Influence of magnetic treatment on properties of groundwater

Somkuan Photharin[1*], Natpapat Chansakhatana[1], Rujikarn Sirival[1], Piyanuch Jaikaew[1], Arporn Srimat[2] and Udom Tipparach[3]
[1]Faculty of Science and Engineering, Kasetsart University Chalermphrakiat Sakonnakhon Province Campus, Tambon Chiang Khrua, Muang district, Sakon Nakhon Province, Thailand
[2]Faculty of Natural Resources and Agro Industry, Kasetsart University Chalermphrakiat Sakonnakhon Province Campus, Tambon Chiang Khrua, Muang district, Sakon Nakhon Province, Thailand
[3]Department of Physics, Faculty of Science, Ubonratchathani University, Warinchamrab, Ubon Ratchathani, Thailand
***Corresponding author: E-Mail: sky_ubu@hotmail.com**

ABSTRACT

The influence of magnetic water treatment on total hardness, TDS and calcium ions (Ca^{2+}) and ferrous ions (Fe^{2+}) in groundwater has carried out through an experimental study. The sample was 15 liters of groundwater which installed in a closed system though the 20 mT direct current (DC) magnetic fields and was pumped with the constant rate of 10 m/s at the circulation time five hours. The total hardness was determined by EDTA titration method, total dissolved solid (TDS) was measured by total dissolved solid meter (TDS meter) and Ca^{2+} and Fe^{2+} in the water were investigated by Atomic Absorption Spectrometer (AA Spectrometer). The results showed the chemical properties of groundwater can be reduced total hardness, TDS and $Ca^{2+}$and Fe^{2+} in the water decreased to 41.06%, 59.66%, 89.52% and 24.08% respectively when increasing of the circulation time.

KEY WORDS: Magnetic Water Treatment, Ground Water, Hardness, TDS.

1. INTRODUCTION

Water is an essential in our daily life. The major water resources include groundwater, lakes, reservoirs, canals, atmospheric water generation, rain water harvesting, fog collection and sea water (Ritu, 2010). Groundwater is one of great importance for drinking, irrigation and industry in semiarid and arid regions and even acts as the only available resource to sustain economic development and ensure water security of local communities in the areas where available surface water resource is scarce (Fei Liu, 2015). Groundwater always contains various dissolved substances, including calcium and magnesium salts, which cause the hardness of water. Hard water is water containing high amounts of mineral ions. The most common ions found in hard water are the metal cations such as calcium and magnesium. Although iron, aluminum, and manganese may also be found in certain areas. These metals are water soluble, meaning they will dissolve in water. The relatively high concentrations of these ions can saturate the solution and consequently cause the equilibrium of these solutes to shift to the left, towards reactants. In other words, the ions can precipitate out of the solution. Hardness can be expressed as the content of Ca^{2+}, in water that the common Ca^{2+} concentration in drinking water remains between 1 and 5 mmol/L. Limestone is a major source of Ca^{2+}. Although hard water does not pose health hazards, it nevertheless leads to inconveniences in the households, by causing scaling on the heating elements during heating, and that in turn causes congestion of pipes, reduction of life of heating devices and increases energy consumption. There are several options for softening water and for reducing the formation of scale. Traditionally, scale is removed by chemical methods, such as add corrosion inhibitor, scale inhibitor, and fungicide in circulating water (Lili Jiang, 2015).

There are several options available to those wishing to treat hard water such as ion exchange, lime softening, reverse osmosis and magnetic treatment. Ion exchange is the traditional style of water softener that generally involves exchanging sodium or potassium ions for the hardness causing calcium and magnesium minerals. Ion exchange units use a sodium ion to replace calcium and magnesium ions in the water. Sodium ions are held on special beads, and as the water flows over the beads the exchange is completed. Once all of the sodium ions have been taken from the beads and they are saturated with calcium and magnesium ions, they need to be regenerated. Beads are regenerated through brining, or being soaked in a solution of water and sodium chloride (salt). While the beads are soaking in the brine, the calcium and magnesium ions are stripped from them and replaced with sodium ions, and the whole process can begin again. Ion exchange is the most common technology used in household applications.

Chemical treatment method is effective, but it is easy to bring secondary pollution (Alimi Fathi, 2006). The physical water treatment process was developed to substitute chemical water treatment methods which are expensive and can be harmful to the environment and human health (Leonard, 2011). The magnetic treatment becomes an important alternative to prevent scaling problems in domestic and industrial systems because of this method can not only reduce cost significantly but also improve utilization ration and protect the environment (Guo Bin, 2011). Recently, the researchers have been a continued interest in the magnetic treatment. In 2011 (Guo Bin), investigate the influence of a magnetic fields on microstructural and dynamic properties of sodium, magnesium and calcium ions in chloride solutions by molecular dynamic (MD) simulation. The effect of magnetic fields leads to the weaker interaction between ions and water, the contact ion pair increase and the solvent separation pair decrease. With the effect of magnetic treatment, the diffusion coefficients of sodium, magnesium and calcium ions increase, while, the diffusion coefficients of anions decrease. Ashraf Kotb (2013), investigated experimentally for water flows in closed loop and, the effect of magnetic treatment on pH, TDS and hardness of water with magnetic flux density of 1.7 mT. The results show that pH increased but the TDS and hardness of water are not affected by magnetic treatment. The magnetic treatment is gradually used in industry due to good 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.

The aim of this paper is to investigate experimentally for groundwater flows in closed loop and the effect of magnetic fields on total hardness, TDS and Ca^{2+} and Fe^{2+} in the water.

Magnetic water treatment: Magnetic water treatment is a method that hard water is passed through magnetic fields. This method has a long and controversial history but it has been reported to have been effective in numerous instances. Its main effect is to either reduce scale deposit or remove existing scale or produce a softer and less tenacious scale. The mechanism is still unclear, although magnetic water treatment has been practically used for over half a century. Understanding how the magnetic fields of relatively low densities precisely modify the precipitation of low magnetic minerals is still being developed because the treatment differs from well-known magnetic separations of high magnetic materials by strong magnetic fields. Iron-containing components have some influence on calcium carbonate precipitation more as a heteronucleator although it is still unclear how the activation by magnetic fields occurs (Kozic and Lipus, 2003).

There have been numerous studies on effect of magnetic fields on mechanism leading to the conclusion that the magnetic water treatment mechanism is complex, consisting of certain processes very sensitive to small charges in water composition and magnetic treatment regime. Although it is almost certain that there are influential factors that are unrecognized at the present time, it can be summarized that the following types of factors most probably affect dispersion stability and crystallization. The magnetic device is fitted to water pipe, through which water flows into a building. Passing through the pipe, water also passes through magnetic fields, an induced pulsating electric fields is generated inside the pipe by Faraday's law:

$$\int \vec{E} \cdot d\vec{s} = -\frac{\partial}{\partial t}\int \vec{B} \cdot d\vec{A}, \tag{1}$$

Where $\vec{E}$ is an induced electric fields vector, S is a line vector along the circumferential direction, $\vec{B}$ is a magnetic fields strength vector, and $\vec{A}$ is the cross sectional area of the solenoid coil. A coil of wire, radius R, came's a current I, It creates a 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

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{s} \times \hat{r}}{r^2}. \tag{2}$$

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

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

Intermolecular interaction for water and ions is expressed as sum of Columbic and Lennard-Jones pair potentials given by (Guo Bin, 2011):

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

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 i is expressed as:

$$F_i = F_i^{pot} + F_i^{mag} \tag{5}$$

Where F_i^{pot} and F_i^{mag} represent the force from the potential force fields and external magnetic fields, respectively. The force from the potential force fields is

$$F_i^{pot} = -\nabla_i U_{ij}. \tag{6}$$

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

$$F_i^{mag} = q_i \cdot v_i \times B \tag{7}$$

Where v_i is the velocity of atom i.

2. EXPERIMENTAL DETAIL

The test rig was illustrated in Figure 1, the groundwater was pumped from 15 litters tank using Jun Aquarium Pump, model: HX-5000, which was manufactured in Hong Kong. The groundwater to treat passed through the 0.5 inch a PVC pipe with 10 m/s 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 fields in the centre are 15 mT and the magnetic fields straight showed in Fig. 2. The DC magnetic fields were parallel to the groundwater flow. The groundwater re-circulated varies time of circulation from 15, 30, 45, 60, 75, 90 and 300 minutes.

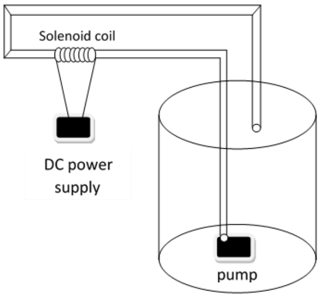

Figure.1. System schematic design

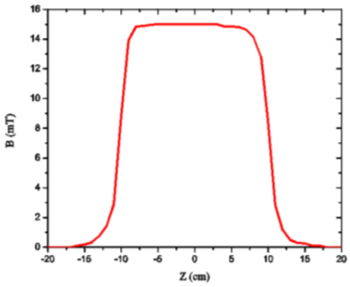

Figure.2. The Magnet fields strength from solenoid coil

The properties of groundwater which were measured were total hardness, total dissolved solid (TDS), and $Ca^{2+}$and Fe^{2+} ion concentration. The EDTA titration method was used to determine the total hardness. TDS meter 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 by after the experiments were carried out by using the following equation, provided that H_i is hardness of water sample before magnetic treatment and H_f is hardness of sample after magnetic treatment.

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

3. RESULTS AND DISCUSSION

Initially, the groundwater was filled in the tank. The total hardness, total dissolved solid (TDS) and calcium ions (Ca^{2+}) and iron ions (Fe^{2+}) in the water of groundwater were measured and considered to be the base line data for the groundwater properties before re-circulated through the system. Then the ground re-circulates through the system with non-magnetic treatment and magnetic treatment.

Unified method of measurements was performed throughout the work; each water sample at each time was measured and chemically analysed 5 times, the values were statistically analysed and the average represents as the result at the time.

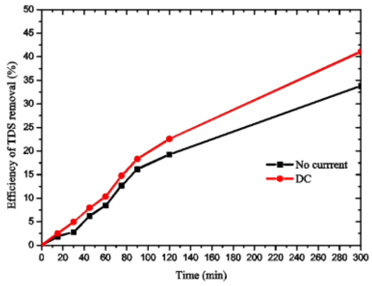

Figure.3. Efficiency of TDS removal

Fig.3, shows the effective of the treatment of dissolved solids (TDS) with the eddy flow condition which has the magnetic fields power in red coil compare to the neutral condition in black coil. Both conditions the TDS, can be reduced. The TDS efficiency of the first case was more than 35% better than the other. The decreasing of TDS was from the eddy flow currents which made the reaction of ions of relate substances, and found the white sediment. The efficiency of the Treatment of Dissolved Solids (TDS) with magnetic fields had more effective than neutron condition. The inorganic solid which in the solution will be become the positively ionized (cationic) and anion (anionic). The ionization of inorganic solid and water were increased and become to sediment to be removed.

The experiment for investigation of the decreasing of TDS related to the hardness in groundwater was performed. The result was showed in Fig.4.

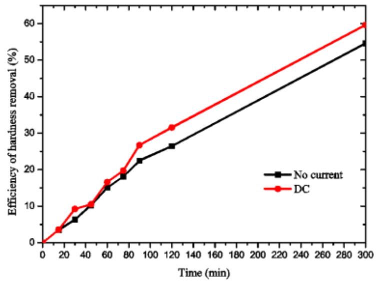

Figure.4. Efficiency of total hardness removal

The efficiency of total hardness removal of re-circulated water versus the time of circulation is presented in Fig. 4. Before water circulation the base line data is clearly identified to be 284.67 mg/l. The 300 minutes of water circulation through the magnetic water treatment, the hardness of water was affected by circulation through the magnetic water treatment.

Fig. 4 shows the effective 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 was better than the others, with efficiency about 53%. The total hardness removal ratio was related to the decrease of ions in hard water. The water in the presence of magnetic fields will induce electric currents. The redox reactions increases amount of OH^- from water molecules as the following equation

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (9)$$

After that hydrogen carbonate ion (HCO_3^-), which composition of the groundwater was reacted with OH^- to give carbonate ion (CO_3^{2-}) by equation

$$OH^- - + HCO_3^- \rightarrow CO_3^{2-} + H_2O \quad (10)$$

$$X^{2+} + CO_3^{2-} \rightarrow XCO_3 \quad (11)$$

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 reacted with CO_3^{2-} giving $CaCO_3$, $MgCO_3$, or $FeCO_3$ precipitates and to be removed.

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 North-East of Thailand. The results as presented in Fig.5, shows that calcium ion (Ca^{2+}) treatment in a magnetic fields with the eddy flow condition can remove calcium ions (Ca^{2+}) about 90%, whereas iron ion (Fe^{2+}) can be reduced about 20%. The removal of Ca^{2+} and Fe^{2+} onto precipitated $CaCO_3$ and $FeCO_3$, explained that dissolution effect of $CaCO_3$ ($Ksp = 4.8 \times 10^{-9}$) higher than $FeCO_3$ ($Ksp = 4.8 \times 10^{-11}$) and supersaturation of solution with respect to calcium carbonate (Mohamed Raii, 2014).

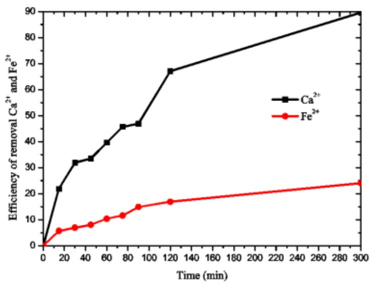

Figure.5. Efficiency of Ca^{2+} and Fe^{2+} removal

4. 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, 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 show that the properties such as, total hardness, TDS, and metal ion concentration of groundwater can be improved and greatly improved when the circulation time of the water was extended.

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