open-loop)

Effect of contact time

At flow rate of 41.93 L/min, the potable water is passed through the PWT device at gradual periods of time. After each interval, water sample was taken and the water parameters were measured instantly. The measured parameters are electrical conductivity, total dissolved salts, pH and temperature. One of these parameters is electrical conductivity (EC) that is measured vs time, as shown in Fig. 5a. For extra visualization, the obtained data were subjected to theoretical approach by using Matlab R2013a to determine the suitable polynomial equation for this treatment condition and the obtained data are summarized in Fig. 5b. It was found that the relation between electrical conductivity vs time is represented in a polynomial function. By plotting this relation, it is found that the polynomial function is 3rd degree with 4 coeifficients (see Eq.3).

$$f(x) = p_1.x^3+p_2.x^2+p_3.x+p_4 \qquad \text{Eq. (3)}$$

where; p_1 = -6.147 x 10^{-18}, p_2 = 0.01, p_3 = -0.95, p_4 = 385. Knowing that; Goodness of fit (SSE) = -6.785 x 10^{-26}, in which it refers to the sum of the squared errors of predication (deviations predicated from actual empirical values of data). In other words, SSE is a degree of the inconsistency between the experimental and theoritical data, which estimated from the model. The small SSE designates a close-fitting of the mathematical model to the obtained data. Using the first derivate test is a procedure to get the critical points that cause an increase and a decrease of a function at them. Solve $f(x) = 0$; so there is a critical point, 47.5. Thus, since it is decreasing to the left and increasing to the right of 47.5, it must be that 47.5 is a local minimum. The relation between total dissolved solids vs. time is shown in the following Fig. 6a, in which this relation is expressed below in Eq. 4, and the form of polynomial function of 3rd degree with 4 coefficients is shown in Fig. 6b.

$$f(x) = p_1 x^3 + p_2 x^2 + p_3 x + p_4 \quad \text{Eq. (4)}$$

where; p_1 = -8.764 x 10^{-19}, p_2 = 0.0067, p_3 = -0.6365, p_4 = 257.9. Knowing that; Goodness of fit (SSE) = 1.454 x 10^{-26}.

There is a critical point, 47.5. Thus, since it is decreasing to the left and increasing to the right of 47.5, it must be that 47.5 is a local minimum. Figure 7a shows the relation between pH vs. time, in which this relation is expressed below in Eq. 5, and the form of polynomial function of 3rd degree with 4 coefficients is shown in Fig. 7b.

$$f(x) = p_1 x^3 + p_2 x^2 + p_3 x + p_4 \quad \text{Eq. (5)}$$

where, p_1 = -3.542 x 10^{-06}, p_2 = 0.0005, p_3 = -0.02158, p_4 = 6.29. Knowing that; Goodness of fit (SSE) = 5.522 x 10^{-30}.

There are two critical points, 33.52 and 60.59. Thus, since it is decreasing to the left and increasing to the right of 33.52, it must be that 33.52 is a local minimum. Also, the function is increasing to the left and decreasing to the right of 60.59, it must be that 60.59 is a local maximum. Figure 8a displays the relation between temperatures vs. time, in which this relation is expressed below in Eq. 6, and the form of polynomial function of 3rd degree with 4 coefficients is shown in Fig. 8b.

$$f(x) = p_1 x^3 + p_2 x^2 + p_3 x + p_4 \quad \text{Eq. (6)}$$

where, p_1 = 1.042 x 10^{-05}, p_2 = -0.001625, p_3 = 0.06083, p_4 = 28.7. Knowing that; Goodness of fit (SSE) = 2.777 x 10^{-28}.

There are two critical points, 24.48 and 79.49. Thus, since it is increasing to the left and decreasing to the right of 24.48, it must be that 24.48 is a local maximum. Also, the function is decreasing to the left and increasing to the right of 79.49, it must be that 79.49 is a

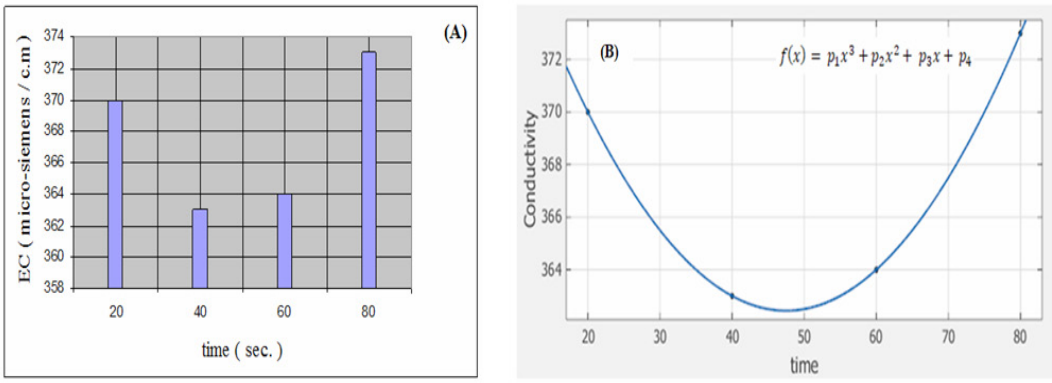


Fig. 5. Electrical Conductivity vs. time, by using tap water in case of opened cycle at flow rate 41.93 l/min.

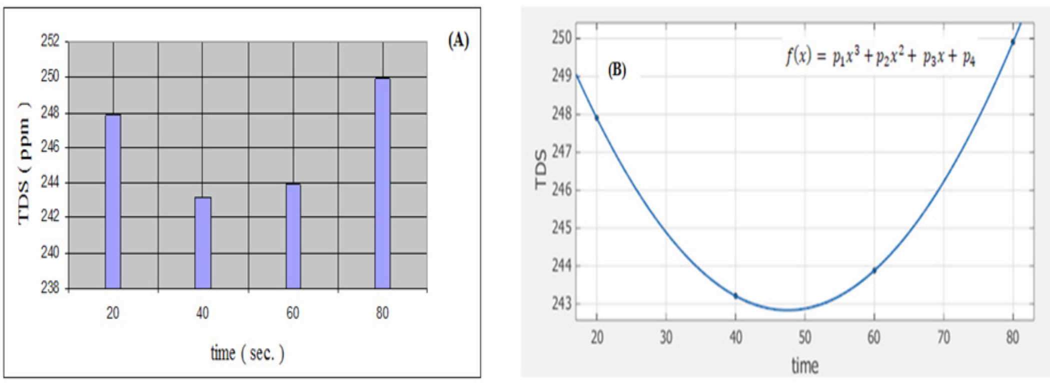


Fig. 6. Total dissolved solids vs. time, by using tap water in case of opened cycle at flow rate 41.93 l/min.

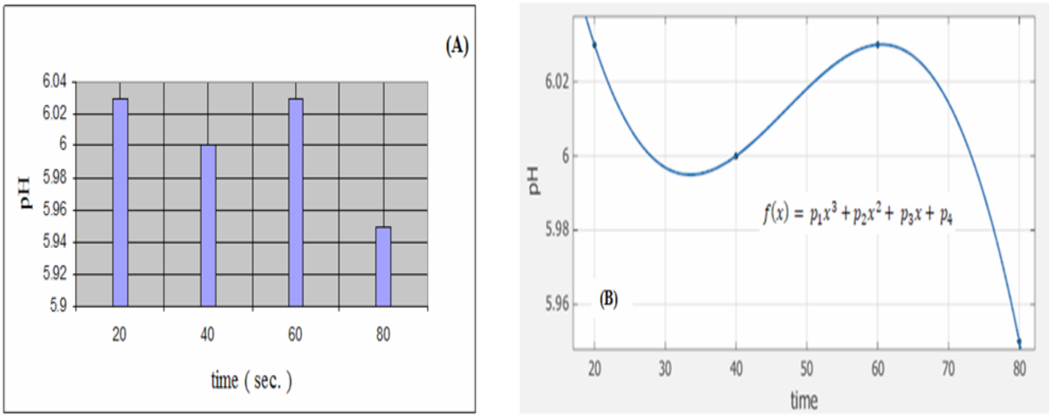


Fig. 7. pH vs. time by using tap water in case of opened cycle at flow rate 41.93 l/min.

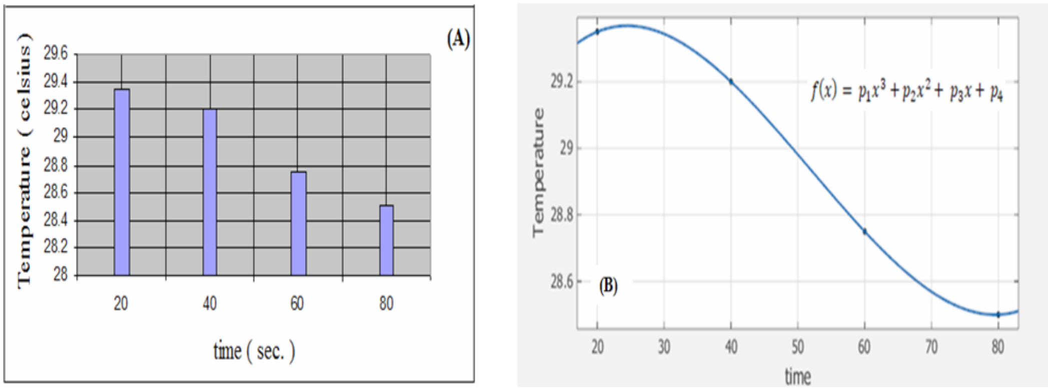


Fig. 8. Temperature vs. time, by using tap water in case of opened cycle at flow rate 41.93 l/min.

local minimum.

Statistical analysis in case of studying the effect of contact time

Before passing the tap water inflow through the (PWT) device, it is analyzed and after outflow from this device is re-analyzed. Knowing that, the measurable parameters of inflow water at the room temperature is kept nearly unchanged, as shown above in Table 2. The sample size (n) that was taken for study is four water samples from the outflow for 20, 40, 60 and 80 sec. respectively, at flow rate of 41.93 L/min. Mean, variance and standard deviation are considered as three descriptive statistics that are calculated for this sample. Sample Mean is the average of the values for each one of the water parameters, where; $\{y_1\, y_2\, , \ldots\ldots , y_n\}$ are the experimental measured values for the items of the sample, $\bar{y}$ is the sample mean value of these interpretations and n is the number of observations in the sample (sample size), see Eq. 7. In addition, sample variance (S^2) is the average of the formed differences from this sample mean, see Eq. 8.

$$\bar{y} = \frac{\sum_{i=1}^{n}(\bar{y}_i)}{n} \qquad \text{Eq. (7)}$$

$$S^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1} \qquad \text{Eq. (8)}$$

Beside this, sample standard deviation (S) is the square root of this sample variance, in which it is a measure of how spreads out the values are. A low sample standard deviation indicates that, the obtained experimental values tend to be nearby to the sample mean. While, a high sample standard deviation specifies that, the gained results are spread out over a broader range of the values (See Eq. 9).

$$S = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}} \qquad \text{Eq. (9)}$$

All these samples were analyzed by the statistical analysis (as shown in Table 3) that was calculated to determine the mean, variance and standard deviation. By comparing the obtained practical data from Table 3 with Table 2, it was noticed that, there is a decrease about 0.3 in the mean value of the temperature of the outflow if it is compared to the value of the temperature of the inflow. In addition, there is a decrease about 0.6175 in the value of mean of the pH of the outflow if it is compared to the value of the pH of the inflow. Also, there is an increase about 10.5 in the value of mean of the EC of the outflow if it is compared to the value of the EC of the inflow. Finally, there is an increase about 7.035 in the value of mean of the TDS of the outflow if it is compared to the value of the TDS of the inflow.

Effect of flow rate

Another Exploratory investigation for the effect of static magnetic field on the same previous water parameters is also performed. Water was exposed for different instant times to this static magnetic field generated from a permanent water treatment (PWT) device, in which such as electrical conductivity (one of these previous parameters) is measured as a function of water flow rate, as shown in Fig. 9a. The data displays the relation between electrical conductivity vs. flow rate, in which this relation is expressed below in Eq. 10, and the form of polynomial function of 5th degree with 6 coefficients is shown in Fig. 9b.

$$f(x) = p_1 x^5 + p_2 x^4 + p_3 x^3 + p_4 x^2 + p_5 x + p_6 \quad \text{Eq. (10)}$$

where; $p_1 = -1.65 \times 10^{-05}$, $p_2 = 0.002522$, $p_3 = -0.1406$, $p_4 = 3.391$, $p_5 = -31.11$, $p_6 = 412.4$, Knowing that; Goodness of fit (SSE) = 1.024×10^{-22}.

There are four critical points; 7.49, 25.40, 40.83 and 48.57. Thus, since it is decreasing to the left and increasing to the right of 7.49, it must be that 7.49 is a local minimum. Also, the function is increasing to the left and decreasing to the right of 25.40, it must be that 25.40 is a local maximum. In addition, the function is decreasing to the left and increasing to the right of 40.83, it must be that 40.83 is a local minimum. Beside this, the function is increasing to the left and decreasing to the right of 48.57, it must be that 48.57 is a local maximum. Figure 10a shows the relation between total dissolved solids vs. flow rate, in which this relation is expressed below in Eq. 11, and the form of polynomial function of 5th degree with 6 coefficients is shown in Fig. 10b.

$$f(x) = p_1 x^5 + p_2 x^4 + p_3 x^3 + p_4 x^2 + p_5 x + p_6 \quad \text{Eq. (11)}$$

Where; $p_1 = -1.105 \times 10^{-05}$, $p_2 = 0.00169$, $p_3 = -0.09416$, $p_4 = 2.272$, $p_5 = -20.84$, $p_6 = 276.3$, Knowing that; Goodness of fit (SSE) = 7.643×10^{-23}.

TABLE 3. Statistical analysis for the outflow in case of opened cycle at flow rate 41.93 l/min.

	4 samples			
	Temp, °C	**pH**	**EC, µS/cm**	**TDS, ppm**
	28.95	6.0025	367.5	246.225
S^2	0.155	1.425×10^{-3}	23	10.3247
S	0.39370	0.03775	4.79583	3.21320

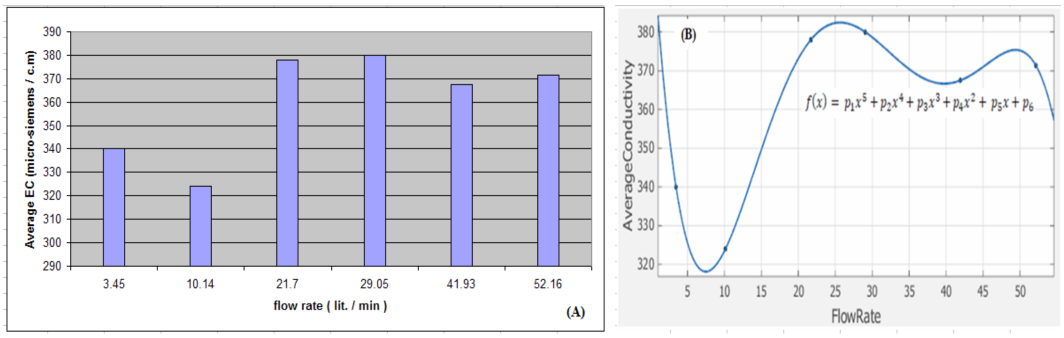


Fig. 9. Average Electrical Conductivity vs. Flow Rate, by using tap water in case of opened cycle at different flow rates.

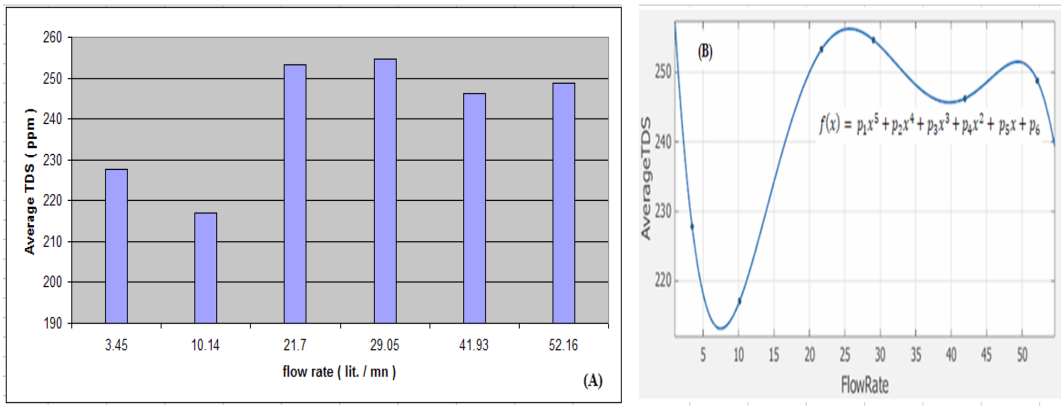


Fig. 10. Average Total Dissolved Solids vs. Flow Rate, by using tap water in case of opened cycle at different flow rates.

There are four critical points; 7.48, 25.73, 39.39 and 49.75. Thus, since it is decreasing to the left and increasing to the right of 7.48, it must be that 7.48 is a local minimum. Also, the function is increasing to the left and decreasing to the right of 25.73, it must be that 25.73 is a local maximum. In addition, the function is decreasing to the left and increasing to the right of 39.39, it must be that 39.39 is a local minimum. Beside this, the function is increasing to the left and decreasing to the right of 49.75, it must be that 49.75 is a local maximum. Figure 11a shows the relation between pH vs. flow rate, in which this relation is expressed below in Eq. 12, and the form of polynomial function of 5th degree with 6 coefficients is shown in Fig. 11b.

$f(x) = p_1 x^5 + p_2 x^4 + p_3 x^3 + p_4 x^2 + p_5 x + p_6$ Eq. (12)

where, p_1 = 5.628 x10^{-08}, p_2 = -4.785x10^{-06}, p_3 = 0.000107, p_4 = -0.0006388, p_5 = 0.01119, p_6 = 6.265, Knowing that; Goodness of fit (SSE) = 6.816 x 10^{-28}.

It was found that there are two critical points; 22.19 and 43.94. Thus, since it is increasing to the left and decreasing to the right of 22.19, it must be that 22.19 is a local maximum. In addition, the function is decreasing to the left and increasing to the right of 43.94, it must be that 43.94 is a local minimum. Figure 12a illustrates the relation between temperatures vs. flow rate, in which this relation is expressed below in Eq. 13, and the form of polynomial function of 5th degree with 6 coefficients is shown in Fig. 12b.

$f(x) = p_1 x^5 + p_2 x^4 + p_3 x^3 + p_4 x^2 + p_5 x + p_6$ Eq. (13)

where, p_1 = 3.263x10^{-08}, p_2 = -1.141x10^{-05}, p_3 = 0.001027, p_4 = -0.03633, p_5 = 0.5366, p_6 = 25.64, Knowing that; Goodness of fit (SSE) = 1.135 x 10^{-26}.

It was found that there are three critical points; 14.26, 26 and 45.81. Thus, since it is increasing to the left and decreasing to the right of 14.26, it must be that 14.26 is a local maximum. Also, the function is decreasing to the left and increasing to the right of 26, it must be that 26 is a local minimum. In addition, the function is increasing to the left and decreasing to the right of45.81, it must be that 45.81 is a local maximum.

Statistical analysis in case of studying the effect of flow rate

Six water samples were taken instantly from the outflow at different flow rates respectively, at 3.45, 10.14, 21.7, 29.05, 41.93 and 52.16 L/min. These samples were analyzed by the statistical analysis and the data are listed in Table 4. By comparing the practical data obtained from Table 4 with Table 2, it was found that, there is a decrease about 0.975 in the value of mean of the temperature of the outflow if it is compared to the value of the temperature of the inflow. There is a decrease about 0.25 in the value of mean of the pH of the outflow if it is compared to the value of the pH of the inflow. There is an increase nearly about 3.138 in the value of mean of the EC of the outflow if it is compared to the value of the EC of the inflow. There is an increase nearly about 2.102 in the value of mean of the TDS of the outflow if it is compared to the value of the TDS of the inflow [31].

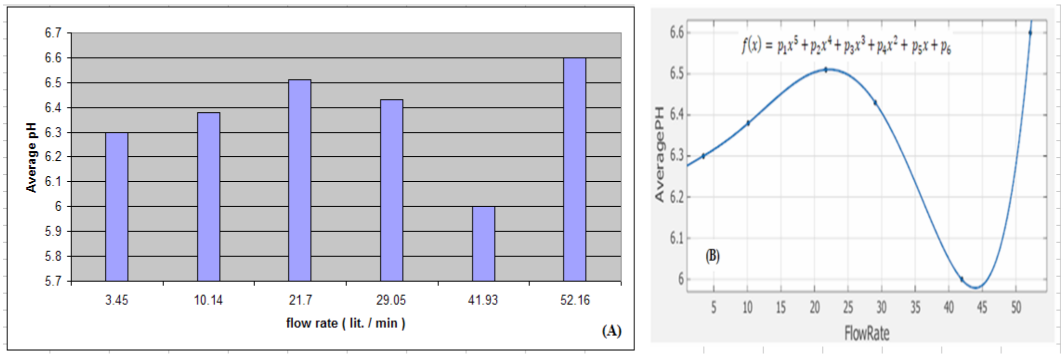


Fig. 11. Average pH vs. Flow Rate, by using tap water in case of opened cycle at different flow rates.

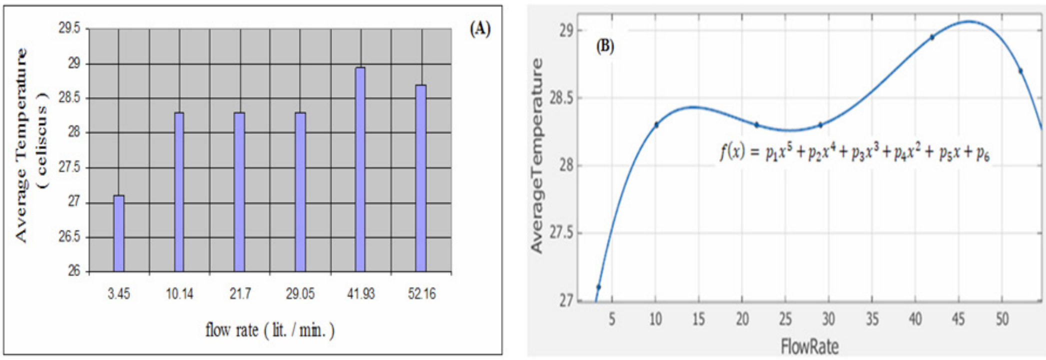


Fig. 12. Average Temperature vs. Flow Rate, by using tap water in case of opened cycle at different flow rates.

TABLE 4. Statistical analysis for the outflow in case of opened cycle at different flow rates.

	6 samples			
	Temp, °C	**pH**	**EC, µS/cm**	**TDS, ppm**
	28.275	6.37	360.1383333	241.2916667
S^2	0.40375	0.0436	520.9008166	233.8192166
S	0.63541	0.20881	22.82325	15.29115

Water parameters in recirculating system (dead end -loop)

Effect of contact time

The potable water exposed to the same magnetic field for 5, 15, 30, 50 and 65 min., respectively, at a constant flow rate of 52.16 lit/min. are presented. After the application of magnetic field, the flow was stopped and the parameters of water sample were measured instantly. One of these parameters is Electrical conductivity in which it is measured as a function of time, as shown in Fig. 13a. That shows the relation between electrical conductivity vs. time, in which this relation is expressed below in Eq. 14, and the form of polynomial function of 4th degree with 4 coefficients is shown in Fig. 13b.

$$f(x) = p_1.x^4+p_2.x^3+p_3.x^2+p_4.x+p_5 \qquad \text{Eq. (14)}$$

where, p_1 = 0.0001602, p_2 = -0.0199, p_3 = 0.772, p_4 = -10.77, p_5 = 426. Knowing that; Goodness of fit (SSE) = 1.376x10^{-24}.

It is obviously noticed that, there are three critical points, 11.35 in which it represents a local minima, 27.03 in which it represents a local maxima and 54.78 in which it reprsents a local minima. Figure 14a shows the relation between total dissolved solids vs. time, in which this relation is expressed below in Eq. 15, the form of polynomial function of 4th degree with 5 coefficients as shown in Fig. 14b.

$f(x) = p_1.x^4+p_2.x^3+p_3.x^2+p_4.x+p_5$ Eq. (15)

where, $p_1 = 0.0001073$, $p_2 = -0.01333$, $p_3 = 0.5172$, $p_4 = -7.218$, $p_5 = 285.4$. Knowing that; Goodness of fit (SSE) = 3.918×10^{-25}.

There are three critical points, 11.36 in which it represents a local minima, 27.03 in which it represents a local maxima and 54.79 in which it reprsents a local minima. Figure 15a shows the relation between pH vs. time, in which this relation is expressed below in Eq. 16, and the form of polynomial function of 4th degree with 5 coefficients is shown in Fig. 15b.

$f(x) = p_1.x^4+p_2.x^3+p_3.x^2+p_4.x+p_5$ Eq. (16)

where, $p_1 = 6.984 \times 10^{-08}$, $p_2 = -1.022 \times 10^{-05}$, $p_3 = 0.0003437$, $p_4 = 0.0071$, $p_5 = 6.747$. Knowing that; Goodness of fit (SSE) = 2.445×10^{-29}.

There are two critical points, 49.11 in which it represents a local maxima and 68.22 in which it represents a local minima. Figure 16a shows the relation between temperatures vs. time, in which this relation is expressed below in Eq. 17, and the form of polynomial function of 4th degree with 5 coefficients is shown in Fig. 16b.

$f(x) = p_1.x^4 + p_2.x^3 + p_3.x^2 + p_4.x + p_5$ Eq. (17)

where, $p_1 = -7.28 \times 10^{-06}$, $p_2 = 0.000902$, $p_3 = -0.03155$, $p_4 = 0.3542$, $p_5 = 25.81$. Knowing that; Goodness of fit (SSE) = 4.064×10^{-27}.

It was concluded that the outflow from the PWT device becomes warm at the time of 50 min. This is consistent with what has been said about the effect of the apparent magnetic field on water in which it restricts the motion of the water molecules, and hence alters the thermal conduction in the state of liquid [20]. In addition, it was found that there are three critical points, 8.31 in which it represents a local maxima, 24.25 in which it represents a local minima and 60.37 in which it represents a local maxima.

Statistical analysis in case of studying the effect of contact time

5 water samples were taken instantly from the outflow during different intervals of time at 5 min, 15 min, 30 min, 50 min and 65 min respectively, at a constant flow rate of 52.16 L/min. These samples were analyzed by the statistical analysis (as shown below in Table 5). In addition, by comparing the practical data obtained from Table 5 with Table 2, it is noticed that, there is a decrease about 0.19 in the value of mean of the temperature of the outflow if it is compared to the value of the temperature of the inflow. There is an increase about 0.372 in the value of mean of the pH of the outflow if it is compared to the value of the pH of the inflow. There is an increase about 17.2 in the value of mean of the EC of the outflow if it is compared to the value of the EC of the inflow. There is an increase about 11.524 in the value of mean of the TDS of the outflow if it is compared to the value of the TDS of the inflow [31].

Computional studies (DFT results)

Hydrogen bond energy values obtained from DFT (B3LYP) calculation with different apparent magnetic field are listed in Table 6. The theoretical calculation indicates that the applied magnetic field can affect the binding energy of water clusters. By increasing the magnetic field from 0 up to 85 T, the interaction energy becomes less negative which imply the breaking down of hydrogen bonding. It is also observed that as the number of water molecule in a cluster increases, the interaction energy becomes more negative as shown in Fig. 17, Hence, the hydrogen bonding increases.

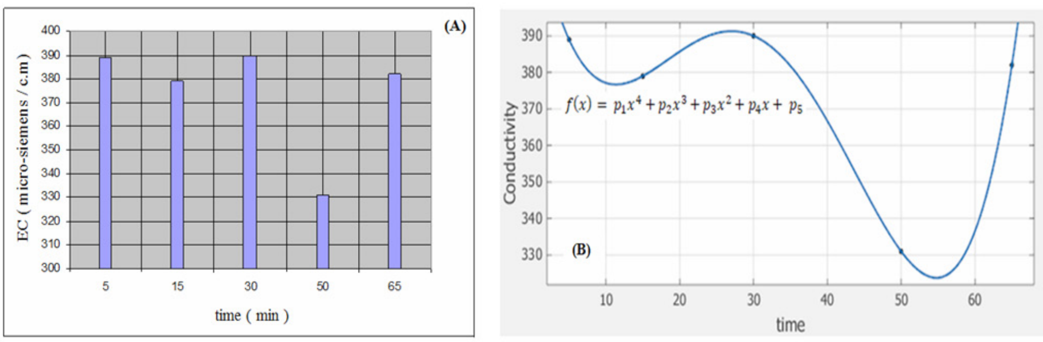


Fig. 13. Electrical Conductivity vs. time, by using tap water in case of closed cycle at flow rate 52.16 l/min.

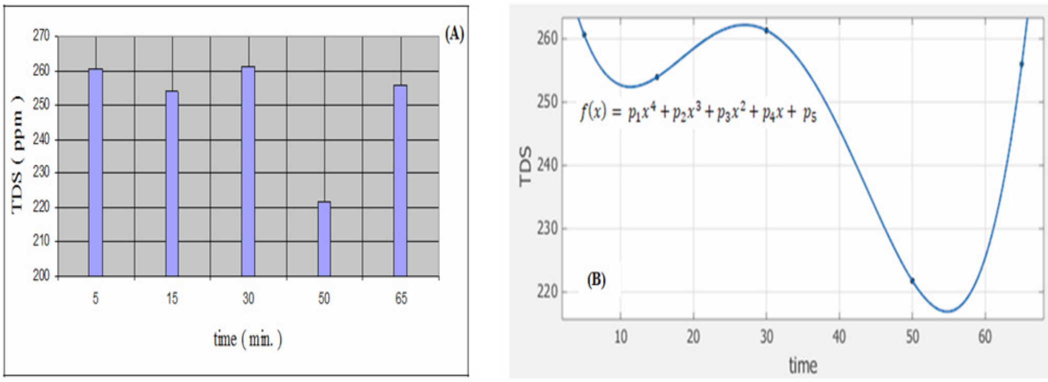


Fig. 14. Total Dissolved Solids vs. time, by using tap water in case of closed cycle at flow rate 52.16 l/min.

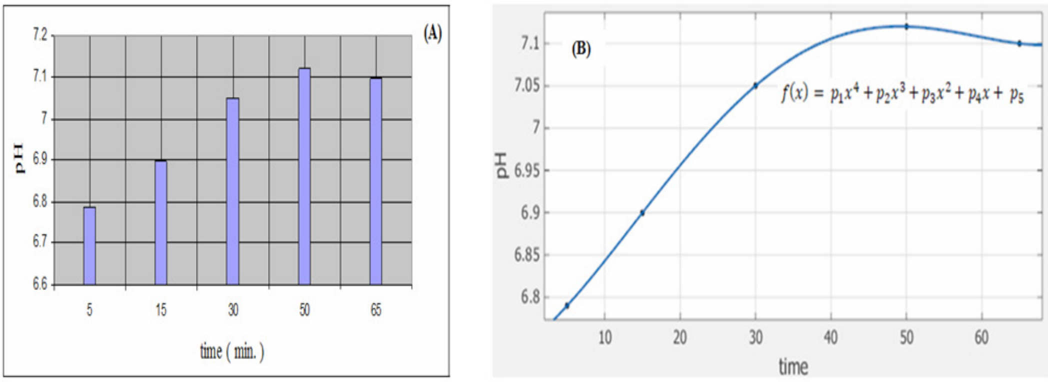


Fig. 15. pH vs. time, by using tap water in case of closed cycle at flow rate 52.16 l/min.

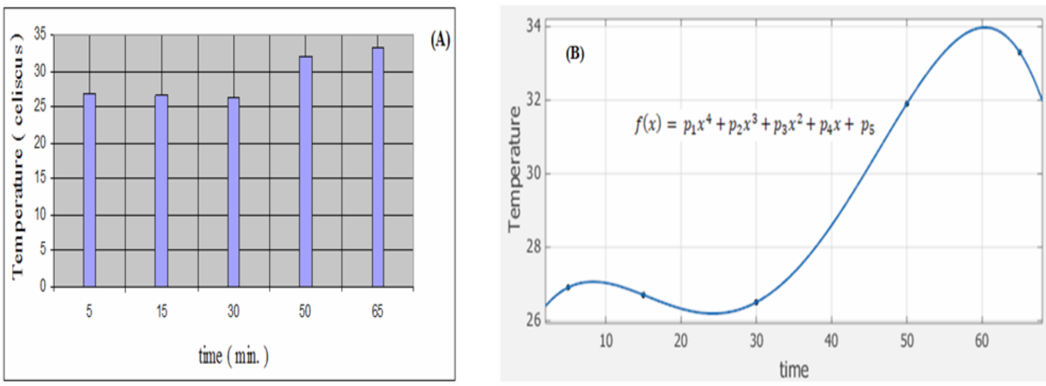
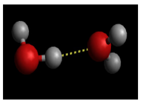
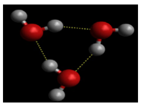
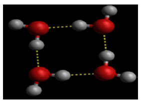
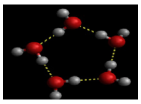
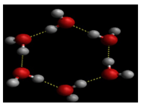
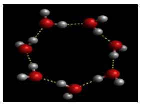
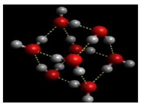
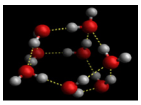
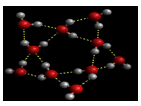
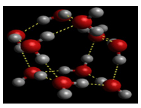


Fig. 16. Temperature vs. time, by using tap water in case of closed cycle at flow rate 52.16 l/min.

TABLE 5. Statistical analysis for the outflow in case of closed cycle at flow rate of 52.16 lit./min.

	5 samples			
	Temp, °C	**pH**	**EC, µS/cm**	**TDS, ppm**
	29.06	6.992	374.2	250.714
S^2	10.708	0.02017	604.7	271.44983
S	3.27231	0.14202	24.59065	16.47573

TABLE 6. Hydrogen bond energy values (kJ/mol) obtained from DFT (B3LYP) calculation using different apparent magnetic field.

Water molecules	n	0 T	1.7 T	17 T	85 T
	2	-15.70	-15.55	-13.94	-11.43
	3	-27.33	-27.31	-25.79	-27.53
	4	-34.98	-33.93	-34.04	-34.04
	5	-38.17	-38.14	-39.85	-38.14
	6	-48.72	-40.96	-40.90	-40.97
	7	-40.91	-40.90	-48.26	-41.26
	8	-51.01	-50.97	-50.70	-49.70
	9	-53.71	-53.72	-53.73	-53.96
	10	-43.64	-43.64	-43.70	-43.78
	11	-54.09	-53.55	-53.42	-52.27

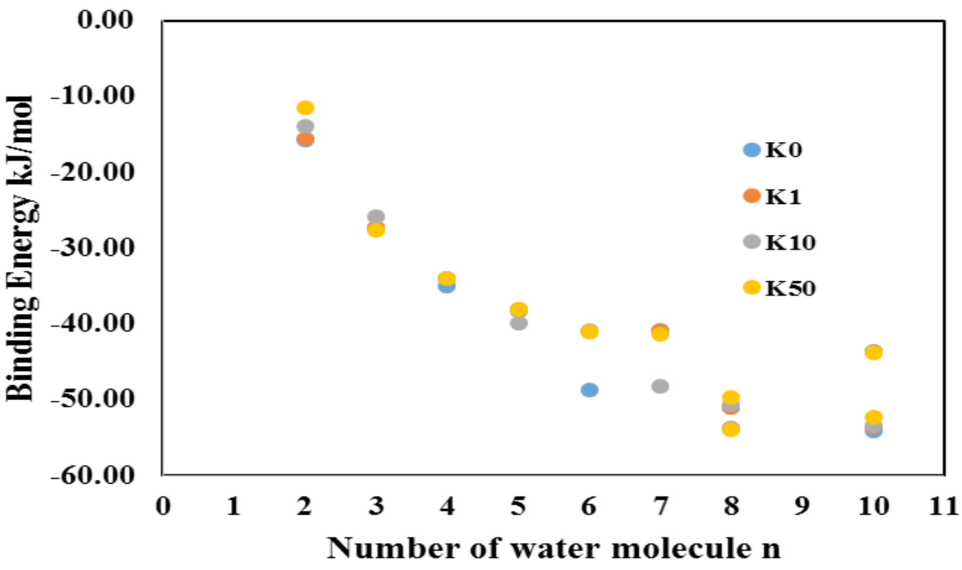


Fig. 17.Variation of hydrogen bonding values of water clusters with apparent magnetic field.

Conclusion

This study proved that the magnetic field has an influence on many factors of water such as; electrical conductivity, total dissolved solids, pH and temperature. The effect can be understood on the underpinning of strengthen of the hydrogen bonds and its disconcertion. The magnetic memory possessions are additionally confirmed under the overhead investigational arrangement. The application of magnetic field in open and circulating water system in manufacturing procedures appears to be auspicious technique permitting to save the energy necessity to reduce the total dissolved salts. It was found that there is a change in the value of standard deviation in case of open and dead end cycle as shown above in the results during exposing the inflow to (PWT) device that generated a permanent magnetic field (B = 1.45 T ± 0.05). Due to this, (PWT) device plays an important role in causing the fluctuations on the previous water parameters. In general, 52.16 L/min (or 3.13 m^3/hr) is the recommended flow rate in case of open cycle at the time of 20 seconds. Also the same flow rate is also recommended in case of dead end cycle at the time of 30 minutes. The results were subjected to theoretical calculations by using Density Functional Theory especially for the inter-molecular interaction energy of hydrogen bonded systems of water clusters under the effect of different values of magnetic field. The results were also performed for statistical analysis for more understanding the effect of this permanent magnetic field on both of open and dead end flow system.

Acknowledgement

The authors would like to express their sincere gratitude to Dr. Ahmed Gomaha Radwan, Dr. Omaima Al-Qadi and Dr. Morsi Amin Morsi for their fruitful discussion and thankful help during this study.

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تأثير المعالجة المغناطيسية لمياه الشرب في شبكات المياه المفتوحة والمغلقة

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تعرضت مياه الشرب لمجال مغناطيسي دائم وبكثافة تدفق مغناطيسي مقدارها 1.45 تسلا وذلك بهدف دراسة تأثير هذا المجال على بعض خصائص المياه ولفترات زمنية مختلفة وعند ظروف التدفق المفتوحة والمغلقة وعند معدلى تدفق 41.93 و 52.16 لتر لكل دقيقة على التوالي. وكان من العوامل التى تم دراستها, الموصلية الكهربائية والكمية الكلية للأملاح الذائبة، ودرجة الحموضة والقلوية وأخيرا درجة الحرارة. تمت دراسة كل هذه العوامل السابقة كدالة في معدل تدفق المياه في حالة نظامى التدفق المفتوح والمغلق وفي وجود هذا المجال المغناطيسي الدائم. وأظهرت النتائج أن المجال المغناطيسي الدائم يؤثر فى مياه الشرب في ظروف التدفق السابقة وقد ظهر ذلك فى تغير كل العوامل قيد الإختبار. وقد تم استخدام مياه الشرب في هذه الدراسة كعمل أولي قبل التطبيق على المياه المالحة. وقد أثبتت النتائج من خلال هذه الدراسة أن هذه الآثار ترجع إلى شبكة الروابط الهيدروجينية التى تميز جزيئات المياة. وقد تم تطبيق وتنفيذ برنامج يعتمد على الحسابات النظرية بهدف حساب طاقة الجزيئات الداخلية بين الروابط الهيدروجينية فى التركيب البللورى لجزىء المياه تحت تأثير المجال المغناطيسي وذلك بتطبيق ''نظرية الكثافة الوظيفية'' باستخدام برنامج جاوس 09.