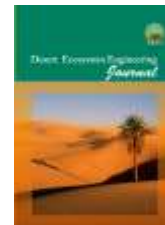




University of Kashan



Impact of the magnetic treatment on some of the unconventional waters' properties

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Abstract

Continued population growth and declining trend of the annual rainfall across the world justified concerns about future access to drinking and agricultural water resources. In response, many researchers have raised the idea of using treated unconventional waters as a solution to water shortage, especially in the arid and semi-arid regions. It has been proven that magnetic fields can affect the structure of mineral compounds and alter some of their properties. The majority of past studies on the use of magnetic fields for water treatment have tested the effect of weak magnetic fields with peak strength of 0.50 T² on a single type of unconventional water. The present study was conducted by exposing several types of unconventional water including saline water, acidic water, alkaline water, and waste water to magnetic fields of 0.75 and 1.0 T. Statistical analysis was performed using the paired t-test. The results showed a significant effect of the 0.75T magnetic field on the pH of waste water, saline water (TDS³=4000mg/l) and saline water (TDS=9000mg/l) treatment groups and a significant impact of the 1.0T magnetic field on the pH of acidic water (pH=6) and alkaline water (pH=8) treatment groups. Magnetic treatment increased the pH of all tested unconventional waters except the alkaline ones. Both magnetic fields reduced the EC⁴ of saline water, but the 0.75T field was more effective in this respect. The 0.75T magnetic field can be used to treat acidic waters so as to reach a greater level of neutrality. The acidity of other unconventional waters can also be altered in the same way, but not as favorably. Exposure to magnetic fields reduced the electrical conductivity of saline waters, but increasing the strength of the magnetic field to 1.0 T did not lead to a higher salinity reduction. The results indicate that magnetic fields can indeed improve the quality of unconventional waters by significantly altering some of their properties.

Keywords: Saline water, Alkaline water, Waste water, Magnetic field, Paired t-test, Water quality, Treatment.

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² Tesla

³ Total Dissolved Solids

⁴ Electrical Conductivity

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1. Introduction

With the continued growth of world population and the decline in annual rainfall, the declining access to drinking and agricultural water resources has become a source of concern. In response to this concern, many researchers have raised and investigated the idea of using unconventional water resources as a solution to water shortage, especially in arid and semi-arid regions, (Hamoda, 2004; Smakhtin and et al., 2001). Magnetic water treatment is a method of treating water by passing it through a constant magnetic field in order to alter its physical and chemical properties, such as hardness, specific weight, viscosity, salinity, electrical conductivity, surface tension, contact angle, and wetting and solvent properties (Pang and Deng, 2008). Magnetic water treatment does not add or remove any material to or from the water, so it can be considered a rather clean and eco-friendly technology (Nasher, 2008).

The hypothesis that a magnetic field can affect the structure of mineral compounds and alter some of their properties has been proven in several studies (Huang and et al., 2012). With the passage of water through the magnetic field and breaking of hydrogen and Van der Waals bonds between water molecules, the surface tension of water decreases (Cai and et al., 2009) and its fluidity and wetting property increase (Alireza Kiani, 2008). As a result, magnetized water has better absorbability than non-magnetized water. Consequently, irrigation with magnetized water can be expected to improve the plant growth and ultimately the yield (Qados and Hozayn, 2010). The changes in the molecular structure of water also alter its solvent property (Cai and and et al., 2009). Naturally, water molecules have a completely random arrangement. When subjected to a single pole of a magnetic field, the oppositely charged water molecules will approach the pole and those with the same charge will be pushed away. This process causes water molecules to shift into a relatively regular arrangement (Holysz and et al., 2007). This magnetization of water increases the

number of water particles per unit volume and water's ability to absorb cations and anions (Alireza Kiani, 2008). At the same time, the use of magnetic fields to reduce scale in water pipes is being investigated (Simonič and Urbanč, 2017). Improvement in water ability to dissolve soil minerals and micro and macro-nutrients facilitate, should increase their transportation and eventual absorption by the root (Tahir and Karim, 2010). Thus, the use of magnetized water for irrigation can increase the plants rates of mineral and nutrient absorption and thereby their growth. The magnetic water treatment also facilitates the passage of water and its minerals through the plant cell membrane (Algozari and Yao, 2006). It has been shown that treatment of water with a 0.1 T magnetic field decreases its calcium and magnesium contents (Coe and Cass, 2000). These effects have been observed in the laboratory experiments as well as soil profile in the form of reduced mineral concentration to a depth of 60 centimeters (Zlotopolski, 2017). In many cases, the effect of magnetic field on the growth of different crops has been proven (Luo and et al., 2020). Today The influence of the magnetic field on the change in water structure has been analyzed using high-frequency electromagnetic fields to enhance their impact on the water structure and the stability of this process has been formulated, but many farmers refuse to accept the benefits of magnetized water as a scientifically proven fact, while many others who use this technology consider it to have beneficial effects on yield as well as agricultural input expenses. If proven, these benefits in addition to cost-effectiveness, energy efficiency, and eco-friendliness will make this technology very attractive (Amiri, 2016). The researchers also continue study about such effect .eg, The effects of magnetic water treatment for improving germination represent a differential effect in plant seed with different temperature. Where the seeds of *F. vulgare* and *C. sativum* gave the highest percentage of germination at 18°C (Rasheed and et al. 2018). The past studies on magnetic water

treatment have typically investigated the effect of exposing one type of unconventional water to weak magnetic fields with a peak strength of 0.5 T (Higashitani and et al., 1992; Nikbakht and et al., 2017; Nikbakht and et al., 2013 Zlotopolski, 2017; Liu and et al., 2015; Gudigar, 2013). The present study, however, was conducted by exposing several types of unconventional water including saline water, acidic water, alkaline water, and wastewater to magnetic fields of 0.75 and 1.0 T. The limitations of this study included the impossibility of continuous use of magnetic fields during the experiment, the absence of very low and very high degrees in the magnetic fields and the impossibility of performing the experiment portable on the field with field conditions.

2. Materials and methods

The effect of magnetic field on the qualitative properties of unconventional waters was investigated in University of Kashan, Iran (laboratories of the Faculty of Physics and the Faculty of Natural Resources and Earth Sciences).

2.1. Water magnetization

Water magnetization was carried out using a magnetic coil with field switching feature. The magnetic field was generated at two levels: 0.75 T and 1.0 T.

2.2. Measured parameters

Experiments were conducted on five treatment

groups per level of magnetic field: distilled water, waste water (treated sewage water), saline water at TDS concentrations of 4000 and 9000 mg/l, acidic water at pH levels of 6 and 6.5, and alkaline water at pH levels of 8 and 9, each with three replicates and one control sample. Calcium content was measured through titration. Magnesium content was determined by first measuring the total calcium-magnesium content and then deducting the calcium content. Sodium content was measured through flame photometry. EC and pH were measured using a pH meter and an EC meter. Total dissolve solids TDS was estimated by equation (1)

$$\text{TDS} = 0.64 \times \text{EC}$$

Where the TDS unit is milligrams per liter and EC unit is micromhos per centimeter (Mahdavi, 1999).

2.3. Statistical analysis

Data analysis was performed in SPSS ver.22. The paired t-test was used to compare the effect of magnetic field on the qualitative properties of unconventional waters.

3. Results

3.1. Effect of magnetic field on water properties

Table (1) and (2) indicate the results obtained from the paired t-test.

Table (1): The effect of 0.75 T magnetic field on the qualitative properties of unconventional waters

Variable	Water Type	Mean difference	t
	Waste	-0.12*	-4.33
PH	Saline (TDS=4000ppm)	-0.33**	-16.6
	Saline (TDS=9000ppm)	-0.63*	-7.08
	Saline (TDS=4000ppm)	2340**	10.21
EC	Saline (TDS=9000ppm)	4236**	23.93
	Acidic (pH=6)	-28.9*	-7.57
	Acidic (pH=6.5)	-1.74*	-4.34
TDS	Saline (TDS=4000ppm)	1497.66**	10.21
	Saline (TDS=9000ppm)	2705.76**	25.25
	Acidic (pH=6)	-18.48*	-7.57
	Acidic (pH=6.5)	-1.1*	-4.38

* and ** represent significance at 5% and at 1% level respectively

Table 2: Results of paired t-test on the effect of 1.00 T magnetic field on the qualitative properties of unconventional waters

Variable	Water Type	Mean difference	t
pH	Acidic (pH=6)	-1.2*	-6.25
	Alkaline (pH=8)	0.35**	29.39
EC	waste	-289**	-12.71
	Saline (TDS=4000ppm)	1510**	19.44
	Saline (TDS=9000ppm)	1883**	15.89
TDS	waste	-171.02**	-97.44
	Saline (TDS=4000ppm)	966.2**	19.31
	Saline (TDS=9000ppm)	1205.33**	15.82

* and ** represent significance at 5% and at 1% level respectively

3.1.1. Acidity

The results of paired t-test (Table 1) revealed the significant effect of 0.75 T magnetic field on the pH in waste water, saline water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment groups and the significant impact of 1.0 T magnetic field on the pH in acidic water (pH=6) and alkaline water (pH=8) treatment groups. The comparison of pre- and post-magnetization mean pH values showed that in waste water, saline

water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment groups, 0.75 T magnetic field increased the pH by 0.13, 0.34 and 0.63, respectively (Figure 1). A similar comparison of pre- and post-magnetization mean pH values showed that 1.0 T magnetic field increased the pH of acidic water (pH = 6) by 1.26 but decreased the pH of alkaline water (pH = 8) by 0.38 (Figure 2).

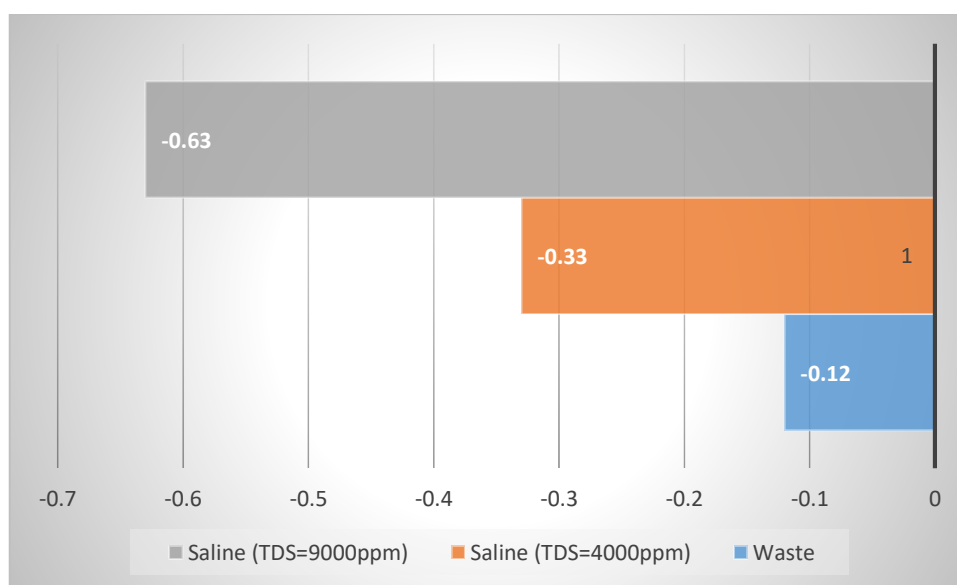


Figure (1): Effect of 0.75 T magnetic field on Mean difference of pH

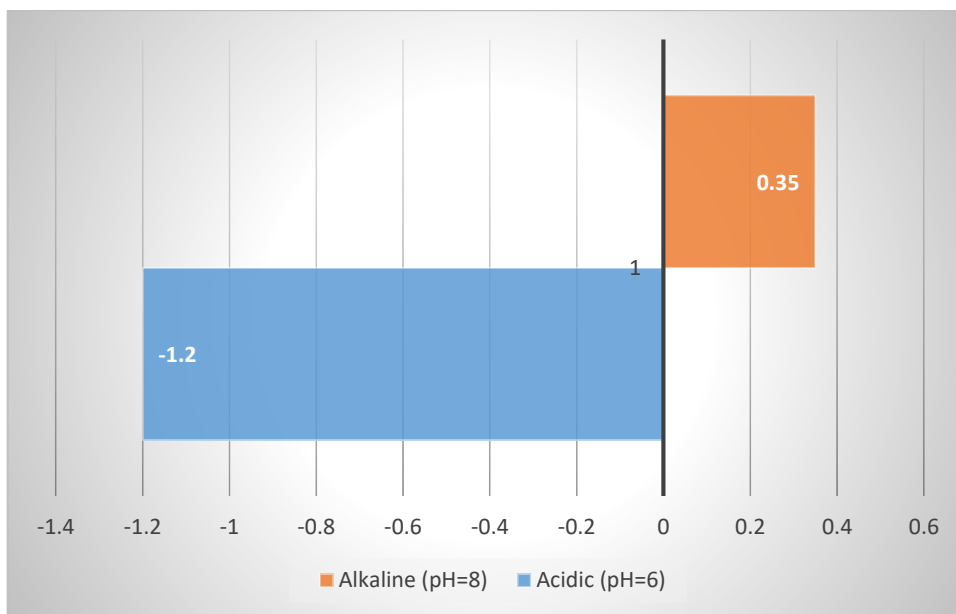


Figure (2): Effect of 1.0 T magnetic field on Mean difference of pH

3.1.2. Electrical conductivity

According to the results, the 0.75 T magnetic field significantly affected the electrical conductivity of saline water (TDS=4000mg/l), saline water (TDS=9000mg/l), acidic water (pH=6), and acidic water (pH=6.5) treatment groups. These results also showed the significant effect of 1.0 T magnetic field on the electrical conductivity of waste water, saline water (TDS=4000mg/l), and saline water (TDS=9000mg/l) treatment groups. The comparison of pre- and post-magnetization mean EC values showed that the 0.75 T magnetic field decreased the mean electrical conductivity of saline water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment groups by 2340 μ s/cm

and 4236.34 μ s/cm, respectively (Figure 3). The same comparison for the 1.0 T magnetic field showed that this field also decreased the mean electrical conductivity of saline water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment groups by 1510 μ s/cm and 1883.33 μ s/cm, respectively, but increased the mean electrical conductivity of waste water by 289 μ s/cm (Figure 4). The comparison of pre- and post-magnetization mean EC values also showed that the 0.75 T magnetic field increased the mean electrical conductivity of acidic water (pH=6) and acidic water (pH=6.5) treatment groups by 28.9 μ s/cm and 1.74 μ s/cm, respectively (Figure 5).

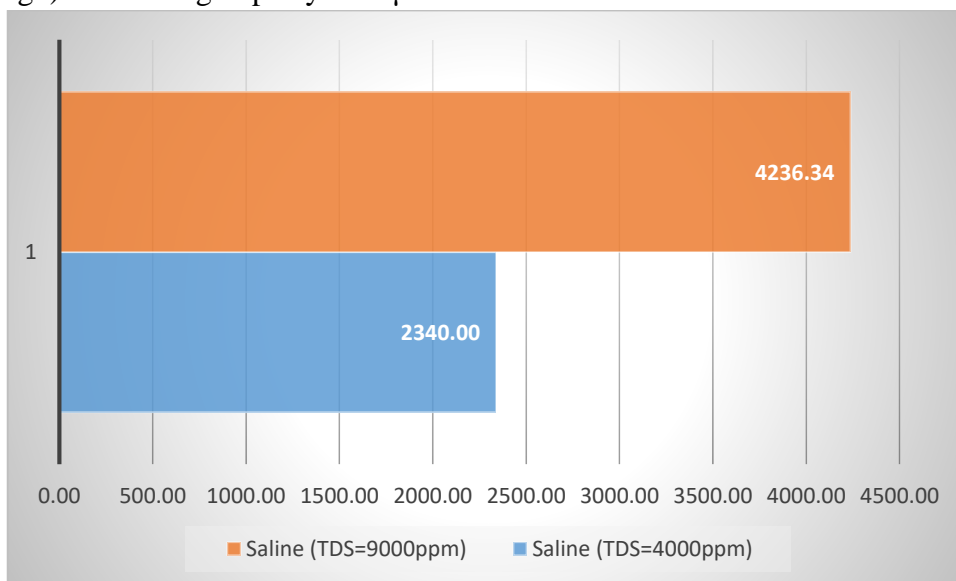


Figure (3): Effect of 0.75 T magnetic field on electrical conductivity (Mean difference)

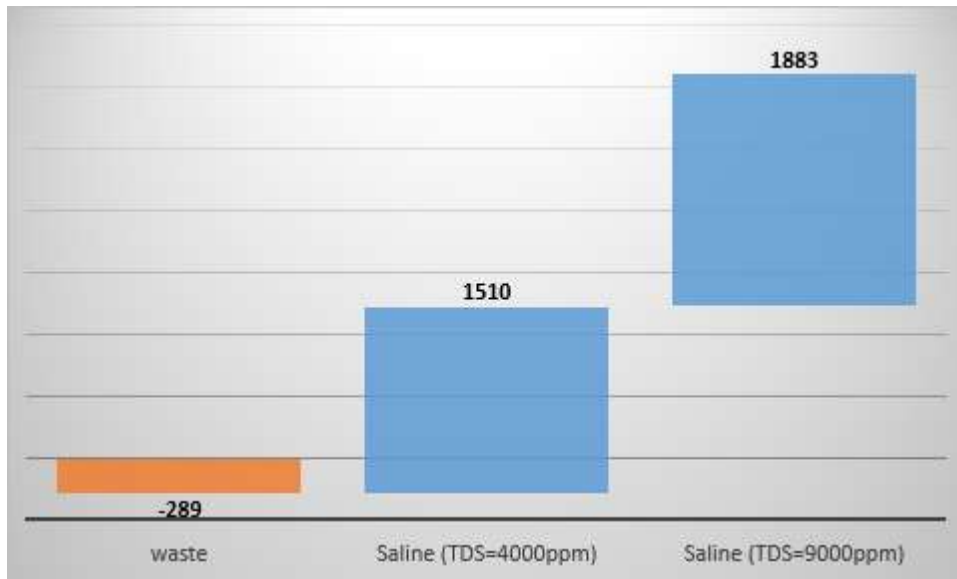


Figure (4): Effect of 1.0 T magnetic field on electrical conductivity(Mean difference)

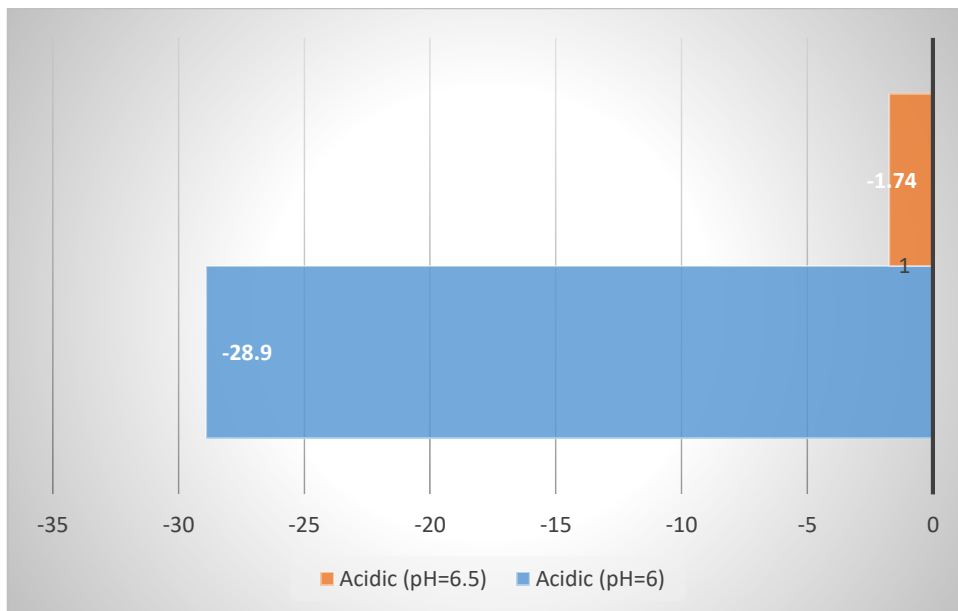


Figure (5): Effect of 0.75 T magnetic field on electrical conductivity

3.1.1. TDS concentration

The results of paired t-test for the TDS concentration of minerals dissolved in the waters subjected to 0.75 and 1.0 T magnetic fields are presented in Tables 1 and 2. As shown in these tables, the 0.75 T magnetic field significantly affected the TDS concentration of saline water (TDS=4000mg/l), saline water (TDS=9000mg/l), acidic water (pH=6), and acidic water (pH=6.5) treatment groups, and the 1.0 T magnetic field had a significant impact on TDS concentration of waste water, saline water (TDS=4000mg/l), and saline water

(TDS=9000mg/l).

The comparison of pre- and post-magnetization mean TDS concentrations showed that in waste water, saline water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment groups, the 0.75 T magnetic field decreased the TDS concentration by 100mg/l, 1497.67mg/l, and 2705.47mg/l, respectively (Figure 6). The comparison of pre- and post-magnetization values of TDS concentration showed that the 1.0 T magnetic field decreased the TDS concentration of saline water (TDS=4000mg/l) and saline water (TDS=9000mg/l) treatment

groups by respectively 966.2mg/l and 1205.33mg/l, but increased that of waste water by 171.02mg/l (Figure 7). A similar comparison revealed that in acidic water (pH=6) and acidic

water (pH=6.5) treatment groups, the 0.75 T magnetic field increased the mean TDS by 1.12mg/l and 18.48mg/l, respectively (Figure 8).

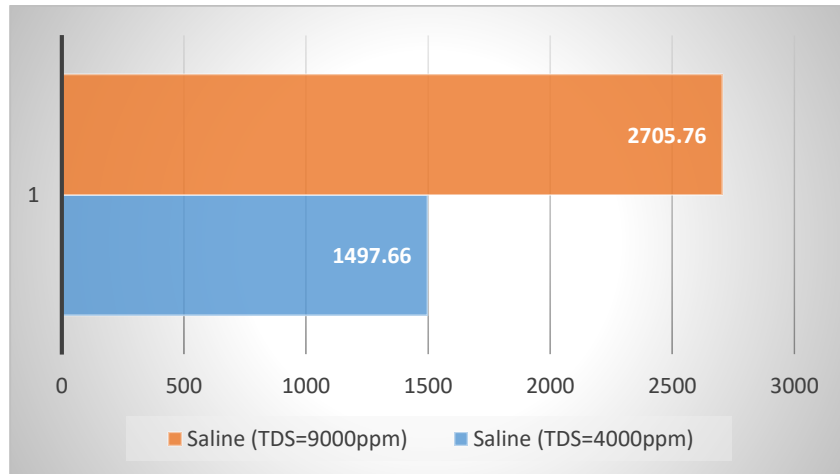


Figure (6): Effect of 0.75 T magnetic field on TDS concentration

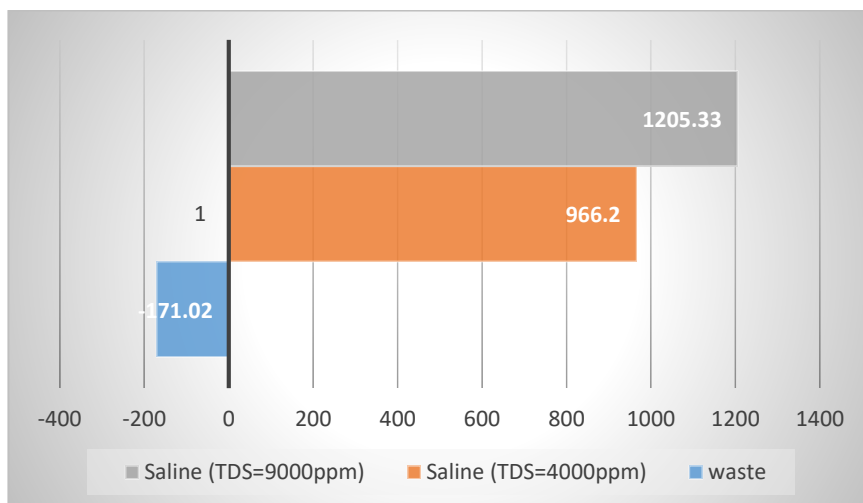


Figure (7): Effect of 1.0 T magnetic field on TDS concentration

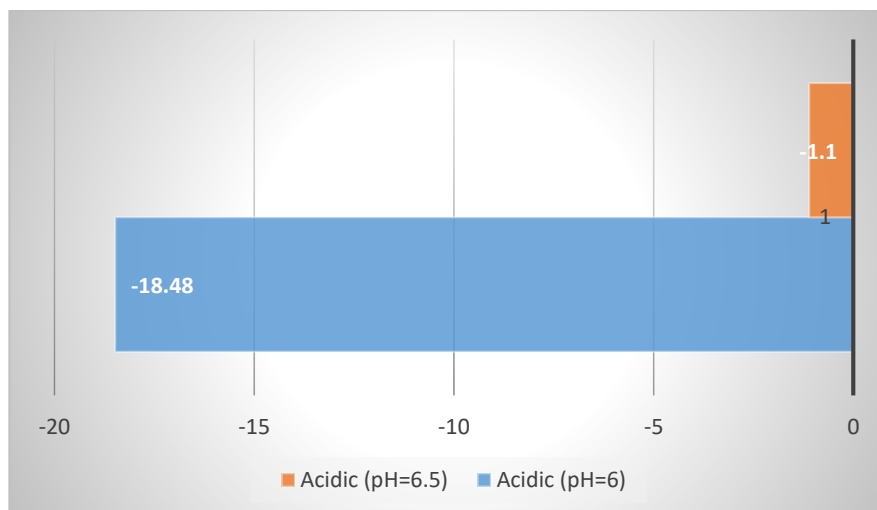


Figure (8): Effect of 0.75 T magnetic field on TDS concentration

The results of paired t-test showed that magnetic fields had no significant impact on sodium content, calcium content, and total hardness. Comparison of means revealed that in the saline water (TDS=9000mg/l) treatment group, the 0.75 T magnetic field reduced the

magnesium content by 3.8mg/l and 1.0 T magnetic field reduced it by 4.87 mg/l. Finally, Figure 9 shows the count of changes in the characteristics of each type of unconventional water.

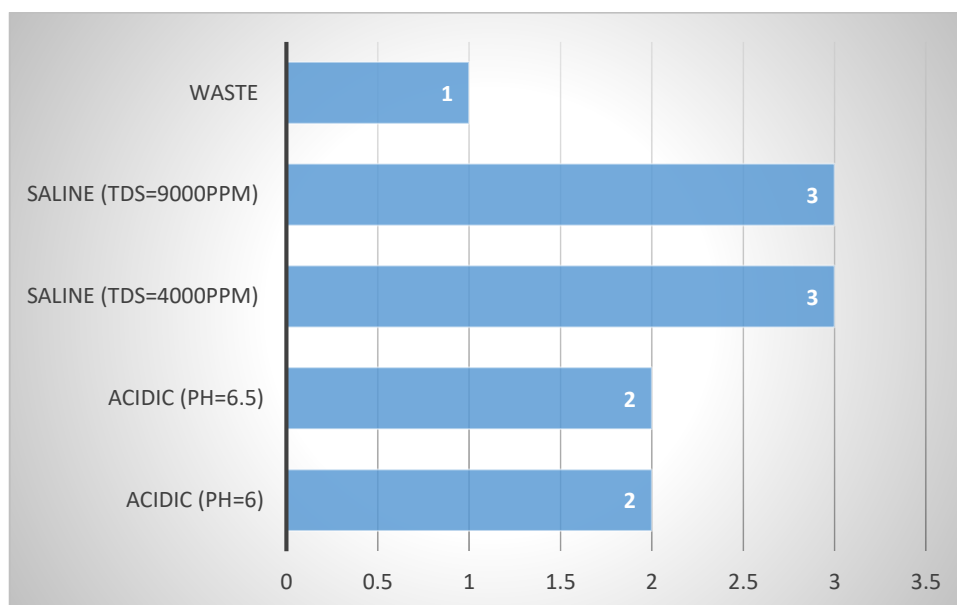


Figure (9): Count of Mean difference by Water Type

4. Discussion

That the results of this study indicate that magnetic field should increase the pH of all types of unconventional water except the alkaline ones. Firoozabadi has also reported the same result (Ghadami Firoozabadi, 2016), but Peterson and Gudiger have reported a decrease in water acidity following the exposure to magnetic field (Patterson and Chestnutt, 1994; Gudigar, 2013). In these studies, the magnetic field has been weaker than 0.75 T. Thus, this difference in findings can be attributed to the use of stronger magnetic fields and therefore stronger polarization of water in the present study. According to the results, magnetic field is effective in reducing the electrical conductivity of saline water but increases the conductivity of other unconventional waters. Also, the 0.75 T magnetic field was found to have a stronger conductivity reduction impact than the 1.0 T field. It can be argued that in the saline water

solutions, which were produced only with NaCl and contained only one type of positive and negative ion, the strong magnetic field has resulted in more regular ion arrangement and therefore reduced electrical conductivity. The increase in electrical conductivity of other water samples can be attributed to the irregular arrangement of different ions in these solutions and the difference in the way that these arrangements are affected by the magnetic field. The reduction in the electrical conductivity of saline water samples indicates that the passage of water through a magnetic field facilitates the combination of active ions into micro-colloidal particles. This reduces the electrical conductivity of water (Ghadami Firoozabadi, 2016), which results in reduced osmotic pressure and easier absorption of water by the root. Moreover, the passage of water through the magnetic field breaks the hydrogen and Van der Waals bonds between water molecules, leading to decreased surface tension and

therefore increased mobility and freedom of movement for water molecules, which ultimately result in improved fluidity and solvent property (Cai and et al., 2009). This finding, i.e. the reduction of electrical conductivity of saline water due to magnetic treatment, is consistent with the reports of Zangeneh (Zangeneh Usefabadi and et al., 2012) and Bogatin (Bogatin and et al., 1999) for magnetically treated irrigation water, and the finding of Holysz (Holysz and et al., 2007) regarding the effect of the static magnetic field on water in similar kinetic condition. The experiments of Saliha (2005) in relation to the effect of magnetic field on physical and chemical properties of soil also showed a significant decrease in electrical conductivity and pH of treated saline samples, which confirmed the utility of magnetic water for dissolving and leaching salts (Saliha, 2005). Szczes and et al. (2011) also report that magnetic fields reduce the electrical conductivity of water at a rate that is inversely proportional to the flow ratesz (Szczes and et al., 2011).

Considering the decrease in TDS concentration of minerals in treated saline and waste water samples and the direct relationship of this concentration with electrical conductivity, the results deduced for the electrical conductivity can be extended to this parameter. The effect of magnetic field on water properties is due to its impact on the structural order of water molecules (Higashitani et al., 1992). Because of the polar nature of water molecules, the forces induced by the exposure to magnetic field draw the oppositely charged poles of these molecules and realign them into a more irregular structure, which occupies less space. Thus, water magnetization increases the

number of water molecules per unit volume and improves the water's cation and anion absorption capability (Alireza Kiani, 2008). Because of these effects, exposure of water to a magnetic field decreases the TDS concentration of its minerals and its surface tension. Our results indicated that application of magnetic field decreases the magnesium content of saline water. This result is consistent with the findings of Nikbakht (Nikbakht and et al., 2013) Coy and Stephen (Coe and Cass, 2000),

5. Conclusion

The 0.75 T magnetic field can be used to treat acidic waters so as to achieve a greater level of neutrality. Although the acidity of other unconventional waters can also be altered in the same way, this method cannot be used to improve their quality. In the case of waste waters, magnetic fields can improve the quality if pH is low (acidic). Exposure to a 0.75 T magnetic field reduces the electrical conductivity (EC) of saline waters, but increasing the strength of the magnetic field to 1.0 T does not result in a higher salinity reduction. Neither 1.0 T nor 0.75 T magnetic fields have a positive effect on the quality of other unconventional waters in terms of electrical conductivity. The results indicate that exposure to a magnetic field can alter some properties of unconventional waters and thus improve the water quality.

6. Acknowledgement

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