

## THE EFFECT OF MAGNETIC FIELD ON WATER HARDNESS REDUCING

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### ABSTRACT

In this study magnetic field intensities of zero Tesla (as a witness), 0.05 Tesla, 0.075 Tesla, and 0.1 Tesla, were examined. Also, it has chose amounts of water influent 4lit/h and 30lit/h. With doing examination by 3 times and analyze the results with SAS software, have shown that changing magnetic field intensity, amounts of water influent, and also together influence there factors, have significant effects at level of 99 percent on reducing of water hardness. In the other way, for finding their mechanisms, analyzes done by X ray. Calcium carbonate exists in two forms, calcite and aragonite. But the main form of sediment is calcite. Results showed that amount of aragonite in compare with calcite, by attention to situation, increased 70 percent to 99.99 percent and ratio between calcite/aragonite had a main reducing.

**Keywords:** magnetic field, water hardness, calcite, aragonite.

### 1. INTRODUCTION

The water hardness is one of the most important of propounded cases on water treatment, specially consumed water on industrial. In principle, the water that is flowing in surface land or saving in subsurface land, for the reason that passing from various levels, that have contain the cations and anions of Calcium and Magnesium, informing of carbonate, hydrogen carbonate or sulfate, is comprising the various salts, that the part of pertain to  $Ca^{2+}$  and  $Mg^{2+}$ , is call water hardness (Habibi [12]).

Determinate of water hardness is necessary experiment for assess the water quality on industrial and domestic parts. In industrial part, is important accomplishing this experiment, for the reason that hard water, while heating make, sediment the calcium carbonate, and consequently to closed the tubes (Tavasoli & Khalili [28]). The most current matter that has made sediment on carbonate water and non-carbonate water in dry zone and half-dry zone is sediment of calcium carbonate. The most important

factors on emitter obstruction is carbonate (Alizadeh [2]) and sulfate of calcium and magnesium (Alizadeh & Khiabani [3]). To take care of magnetic science, has started by observation some of mineral stones, that to be able attracting iron particles. Origin of magnetic word is Magnesia zone that is situated in Asia, and knew mentioned above mineral stone on there, that named Magnetic. Magnetic field is importing deviated force on portable electrical charge (Alghabi et al [1]). Indicated results of some research that, magnetic field, changing the process of sedimentation calcium carbonate (Fathi et al [7]). Magnetic treatment has been employed for more than a half century. The first commercial device was patented in Belgium in 1945 (Vemeiren [29]). Powerful electromagnets were used in hot water systems since the 1960s in the Soviet Union (Grutsch [10]). The application of magnetic treatment was reported in the United States since 1975 (Grutsch & McClintock [11]). The phenomenon of water treatment with an applied magnetic field has been known for many years and has been reported as being effective in numerous instances (Kobe et al [15]). Despite its ubiquity this science, there is relatively little scientific literature on magnetic water treatment. It is not clear how or even if, it works (Coey & Cass [6]). In many industrial processes, that use natural water supplies scale formation is a common and costly problem. Magnetic water treatment (MWT) plays an increasing important role among chemical water conditioning methods regarding scale control and amelioration of dispersion separations (Lipus et al [18]). The laboratory-based study tested the effect of treating solutions and particulates of  $\text{CaCO}_3$  and showed that a repeatable magnetic effect on precipitation is observed (Kney & Parsons [14]).

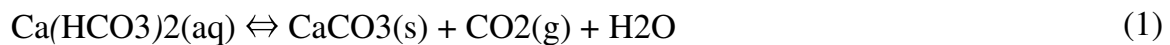
In many cases, the field is delivered by permanent magnets in various geometrical configurations. Several devices are based on AC or pulsed fields (Oshitani et al [24]). Ferreux assumed that the free enthalpy of calcium carbonate formation would be modified by the magnetic field (Ferreux [8]). The scaling power of the treated water was estimated through an electrochemical scaling test (Gabrielli et al [9]).

Lundager Madsen has concluded that the field accelerates the crystallization of sparingly soluble diamagnetic salts of weak acids such as carbonates and phosphates. He suggested that MF is able to change the orientation of the proton spin and to disturb dehydration phenomena by hindering the transfer of the proton to a water molecule (Madsen [19] & Madsen [20]). The magnetic field (MF) would be able to disturb the double ionic layer surrounding the colloidal particles and their zeta potential (Parsons et al [26]). Recently, it has been shown that the profile of the flow of a conducting solution in a pipe is perturbed when a magnetic field is applied (Martemianov & Sviridov [21]). The magnetic treatment has a significant effect on water quality of irrigation (Bogatin [4]). Enhancement of coagulation by particle alignment has been considered and demonstrated an increased rate of aggregation, as determined by sediment weight, from treating a static solution with magnetic field (Wang et al [31]). Results show that the compressive strength of mortar samples mixed with magnetic water of 0.8 – 1.35 T increased 9-19 % more than those mixed with tap water (Nan Su et al [23]). However, if magnetic water is used instead, water molecules can easily penetrate into the cement particles, allowing a more complete hydration process to occur and enhancing the mechanical strength of concrete (Wang [30]).

The following are the most recognized benefits of magnetic water treatment for various water-using equipments:

- Prevents pollution
- Reduces energy
- Conserves water
- Saves time and money
- Lengthens service life of existing fluid movement equipment
- Eliminates existing chemical cost to inhibit scale
- Reduce the need for periodic acid cleaning
- Increasing protection against corrosion within the system
- Eliminates continual operating cost as compared to chemical system (Brower [5]).

Using magnetic water treatment, industrial and agriculture processing will change, and foods, cosmetics and sanitation, etc. might be improved (Otsuka & Ozeki [25]). As the solubility of CO<sub>2</sub> gas decreases with increasing temperature or decreasing pressure, the solution tends to restore the equilibrium (1) by the shift toward CaCO<sub>3</sub> precipitation (Lipus & Dobersek [17]).



Precipitated CaCO<sub>3</sub> may be a mixture of various phases: crystalline phases, amorphous and hydrated phases. The crystalline phases are:

- Calcite (with trigonal structure, usually in form of rhombohedral crystals),
- Aragonite (with orthorhombic structure, often in form of needle-like crystals) and
- Vaterite (with hexagonal structure, often in form of spherical crystals) (Lippmann [16]).

Among these phases calcite is thermodynamically the most stable at ambient temperature and atmospheric pressure (Rudert & Müller [27]).

The most abundant cation to formed calcium carbonate soils crystal, is calcite and aragonite, that aragonite is permanent half in compare of calcite [Table 1] (Karimian [13]).

**Table 1: Equilibrate Constant of aragonite and calcite (temperature of 25° and pressure of 1 atmosphere)**

Log K <sub>s</sub> <sup>o</sup>	Reaction	Material
-8.22	$\text{CaCO}_3(\text{s}) \rightleftharpoons \text{Ca}^{2+} + \text{CO}_3^{2-}$	Aragonite
-8.35	$\text{CaCO}_3(\text{s}) \rightleftharpoons \text{Ca}^{2+} + \text{CO}_3^{2-}$	Calcite

Aragonite has a orthorhombic system and organized of pure calcium carbonate. Calcite has crystallized in orthorhombic class and hexagonal system. Chemical stability of calcite is more than aragonite (Musavi Herami [22]).

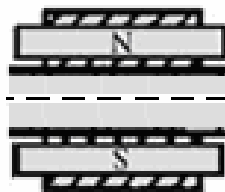
Target of this research is survey of magnetic field effects on changing of water hardness. This research has considered effect of changing of magnetic field intensity, and amount of water influent on water hardness reducing.

## 2. MATERIALS AND METHODS

In order to survey of magnetic field effect on hardness water reducing, has done water treatment experiment in present of magnetic field, in Water Quality Laboratory (Agriculture Faculty).

### 2.1. The method of preparing magnetic field

This device is containing of seven U shape magnet, with north pole and south pole (Figure 1), That have consoled in form of same axis and is create length equal 25 cm on the magnetic field.



**Figure 1: Sample of magnet with north pole and south pole**

This magnet is formed from central nucleus that has twisted of copper suggested armature with determining round number on that. It has used from 300 gram copper wire, for each magnet, in such a manner copper wire has twisted as handmade round of central nucleus.

For being the work, calculated magnetic field intensities on Electronic Laboratory in Bu-Ali-Sina University. For measuring magnetic field intensity of each magnet, we used the magnetic balance. The magnetic field intensity of magnets is calculated by reading the magnetic balance force (equation 2).

$$B = \frac{F \times 10^{-5}}{i \times L} \quad (2)$$

In this equation:

$B$  is a magnetic field intensity according to Tesla,  $F$  is a read force amount by magnetic balance (that calculated according to Newton by to multiply on  $10^{-5}$ ),  $i$  is a flow intensity on magnetic balance according to Amperes,  $L$  (according to cm) is length of part of balance that magnet is consoled on this part. In this balance  $L$  equivalent is 2 cm and  $I$  is equivalent 1 Amperes that worked with voltage of 5 V. Also, hinder this system in order to prevent of warmth interchange with environment.

## **2.2. Samples**

Because has accomplished experiments on 4 level of magnetic field intensity, 2 level of water influent; it has take action of factorial plan  $4 \times 2$ . Then we analyzed data by drawing of connected tables. Statistical accounts have done in this research by SAS software and also analyzed by X-ray. Then drew connected graphs, careful of results. It is necessary to say that we do not publishing all graphs, for the reason that has a limited on number of article pages.

### **2.2.1. Magnetic field intensity**

In order to study effect of magnetic field intensity in experiment, selected 4 level of magnetic field intensity, with zero Tesla (as a witness), 0.05 Tesla, 0.075 Tesla and 0.1 Tesla, or, in other word, in order to compare, has done experiment without magnetic field as a witness.

### **2.2.2. Amount of water influent**

In order to survey effect the amount of water influent on results, has done experiments on 2 level of water influent (with amount of 4 and 30 lit/h).

## **2.3. Experiment**

In order to reduce error and increase carefulness coefficient on experiment, all the experiment has been repeated 3 times.

Indicated to accomplish states of experiment in presence, various intensity of magnetic field, amount of water influent, (Table 2).

**Table 2: Process of experiment**

Number the repeat	Water influent (Lit/h)	Intensity of magnetic field (Tesla)	Process of experiment
3	4	Zero( as a witness)	1
3	30	Zero( as a witness)	2
3	4	0.05	3
3	30	0.05	4
3	4	0.075	5
3	30	0.075	6
3	4	0.1	7
3	30	0.1	8

Calculated treatment efficiency after done experiments by equation (3), that  $[H]_i$  is hardness of water sample before magnetic treatment and  $[H]_f$  is hardness of water sample after magnetic treatment.

$$E_m = \frac{[H]_i - [H]_f}{[H]_i} \times 100 \quad (3)$$

#### 2.4. Water chemical analyze by X-ray

Studied form of crystals and sediment of calcium carbonate in presence of magnetic field in order to consider of process of sediment on water flow systems. This measuring has done on Geology laboratory of Bu-Ali-Sina University.

Target of this work, was study of particles size and particles number of calcium carbonate that existed on water sample and also kind of particles that were available in water in forming of aragonite and calcite. Device X-ray used in this experiment was Cu k  $\alpha$ , Ital structure and worked by copper lamp. The vertical axis on drawn graphs in article is intensity and horizontal axis is twice as much of  $\theta$  angle that is called background, usually. Analyze have done in limited of  $2\theta$  angle, from 5 angle until 60 angle in steps of 0.1. In total, 5501 repeats and drawing graphs by Excel software have been done.

#### 2.5. Consideration of crystals by using of electronic microscope

In order to study of calcium carbonate crystals before and after magnetic treatment considered pictures by electronic microscope.

### 3. RESULTS

It has been organized factorial plan in order to analyze of water hardness reducing in presence of magnetic field, and consideration any factors of magnetic field intensity, water influent, and also reciprocal effect this factors, and inserted results in table 3. According the results of Table 3, inference that the effect of magnetic field intensity factor and amount of water influent, on magnetic field, on water hardness reducing, had a meaning in level 99%. Also reciprocal affect this factor together has been mean in level 99%. It mean that, when the other factors is constant, to be different water hardness reducing amount, in comparison different levels any remainder factor, and it will show manifest different. It has used from Dankan test in order to recognition different samples. Inserted on Table 4 resulted of Dankan test for water hardness reducing in level 99%. In this table has not manifest different together, samples that have a common letter at least.

**Table 3: Variance analyze for factorial plan of water hardness reducing**

SV (changing source)	df	SS (sum of squares)	MS (average of squares)	Pr > F
Intensity of magnetic field	3	13052.04	4350.68	**
water influent	1	65.30	65.30	**
Intensity of magnetic field × water influent	3	40.71	13.57	**
Error	16	0.057	0.0035	
Total	23	13158.12		

In Table 3, F is an intensity of magnetic field and R is a amount of water influent. According to Table 4, it showed Dankan test results, the least of efficiency in case witness sample (without magnetic field)with zero Tesla, is zero percent and greater of efficiency in sample with intensity of magnetic field 0.1 T and amount of water influent 30 Lit/h.

**Table 4: Results of Dankan test for water hardness reducing**

		Intensity of magnetic field (Tesla)					
Without MF	Without MF	0.05	0.05	0.075	0.075	0.1	0.1
		Water influent (Lit/h)					
4	30	4	30	4	30	4	30
F	F	E	D	D	B	C	A

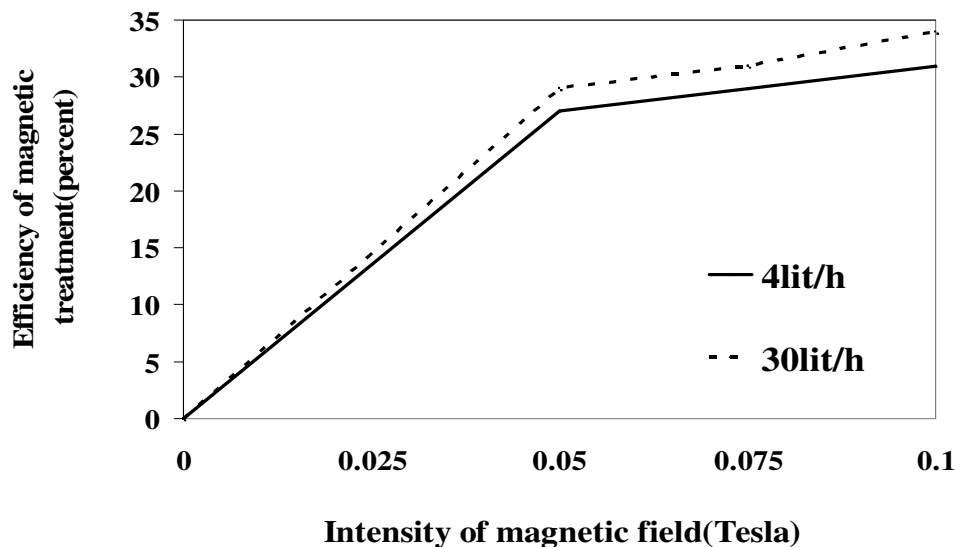
In this table has not manifest different together, samples that have a common letter at least.

### 3.1. Role of magnetic field intensity in efficiency of magnetic treatment

Results from all graphs show that the efficiency of magnetic treatment is zero, when there is no magnetic field. It has changed the efficiency of magnetic treatment when to consoled water in magnetic field. Also, in the same manner, it will increase the efficiency of magnetic treatment, when magnetic field intensity is increasing.

### 3.2. Role of amount of water influent on magnetic treatment efficiency

Efficiency of the treatment increased with increasing of amount of entrance of water flow from 4 until 30 lit/h (Figure 2). We can say that increasing the amount of enter water flow is occasion the water flow is turbulence and is a whirlpool situation that due to reduced sediment of  $\text{CaCO}_3$ .



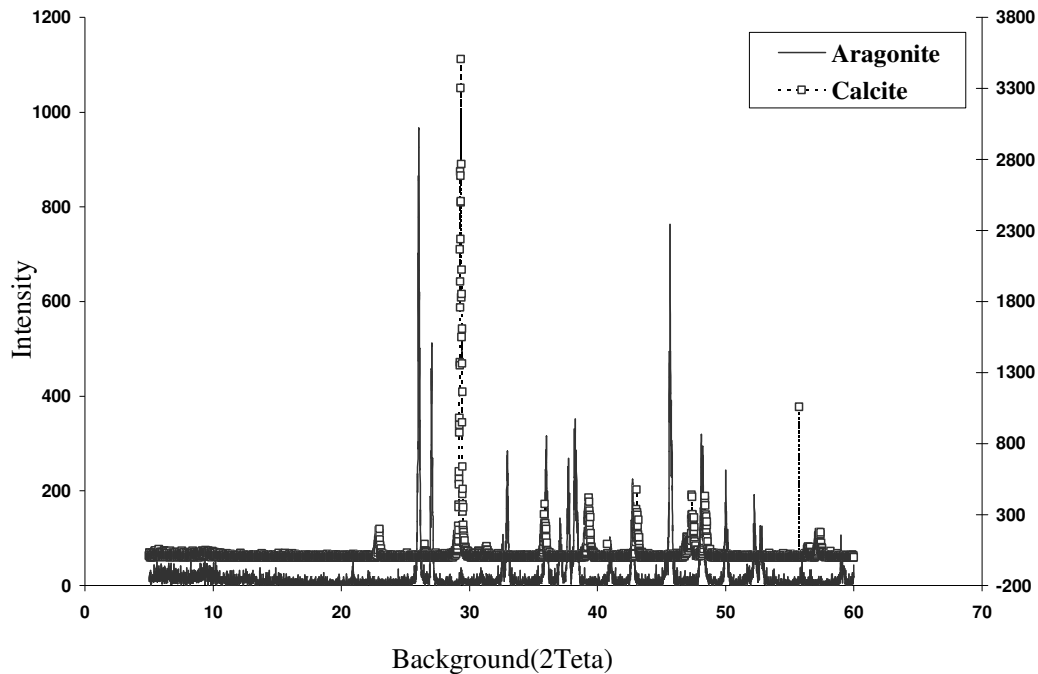
**Figure 2: The comparison of water hardness reducing in presence of MF and without MF in states of various water influent**

### 3.3. Results of chemical analyze by X-ray

Result of chemical analyzes by X-ray shows that in presence of magnetic field, produced aragonite more than calcite. The experiments show that the amount of aragonite in sediment of  $\text{CaCO}_3$  has increased to 70 percent and this increased is to 99.99 percent according to magnetic field intensity and other factors and situation. The



results of X-ray show that  $\text{CaCO}_3$  in form of calcite and aragonite usually is available. In non-magnetic water is available  $\text{CaCO}_3$  in stable situation, instate of calcite crystal, after magnetic treatment it had reduced the size and greater particle number. Down drainage to ensue of X-ray have analyze in Figure 3.

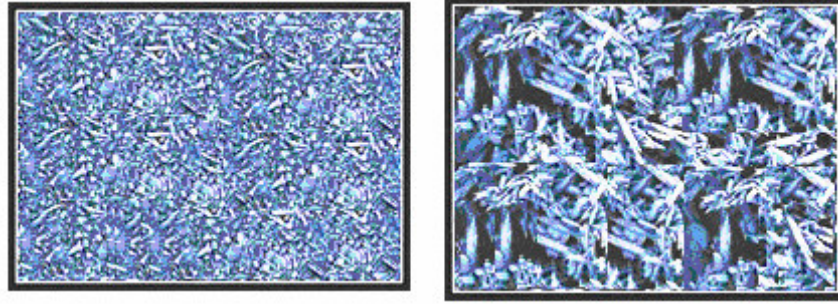


**Figure 3: Results of X-ray before and after of magnetic treatment (above graph is before MT and blew graph is after MT)**

The peck has consoled on background of 29-30 in case calcite, and the peck in case of aragonite, has consoled on other background (other than 29-30). In the same manner that seen the chief of sediment it was calcite before magnetic treatment and it changed to aragonite after magnetic treatment. The reason of non-sediment and increasing of water hardness is transformation of  $\text{CaCO}_3$ .

### 3.4. Results of electronic microscope

It has seen the accruing picture of electronic microscope in Figure 4. This picture shows the crystals of  $\text{CaCO}_3$  that was found in form of calcite on hard water. in the picture of right side shown the smoother and clarifier, that is aragonite in left side picture, that productive after crossing of magnetic field. This crystals do not stick together and do not stick itself on walls of tube and device, and crossing from among them simplicity and non-determinate.



**Figure 4: Crystals of calcium carbonate (before and after MT)**

#### **4. CONCLUSION**

Experiments have shown that the magnetic field affected on water quality and that production of magnetic water has an ability on water hardness reducing until 51 percent. The factors of magnetic field intensity, situation of magnets setup, amount of enter water flow and enter water hardness has a significant effects on water hardness reducing and increasing of treatment efficiency in level 99 %. Increasing on amount of enter water flow and increasing on magnetic field intensity, has culminated in increasing efficiency of treatment, and in results, reduced of water hardness. Setup of magnets inform of inversion, shown increasing the efficiency rather than state of non-inversion. The results of water chemical analyze shown that after magnetic treatment, has reduced size and greater particles number.

The magnetic treatment has increased amount of aragonite in sediment of  $\text{CaCO}_3$  to 70 percent. This increase is being to 99.99% according to the magnetic field intensity and other factors.

Advantage of this treatment is avoiding the using of dangerous chemical materials and expensive for human and environment. With magnetic water (without adding any acid, chemical materials and poisonous materials to water) sediments of available on surface in touching with water (that they built-up since before), removal, and also avoid of making the new sediments.

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