Journal of Engineering and Applied Sciences 14 (Special Issue 2): 5522-5526, 2019
ISSN: 1816-949X

Laboratory Investigating of Magnetic Treatment Influence on Groundwater Characteristics

[1]Ahmed Samir Naje, [2]Hussein A.M. Al-Zubaidi, [3]Zaid Abed Al-Ridah and [4]Isam M. Ali
[1]Department of Architect Engineering, College of Engineering, Al-Muthana University, Al-Muthana Governorate, Iraq
ahmednamesamir@yahoo.com; +9647811468383
[2]Department of Environmental Engineering, College of Engineering, University of Babylon, Babylon, Iraq
[3]College of Water Resources Engineering, Al-Qasim Green University, Babylon, Iraq
[4]Karbala Technical Institute, Al-Furat Al-Awsat Technical University, 56001 Karbala, Iraq

Abstract: This study explored the impact of magnetic treatment on groundwater characteristics such as total hardness, Total Dissolved Solid (TDS), Calcium ions (Ca^{2+}) and Ferrous ions (Fe^{2+}). About 15 L of groundwater was introduced to a closed system through the 20 mT Direct Current (DC) magnetic fields and was pumped at a consistent rate of 10 m/sec and the circulation time of 5 h. The total hardness was determined by EDTA titration method while TDS was measured by TDS meter. The compositions of Ca^{2+} and Fe^{2+} in the water were investigated by Atomic Absorption Spectrometer (AA Spectrometer). The results showed a reduction in the chemical properties of the groundwater. The total hardness, TDS and Ca^{2+} and Fe^{2+} in the water decreased to 41, 60, 89 and 24%, respectively with an increase in the circulation time.

Key words: Ground water, hardness, magnetic water treatment, TDS, water modeling, absorption

INTRODUCTION

Life has no survival without water. Groundwater, canals, lakes, rainwater, reservoirs, canals, fog condensation and sea water are the major sources of water on Earth (Ambashta and Sillanpaa, 2010). The proper utilization of groundwater is very important and which is in general used for drinking, industry and irrigation in semiarid and arid areas. One of the major contributions of the groundwater is its provision to the local communities for daily life, their crop and diary production for a sustainable growth (Liu *et al*., 2015). The issue related to the groundwater is the presence different substances and salts like calcium, sodium and magnesium. Salts of magnesium and calcium cause the hardness of water. In general, metal cations of magnesium and calcium are found in hard water. Depending on the region, ions of aluminium, iron, manganese or other heavy metals which are soluble, may also be present. As the concentration of these metals keeps increasing, they reach the saturation level and there is a chance that metals start precipitating out on the water. The Ca^{2+} contents show the qualitative hardness of the water which generally is observed as 1-5 mmol/L of the water. Ca^{2+} is usually generated from the limestone. Although, hard water is not associated with any major health issues, it creates difficulties for the household consumption for instance scaling of the heating elements resulting in the pipe congestion, shortening the life of heating devices and enhances energy requirement. Open literature shows a wide range of traditional methods of water softening and minimization of scale through chemicals methods and addition of corrosion inhibitors, scale inhibitors and fungicides in circulating water (Jiang *et al*., 2015).

Typical methods for water softening include but not limited to ion exchange, lime softening, reverse osmosis and magnetic treatment. Traditionally ion exchange has been used for water softening which in general involves the exchange of sodium or potassium ions on the expense of calcium and magnesium ions. Salt beds of sodium ions are used for this purpose and water flows over them resulting an ion exchange. The regeneration of sodium ions is carried out once they are saturated with calcium and magnesium ions. The regeneration of sodium beds is conducted using water, either by circulating the soft water or soaked the bed in the water. As the beds get soaking in brine, the calcium and magnesium ions are stripped from them and replaced with sodium ions. To run a cycle, the higher efficacy was observed for chemical treatment method which brought about secondary pollutants

Corresponding Author: Ahmed Samir Naje, Department of Architect Engineering, College of Engineering, Al-Muthana University, Al-Muthana Governorate, Iraq, ahmednamesamir@yahoo.com; +9647811468383

(Fathi *et al*., 2006). On the other hand, physical methods are expensive and injurious to human health and environment (Tijing *et al*., 2011). Aviable alternative to chemical and physical treatment is magnetic treatment which is cost effective and efficient at domestic and industrial level without penalizing the environment (Guo *et al*., 2011). Currently, magnetic treatment has attracted the attention of researchers. In magnetic separation, magnetic effect engenders weaker interaction between water molecules and ions which leads to the higher contact ion pairs increment and reduces the solvent separation pairs (Guo *et al*., 2011). Magnetic treatment helps improve the calcium ions, magnesium and diffusion coefficients of sodium and reduce the anions diffusion coefficients. Kotb (2013) experimentally investigated the effect of magnetic treatment on pH, TDS and hardness of water using water flows in closed loop with magnetic flux density of 1.7 mT. They reported an increase in pH while the hardness of water and TDS are not significantly influenced by the magnetic treatment. The magnetic treatment is gradually used in industry due to beneficial effect, low cost and the absence of secondary pollution. Calcium carbonate scaling is one of the most common fouling methods found in cooling water applications. Therefore, the objective of this study is to investigate the effect of magnetic treatment on the total hardness, TDS, Ca^{2+} and Fe^{2+} in groundwater using closed loop flow together with the magnetic field.

MATERIALS AND METHODS

Magnetic water treatment: Magnetic water treatment is a technique which involves passage of hard water through a magnetic field. The method is effective in minimization and removal of the scale. However, the mechanism of magnetic treatment is still unclear, even though it has been in practice for several years. The knowledge of how the magnetic field with moderately low flux density accurately alters the low magnetic minerals precipitation is yet to be developed, since, the treatment differs from renowned magnetic separations of high magnetic materials by strong magnetic fields. The presence of iron-containing constituents significantly affects $CaCO_3$ precipitation rather as a heteronucleator, even though the occurrence of magnetic fields activation is not well understood (Kozic and Lipus, 2003).

Several studies have been conducted on the effect of magnetic fields on magnetic water treatment mechanism. Their reports showed that the treatment mechanism is so complex, since, it consists of some processes which are highly sensitive to magnetic treatment regime and small charges in water composition. Furthermore, some significant factors are yet unidentified. The following factors could influence crystallization and dispersion stability. The magnetic device was fitted to water pipe via which water flows into the building. As the water passes through the pipe, it also flows through magnetic fields, some persuaded pulsating electric fields is formed inside the pipe according to Faraday's law:

$$\int \vec{E}.d\vec{s} = -\frac{\partial}{\partial t}\int \vec{B}.d\vec{A} \quad (1)$$

Where:

- $\vec{E}$ = An induced electric fields vector
- S = A line vector along the circumferential direction
- $\vec{B}$ = A magnetic fields strength vector
- $\vec{A}$ = The solenoid coil cross sectional area

A coil of wire of radius R carries a current. It creates magnetic fields at a distance r from long straight wire. The magnetic fields due to a tiny segment of coil, up at top of loop is:

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{s}\times\hat{r}}{r^2} \quad (2)$$

Consider a section of solenoid of length dx, the total magnetic fields at point P which is D away from the edge of the solenoid is:

$$\vec{B} = \frac{\mu_0 InR}{2}\int_{x=0}^{x=L}\frac{d\vec{x}}{\left([D+x]^2+R^2\right)^{3/2}} \quad (3)$$

Intermolecular interaction for ions and water is giving as sum of Lennard-Jones and Columbic pair potentials given by Guo *et al*. (2011):

$$U_{ij} = \frac{q_i q_j}{r_{ij}} + 4\varepsilon_{ij}\left[\left(\frac{\sigma_{ij}}{r_{ij}}\right)^{12} - \left(\frac{\sigma_{ij}}{r_{ij}}\right)^{6}\right] \quad (4)$$

where, q_i, q_j and r_{ij} are the charges of atom i, j and the distance between them and ε_{ij}, σ_{ij} using the Lorentz-Berthelot rules. The force on atom is expressed as:

$$F_i = F_i^{pot} + F_i^{mag} \quad (5)$$

where, F_i^{pot} and F_i^{mag} denote the force from the potential force fields and external magnetic fields. The potential force fields is given by:

$$F_i^{pot} = -\nabla_i U_{ij} \quad (6)$$

The magnetic fields was treated in most common physical way and the force from the magnetic fields B is:

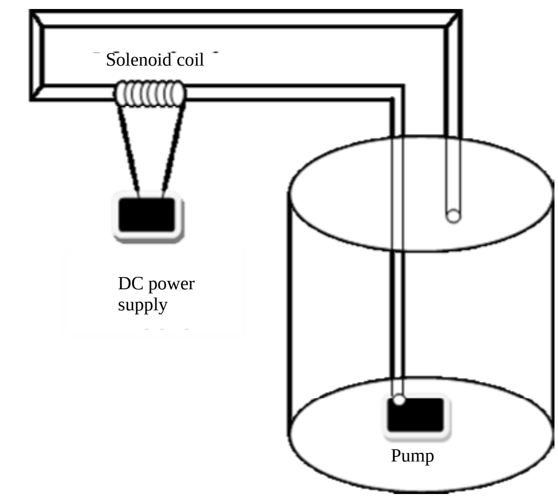

Fig. 1: System schematic design

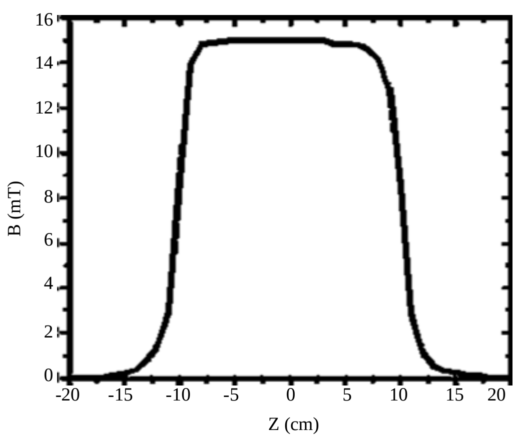

Fig. 2: The magnet fields strength from solenoid coil

$$F_i^{mag} = q_i.v_i \times B \quad (7)$$

where, v_i is the velocity of atom i

Experimental procedur: The test rig was illustrated in Fig. 1. The groundwater was pumped from 15 L tank using Jun Aquarium Pump, Model: HX-5000 which was manufactured in Hong Kong. The groundwater to be treated was passed through a 0.5-inch PVC pipe with 10 m/sec constant flow rate. The solenoid coil of length 20 cm designed to create DC magnetic fields. When 1.60 A of a direct current pass through, it creates a uniform DC magnetic fields inside. The DC magnetic field in the centre is 15 mT and the magnetic field is shown in Fig. 2. The DC magnetic field is parallel to the groundwater flow. The groundwater was re-circulated at varying time (15, 30, 45, 60, 75, 90 and 300 min).

The obtained properties of groundwater are total hardness, TDS and Ca^{2+} and Fe^{2+} ion concentration. Furthermore, EDTA titration method was used to determine the total hardness. The value of TDS can be obtained by using Eutech, Model PC700. The ion concentration of Ca^{2+} and Fe^{2+} ions was determined by using atomic absorption spectrometer with Shimadzu Model AA-6300. The treatment efficiency (ε) was obtained after the experiments using the following Eq. 8, provided that H_1 is hardness of water sample before magnetic treatment and is H_f hardness of sample after magnetic treatment:

$$\varepsilon(\%) = \left|\frac{H_i - H_f}{H_i}\right| \times 100\% \quad (8)$$

RESULTS AND DISCUSSION

Initially, the groundwater was filled in the tank. The total hardness, Total Dissolved Solid (TDS), Calcium ions (Ca^{2+}) and iron ions (Fe^{2+}) in the water of groundwater were recorded and regarded as the base line data for the groundwater properties prior to re-circulation through the system. Then the groundwater re-circulates through the system with non-magnetic treatment and magnetic treatment. Integrated method of measurements was used throughout this study all the water samples are measured and chemically analysed five times. The obtained values were statistically analysed and the average values were used as the result for each sample.

Figure 3 shows the effectiveness of the treatment on TDS with the eddy flow condition which has the magnetic fields power in red coil compare to the neutral condition in black coil. For both conditions, the TDS can be reduced. The TDS efficiency of the first case was over 35% better than that of other cases. The decrease in TDS was stimulated by the eddy flow currents which resulted in reaction of ions of related substances and formation of white sediment. The efficiency of the treatment of TDS with magnetic fields is more effective than neutron condition. The inorganic solid in the solution will be become the positively ionized (cationic) and anion (anionic). The ionization of inorganic solid and water were increased, leading to sedimentation.

Figure 4 shows the experimental investigation of the effect of magnetic treatment on TDS in relation to the hardness in groundwater. This reveals the efficiency of total hardness removal of re-circulated water vs.

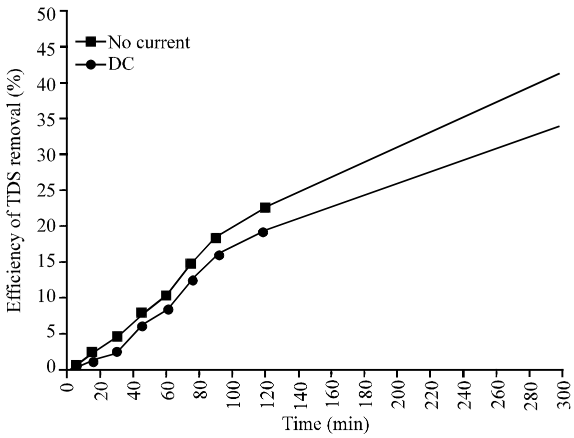

Fig. 3: Efficiency of TDS removal

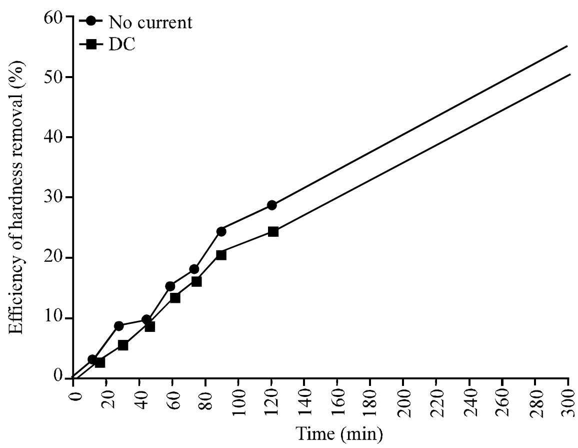

Fig. 4: Efficiency of total hardness removal

circulation time. Before circulating the water, the base line data was clearly recorded as 284.67 mg/L. After 300 min of circulating the water through the magnetic system, the hardness of water was significantly altered. Also, Fig. 4 presents the effectiveness of the treatment of total hardness with the eddy flow condition which has the magnetic fields power in the red coil compared with the neutral condition in the black coil. Both conditions can reduce the total hardness. The total hardness removal efficiency of the first case was about 60% which is better than others with efficiency about 53%. The total hardness removal ratio was ascribed to the reduction of ions in hard water. The presence of magnetic field in water will induce electric currents. The redox reactions increases amount of OH^- from water molecules as the following Eq. 9:

$$2H_2O+2e^- \rightarrow H_2+2OH^- \tag{9}$$

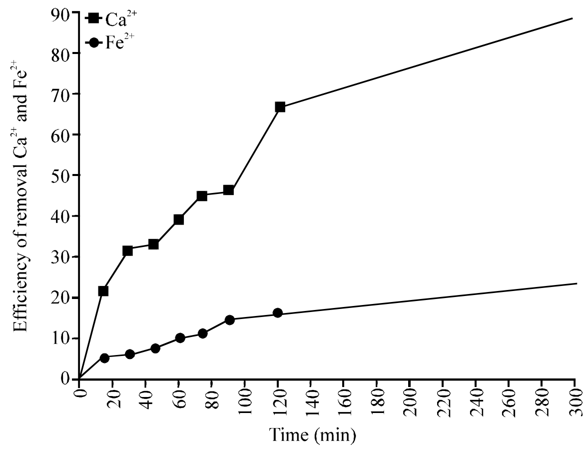

Fig. 5: Efficiency of Ca^{2+} and Fe^{2+} removal

After that Hydrogen Carbonate ion (HCO^-_3) which composition of the groundwater was reacted with OH^- to give Carbonate ion (CO^{2-}_3) by Eq. 10 and 11:

$$OH^- + HCO^-_3 \rightarrow CO_3^{2-} + H_2O \tag{10}$$

$$X^{2+} + CO_3^{2-} \rightarrow XCO_3 \tag{11}$$

where, X^{2+} is Ca^{2+}, Mg^{2+} or Fe^{2+}

Equation 11 showed reaction of Ca^{2+}, Mg^{2+} or Fe^{2+} which dissolved in groundwater and reacted with CO^{2-}_3 to form $CaCO_3$, $MgCO_3$ or $FeCO_3$ precipitate.

Hard water always contains Ca^{2+}, Mg^{2+} and Fe^{2+} ions. This research has investigated the effective of Ca^{2+} and Fe^{2+} ion treatment. These substances are usually found in groundwater in the Northeast of Thailand. The results as presented in Fig. 5, show that Calcium ion (Ca^{2+}) treatment in magnetic fields with the eddy flow condition can remove about 90% of Calcium ions (Ca^{2+}) whereas iron ion (Fe^{2+}) removal is about 20%. The removal of Ca^{2+} and Fe^{2+} onto precipitated $CaCO_3$ and $FeCO_3$ and the dissolution effect of $CaCO_3$ ($Ksp = 4.8\times10^{-9}$) is higher than that of $FeCO_3$ ($Ksp = 4.8\times10^{-11}$), leading to super saturation of the solution with respect to calcium carbonate (Raii *et al*., 2014).

CONCLUSION

The influence of magnetic water treatment on total hardness, TDS, Ca^{2+} and Fe^{2+} in the groundwater has been carried out experimentally. The total hardness was determined by EDTA titration method and the TDS was determined by TDS meter. The concentration of Ca^{2+} and

Fe^{2+} ions in hard water was obtained by AA spectrometer. The results showed that the properties such as total hardness, TDS and metal ion concentration of groundwater can be improved, especially with extended water circulation time. In addition, the dissolution effect of $CaCO_3$ is higher than that of $FeCO_3$.

ACKNOWLEDGEMENT

The researchers thank the Collage of Science Almuthana University and the Iraqi Ministry of Higher Education and Scientific Research for funding this research.

REFERENCES

Ambashta, R.D. and M. Sillanpaa, 2010. Water purification using magnetic assistance: A review. J. Hazard. Mater., 180: 38-49.

Fathi, A., T. Mohamed, G. Claude, G. Maurin and B.A. Mohamed, 2006. Effect of a magnetic water treatment on homogeneous and heterogeneous precipitation of calcium carbonate. Water Res., 40: 1941-1950.

Guo, B., H.B. Han and F, Chai, 2011. Influence of magnetic field on microstructural and dynamic properties of sodium, magnesium and calcium ions. Trans. Nonferrous Met. Soc. China, 21: s494-s498.

Jiang, L., J. Zhang and D. Li, 2015. Effects of permanent magnetic field on calcium carbonate scaling of circulating water. Desalin. Water Treat., 53: 1275-1285.

Kotb, A., 2013. Magnetized water and memory meter. Energy Power Eng., 5: 422-426.

Kozic, V. and L.C. Lipus, 2003. Magnetic water treatment for a less tenacious scale. J. Chem. Inf. Comput. Sci., 43: 1815-1819.

Liu, F., X. Song, L. Yang, D. Han and Y. Zhang *et al*., 2015. The role of anthropogenic and natural factors in shaping the geochemical evolution of groundwater in the Subei Lake basin, Ordos energy base, Northwestern China. Sci. Total Environ., 538: 327-340.

Raii, M., D.P. Minh, F.J.E. Sanz and A. Nzihou, 2014. Lead and Cadmium removal from aqueous solution using an industrial gypsum by-product. Procedia Eng., 83: 415-422.

Tijing, L.D., D.H. Lee, D.W. Kim, Y.I. Cho and C.S. Kim, 2011. Effect of high-frequency electric fields on calcium carbonate scaling. Desalin., 279: 47-53.