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Experimental Study of Magnetization Effect on Ground Water Properties

Kadhim Naief Kadhim [1] ***and Ahmed Hameed Rustum Al-Rufaye*** [2]

[1] Assistant Prof., Civil Engineering Department, College of Engineering, University of Babylon, Hilla, Iraq.
[2] MSc Candidate, Civil Engineering Department, College of Engineering, University of Babylon, Hilla, Iraq.

ABSTRACT

This study is structured to improve groundwater quality used for irrigation by investigating the effectiveness of a locally made magnetic physical water treatment device (PWTD). Four permanent magnet types with different dimensions were used to make a device, where the material of magnetic blocks is NdFeB with a high intensity ranging between 4000 and 14000 Gauss. Water was passed through the PWTD with different flow rates (0.1, 0.3, 0.5, 0.7 and 1) lit/sec using drip irrigation with different passing times (1x, 2x and 3x) to obtain the effectiveness of magnetic field and flow rate and the influence of water on magnetic field area. The results showed that magnetic field has a clear impact on the values of pH, ORP, TDS and EC with different flow rates, where slower flow rates have better effectiveness for water treatment than faster flow rates. On the other hand, increasing the time of passing of water through the PWTD raised the efficiency of treatment. Exposing water to a wider area of magnetic field will increase the changes in water properties. Flow rate of (0.1) lit/sec with three times of passing (3x) increased pH, EC and ORP in average by 3.7%, 9.6% and 26%, respectively.

KEYWORDS: Groundwater quality, Magnetization effect, Water flow rate, Water passing times.

INTRODUCTION

At the beginning of the 20th century, interest has raised to study the relationship between water flow and the effect of magnetic field. The interest increased more in this subject in the middle of that century after World War II, where magneto-hydrodynamics was used to study the influence of magnetic field on a moving conductive fluid, such as fluids including plasmas, salt water and liquid metals or electrolytes. This technique has become appropriate to play a role in many fields, being industrial or agricultural; therefore, many researchers expressed their interest in this field to achieve the best results by using three different devices: solenoid coil, permanent magnet and high-voltage electrode.

The use of magnetic devices in water treatment remains controversial in spite of the large number of studies that showed the effects of magnetic fields on physical and chemical properties of water, but the results of those studies differed largely. Some studies proved that magnetic fields have the ability to change the properties of water according to certain conditions. Other studies did not find any effects on water properties. Murugan et al. (2013) exposed three different types of water (tap water, domestic storage tank water and groundwater) to a weak (8±4 μT) decelerating frequency-modulated magnetic field for 12 hours. Results displayed an increase in pH ranging from 0.5 to 1 after about (7-8) hrs. Ameen (2013) studied the changes in water properties before and after magnetic treatment by using a magnetic device of AQUARETTE type with a field intensity of 130 Gauss and a pipe diameter of 0.5 cm. Three water samples passed through the magnetic device with a flow rate of

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3.7mlit/sec. The results obtained indicated a significant magnetic treatment for pH, EC, DO, total hardness, calcium, sodium, potassium, chloride and nitrate. Maximum increasing rate in pH for tap water, domestic storage tank water and groundwater was 1.3%, 4.1% and 5%, respectively. Musa and Hamoshi (2012) studied the changes in electrical conductivity EC for salt water by exposing it to a static magnetic field with a magnetic strength of 450 Gauss by passing water 1, 5 and 10 times with a flow rate of 41.66 mlit/sec. The study showed that there is a relationship between the change in soluble salts and the number of times of water exposure to magnetic field, where electrical conductivity was increased compared with that of magnetically untreated water, indicating an increase in the solubility of salts (calcium chloride and sodium chloride). Ibrahim (2006) witnessed an increase in electrical connectivity as a result of using a static magnetic field. The experiment used different magnetic intensities (1440, 2290, 3140, 4000 and 5000) Gauss with a variable magnet gap varying from 0.5 to 9 cm. The results indicated a decrease in flow rate because of magnetic field resistance to the movement of water molecules. Masumi et al. (2003) investigated the changes in pH and oxidation reduction potential (ORP) of distilled and deionized water after exposure to magnetic fields (AC and DC) of various strengths. Readings showed slow and large fluctuations (0.05−0.1 pH unit, 60 mV for ORP) during the first several hours, where pH and ORP generally changed slowly toward equilibrium in a quasi-linear fashion. They changed faster, on average, in those samples exposed to higher magnetic fields. These results indicated the effects of weak magnetic fields on water. Banejad and Abdosalehi (2009) examined different magnetic field intensities (0, 0.05, 0.075 and 0.1 Tesla) with a magnetic length equal to 25 cm and water flow rates of 4 and 30 lit/hr. The study proved that magnet fields have an effect on water quality and found that when increasing velocity, the magnetic field intensity needs to be increased for greater efficiency of treatment.

MATERIALS AND METHODS

The samples of water were collected from a desert areas in Karbala city (coordinates: 32N, 44E) located about 100 km far from Baghdad. The test of water properties was carried out at Karbala Agricultural Department. Table 1 shows the water analysis data for water samples from three wells.

Table 1. Water analysis data for water samples from three wells

Parameter	Ww1	Ww2	Ww3
pH	8.11	8.21	8.18
Ca^{+2}(mg/lit)	269	408.81	452.9
Mg^{+2}(mg/lit)	15.12	30.74	17.5
Na^{+}(mg/lit)	552.5	609	563.3
K+(mg/lit)	164.8	185.8	171.2
HCO_3^- (mg/lit)	61	42.7	67.1
SO_4^{-2} (mg/lit)	2115.5	1954.2	2012.2
Cl^-(mg/lit)	710	1065	718
EC(dS/m)	4.27	6.5	5.68
TDS(mg/lit)	2732.8	5200	4520
TH(mg/lit)	1155.5	1816.3	1640.2

Water was exposed to a magnetic field using a physical model that contains a 70-liter constant-level water tank filled with water samples from three water wells. The tank discharges to different pumps by a plastic hose, then water is pumped by a plastic hose passing through the PWTD. Samples of magnetized water are collected in a 70-liter water tank to conduct the necessary tests. A flow meter was used for monitoring the water flow rate (type LZT-2020-G) with a maximum capacity of 70 liters per minute and control valves were fitted into a PVC pipe as experimentally required. The length of magnetic filed was 70 cm, which can be considered as the region of direct exposure of water to the magnetic field generated by the magnets on the PWTD. However, a magnetic field of less value could also exist on both sides of the direct magnetization region. A schematic diagram of the experimental setup is illustrated in Figure 1.

Each water sample was tested at (1x, 2x and 3x) times of passing through the PWTD to evaluate whether successive passes altered the sample's properties. This is done by passing water well samples stored in a water tank through the PWTD and collected in another tank to be tested for water properties (pH, TDS and ORP). After that, the collected water was passed again (2 times) to the magnetic device and tested for water properties. In the same way, this process was repeated (3 times pass). Water samples were collected in a flask of plastic (or glass), clean and air-tight, with as less space as possible above the water surface. The flasks were numbered and data on samples was recorded, including strength of the magnet, number of passing times, flow velocity and type of water used.

When water flows out of the magnetization region of the setup to the collecting reservoir, a glass flask of 0.5 liter was immediately used to transfer samples of magnetized and non-magnetized water into a number of test flasks. These samples were taken from the collecting reservoir and/or from the test flasks. It's worth mentioning that these test flasks were thoroughly cleaned and dried before each test. Three more parameters have been studied in the present study, which are pH, EC and ORP. pH has been measured by using pH-200 instrument (dimensionless). TDS in (ppm or mg/lit) and EC in (dS/m) have been measured by using COM-100 meter. TDS value of both magnetized and non-magnetized water was measured by using 0.5 liter of water in a flask with a probe dipped inside the flask. Three readings for the same sample were recorded and the final value of the TDS was their average. From another channel in the instrument, the EC value was recorded, since there is a relationship between TDS and EC, where more TDS brings about higher EC. Moreover, the pH measuring procedure is similar to that followed in measuring TDS and the time required for having the probe in water is 30 sec for getting the final reading. Also, ORP (in mV) of both magnetized and non-magnetized water was measured by using 0.5 liter of water in a flask with a probe dipped inside the flask with the aid of ORP-200 instrument.

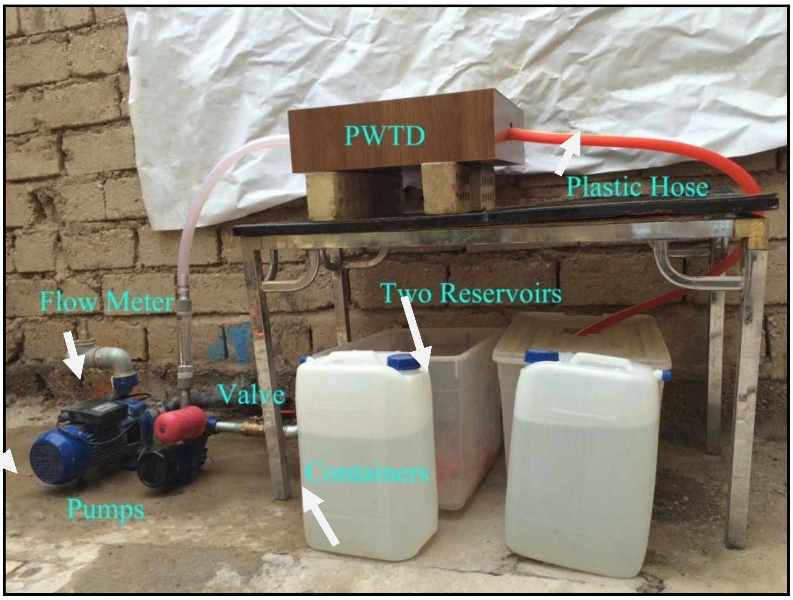

Figure (1): Schematic diagram of the experimental setup

DESIGN of MAGNETIC TREATMENT DEVICE

Four permanent magnet types with different intensities are used to make the physical water treatment device (PWTD), named neodymium block magnets, with different intensities (1400, 1300, 7200 and 6500 Tesla). The magnets were pointed depending on their strength, which determines the arrangement and configuration of these magnets. The optimal configuration for these magnets was identified according to the report of ASHRAE, Inc. published in 2003, where the report explained through experimentation the best arrangement of magnets when put so that the north pole is in exchange to the south pole. This constituted perpendicular magnetic flow lines with right angles to the flow of water in the pipe to give a greater impact of the Lorentz force on water flow, as can be seen in Figure 2.

The importance of magnets' arrangement lies in obtaining a greater impact of the magnetic field on water molecules as well as on suspended or dissolved particles. The magnets' block will be arranged in two forms in the PWTD: first, sequential as shown in Figure 3A and second, non-sequential as shown in Figure 3B).

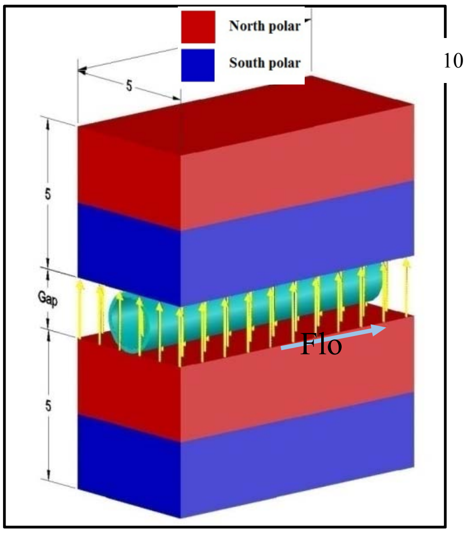

Figure (2): The best magnetization arrangement

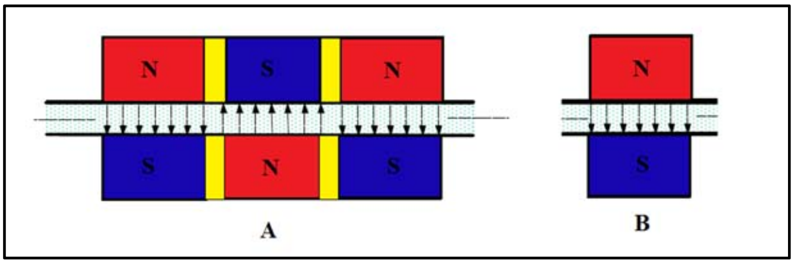

Figure (3): (A) Sequential arrangement of magnets; (B) Non-sequential arrangement of magnets

Water flow section depends mainly on the magnetic field strength that is required to treat water. The strength of field magnetic is inversely proportional to the distance between two magnets, where the strength increases when the gap between the magnets decreases. Cho (2002) conducted experiments on the arrangement of magnets and the gaps between them. The results showed the effectiveness of gaps (0.68, 1.27 and 1.57 cm).

Taking into consideration that there are other criteria, such as flow velocity and pipe cross-section available in local markets, several experiments examined field strength using rectangular cross-section for the duct to obtain the largest area of water exposed to magnetic field, as can be seen in Table 2. Magnetic field was measured with a digital Tesla-Meter (PHYWE, Germany). Three gaps (1, 0.75 and 0.5 cm) were selected between two magnets. The examined intensities for the gaps were (7260, 5530, 3630 and 3010) Gauss, respectively, for type I, II, III and V, but these values are considered relatively small compared with the single magnet intensity ranging from 6500 to 14000 Gauss due to losses in magnetic field intensity. The magnetic field intensity increased by using a horseshoe made of iron called a yoke to eliminate intensity losses associated with permanent magnets. The iron yoke over the permanent magnets has been found the most cost-effective method to provide the required magnetic shielding and to create a closed magnetic loop, as shown in Figure 4. The intensity of the field was calculated after adding the iron yoke for the three gaps, where the results showed an improvement in field intensity ranging from 6% to 15%, as shown in Table 2.

Table 2. Gaps and cross-section duct between two magnets

No.	Cross-section (cm)	Magnetic Type	Field Intensity without Yoke (Gauss)	Field Intensity with Yoke (Gauss)
1	1x5	I	7260	8650
2	0.75x5	II	5530	5910
3	0.5x2	III	3630	3940
4	0.5x2	V	3010	3410

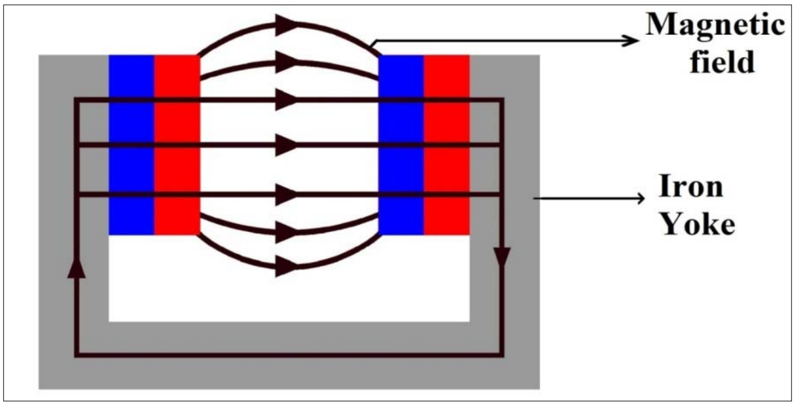

Figure (4): Magnetic field lines by using an iron Yoke

Figure 5 shows the final design of the PWTD. All criteria mentioned above were taken into account in the design by using four magnet types. The basic idea is that water was exposed to larger magnetic field when flowing into the PWTD, where the length of magnetic field was 70 cm. It is also possible to reduce the number of cycles and give better water treatment. PWTD design consists of:

- Inlet circular pipe with a diameter of 2.5 cm and a length of 10 cm.
- First exposure to magnetic field, using magnet type I, with rectangular duct and dimensions of 1x5x10 cm.
- Second exposure to magnetic field, using magnet type II, with rectangular duct and dimensions of 0.75x5x10 cm, in two phases.
- Third exposure to magnetic field, using magnet types III and V, with rectangular duct and dimensions of 0.5x2x2 cm, in four phases.

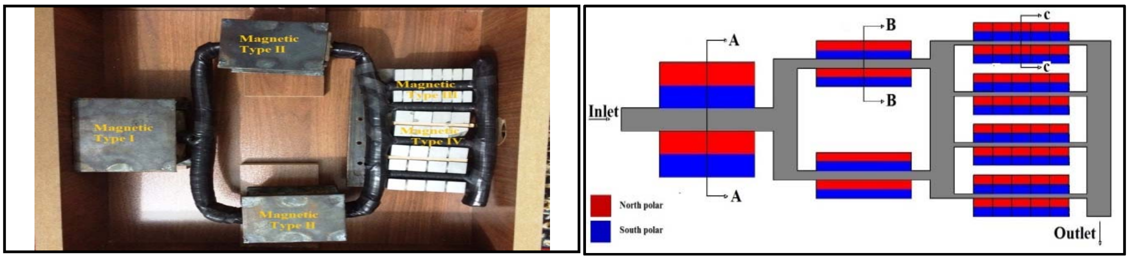

Figure (5): Final design for PWTD

RESULTS AND DISCUSSION

Recording pH and EC values for water samples that passed through the PWTD showed increases compared with those of untreated water. The increases in pH and EC values are directly proportional to the number of cycles, where the values increase when the times of water passes into the PWTD increase. The increasing rate for pH ranged from 0.12% to 3.82 % and for EC ranged from 0.7% to 10.3%, as shown in Tables 3, 4, 5, 6 and 7. Experiments showed that increasing the flow rate decreases the changes in pH and EC values. Changes in pH due to hydrogen bonds between molecules either change or disintegrate; this disintegration causes energy absorption, reduces the level of united water parts, increases the susceptibility to electrolysis and affects the decomposition of the crystals (Rao, 2002). Ibrahim (2006) explained the changes' reason. Lorentz force caused the vibration of water molecules that surround the salts' ions. In magnetically treated water, there is a maximum of four hydrogen bridge connections containing protons that spin in the same direction. These are called clusters. The clusters of water are not stable, but very sensitive and unstable units. The magnetic fields influence water and change the dimensions of these clusters, which affects the physical properties of water. The smaller changes in ORP ranged between 20 mV and 50 mV. The ORP reading changes only slightly depending on the chemical composition (Na^+, Cl^- and HCO_3^-) of the water samples. The results showed an increase in ORP value. James (2004) explained that the reason of changes is related to the ORP electrode responding to the flow of electrons from the organic molecules to the oxidizer molecules and not to the oxidizer concentration. ORP describes the net magnitude and direction of the flow of electrons between pairs of chemical species, called REDOX pairs. In REDOX reactions, one chemical of the pair loses electrons, while the other chemical gains electrons. The chemicals that acquire electrons are called the oxidants (HOCl, OCl^-, ClO_2, bromine, hydrogen peroxide,… etc.). The chemicals that give up electrons are called the reductants (Li, Mg^{2+}, Fe^{2+}, Cr,… etc.). Oxidants acquire electrons through the process of reduction; i.e., they are reduced. Reductants lose their electrons through the process of oxidation; i.e., they become oxidized. Figures 6, 7 and 8 show the relationship between water sample examination and different flow rates. Accordingly, the comparison will give an indication of flow rate effects. When the flow rate increases, the changes in water properties decrease as a result of less effectiveness of the magnet. Also, the increase in water passing times (1x, 2x and 3x) causes increasing the changes in water properties.

Table 3. Percentage of variation for experimental results with a flow rate of 0.1 lit/sec

No.	Test	No. of Cycles	Percentage of Variation by PWTD		
			Ww1	Ww2	Ww3
1	pH	1x	0.94%	1.34%	0.98%
		2x	1.97%	2.56%	2.20%
		3x	3.82%	3.78%	3.42%
2	ORP	1x	18.2%	16.5%	13.5%
		2x	20.0%	18.6%	19.5%
		3x	30.0%	23.9%	24.3%
3	EC	1x	3.0%	2.9%	3.3%
		2x	5.6%	5.4%	6.0%
		3x	9.1%	10.3%	9.3%

Table 4. Percentage of variation for experimental results with a flow rate of 0.3 lit/sec

No.	Test	No. of Cycles	Percentage of Variation by PWTD		
			Ww1	Ww2	Ww3
1	pH	1x	0.83%	1.34%	0.61%
		2x	1.97%	1.91%	2.35%
		3x	3.45%	3.17%	2.93%
2	ORP	1x	12.4%	10.6%	7.0%
		2x	15.9%	14.9%	14.6%
		3x	26.5%	20.2%	20.0%
3	EC	1x	2.1%	2.6%	3.0%
		2x	4.0%	4.8%	4.9%
		3x	8.7%	8.3%	8.8%

Table 5. Percentage of variation for experimental results with a flow rate of 0.5 lit/sec

No.	Test	No. of Cycles	Percentage of Variation by PWTD		
			Ww1	Ww2	Ww3
1	pH	1x	0.76%	0.64%	0.66%
		2x	1.56%	1.34%	2.20%
		3x	2.01%	1.86%	1.91%
2	ORP	1x	8.8%	6.9%	7.0%
		2x	17.1%	12.8%	16.2%
		3x	24.1%	17.0%	18.4%
3	EC	1x	2.1%	2.3%	2.3%
		2x	4.2%	4.9%	4.8%
		3x	7.5%	7.8%	8.3%

Table 6. Percentage of variation for experimental results with a flow rate of 0.7 lit/sec

No.	Test	No. of Cycles	Percentage of Variation by PWTD		
			Ww1	Ww2	Ww3
1	pH	1x	0.76%	0.64%	0.66%
		2x	1.56%	1.34%	2.20%
		3x	2.01%	1.86%	1.91%
2	ORP	1x	8.8%	6.9%	7.0%
		2x	17.1%	12.8%	16.2%
		3x	24.1%	17.0%	18.4%
3	EC	1x	2.1%	2.3%	2.3%
		2x	4.2%	4.9%	4.8%
		3x	7.5%	7.8%	8.3%

Table 7. Percentage of variation for experimental results with a flow rate of 1.0 lit/sec

No.	Test	No. of Cycles	Percentage of Variation by PWTD		
			Ww1	Ww2	Ww3
1	pH	1x	0.11%	0.14%	0.12%
		2x	0.16%	0.15%	0.18%
		3x	0.30%	0.46%	0.34%
2	ORP	1x	1.18%	0.00%	0.54%
		2x	2.94%	2.13%	2.16%
		3x	5.88%	4.79%	4.86%
3	EC	1x	0.70%	0.77%	0.70%
		2x	1.41%	1.69%	1.58%
		3x	2.34%	3.23%	2.99%

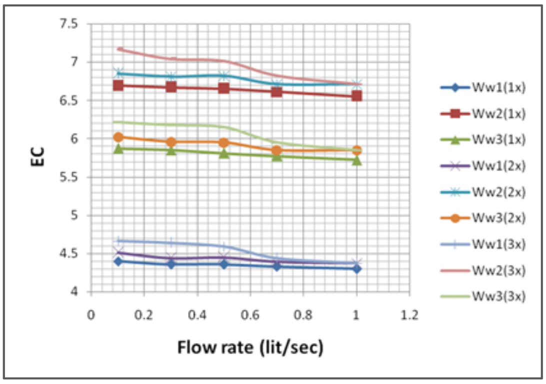

Figure (6): Relationship between EC and flow rate

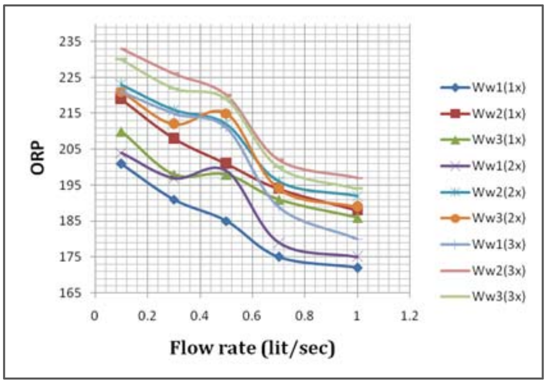

Figure (7): Relationship between ORP and flow rate

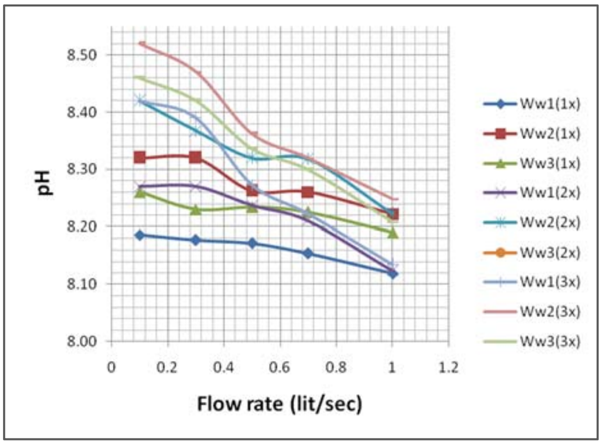

Figure (8): Relationship between pH and flow rate

CONCLUSIONS

1- Magnetic field has a clear effect on the vales of pH, ORP, TDS and EC with different flow rates, where slower flow rates have better effectiveness for water treatment than faster flow rates. The average percentages of changes for pH, ORP and EC at 0.1 lit/sec with one pass (1x) were 1%, 16% and 3%, respectively and at 1lit/sec 0%, 1% and 1%.

2- The times of water passing through the PWTD raised the efficiency of treatment or changes in water properties, which indicates that when water is exposed to a wider area of magnetic field, the changes in water properties are increased. With a flow rate of 0.1 lit/sec and three times of passing (3x), the averages of increase in pH, ORP and EC were 3.7%, 26% and 9.6%, respectively and at 1 lit/sec with 3x passing were 0%, 5% and 3%.

3- Increased magnetic intensity affects the quality of treatment, where exposing water to a magnetic field with various intensities and a length of 70 cm for one time (1x) resulted in an effectiveness which increased after passing three times with a length of 210 cm.

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