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Study of Calcium Chloride Dissolved Water under the Effect of Magnetic Field

Gunvir Kaur, P.S.Tarsikka

Department of Mathematics, Statistics and Physics, Punjab Agricultural University, Ludhiana, Punjab, India

Abstract**—** *Life and water are linked closely as it is essential for life to begin and for life to live on. Water passes through soil and aquifers often come in contact with minerals which at the correct environmental conditions, dissolve in the ground water to make it hard. The high mineral content water is normally not dangerous to human's health, but it causes many household problems which makes it less desirable. A physical technique using magnetic field to purify water is cheap, require no energy to run and create no pollutants but the efficiency of this treatment is still a controversial question. In present study, the physical parameters like total dissolved salts (TDS), electrical conductivity (EC) and pH have been evaluated in magnetized (0.05T – 0.20T) calcium chloride solution. Data collected during the experiment was analyzed statistically (SPSS-20.0). This analysis shows that the increase in TDS, EC and pH under the effect of magnetic field was significant ($p < 0.01$). The regression analysis was used to show linear relation between TDS and EC of water.*

Keywords—Electrical conductivity, Hard water, Magnetic field, pH, Total dissolved salts.

I. INTRODUCTION

Life is impossible without water as it is required for beginning and continuation of life. It affects all facts of life either directly or indirectly. There would be no vegetation, no oxygen to breathe and the planets would look completely different than it does today, without water. So, in order to keep environment and people healthy, water should be admired and protected as the valued resource as it is. As we know, hard water is being supplied to a large portion of the world population. Water that has high mineral content is called as 'Hard water'. As water passes through soil often come in contact with minerals such as limestone and dolomite**.** At the correct environmental conditions, small quantity of rocks dissolve in the ground water and make the water "hard"**.** The high mineral content water is normally not dangerous to human's health**,** but it causes many household problems e.g. require more soap for effective cleansing**,** toughens vegetables during cooking and form scale in boilers**,** hot water heaters**,** pipes**,** kettles and on cooking utensils**.** It also enhances expenditure of energy.

There were large number of chemical methods to remove hardness present in water which includes boiling of hard water, adding lime, distillation, ion exchange process and reverse osmosis. As calcium and magnesium ions exists as non-volatile salts or can be eliminated through the process of distillation of water, which is too costly in some cases. In ion exchange method, Ca^{2+} and Mg^{2+} ions are replaced by Na^{+} which may cause health problems for people suffering from high blood pressure. In Reverse osmosis (RO) technique, pure water can be obtained from salt/hard water. The membrane has sufficient pore size for passage of water molecules but ions such as Ca^{2+} and Mg^{2+} which are responsible for hardness remain behind and are flushed away by excess water into a drain, results in to water which is free of ions of hardness. But due to limited capacity, membranes require regular replacement. Also the solution chemistry gets changed by all anti-scale water treatments. Thus a physical method uses magnetic field to clean the water was introduced which is physical, cheap, require no energy to run and create no pollutants.

Water operated by the magnetic field or pass through a magnetic device is called magnetized water as stated by (Hozayn & Qados, 2010)**.** It doesn't mean that the water has attained magnetic strength but undoubtly; it is found that some properties of water get changed when magnetic field is subjected to it. These anomalous properties of water are unique and may result in many variations of macroscopic properties. The influence of magnetic field on liquid water has been deeply studied from last fifty years. To many people, magnets are complete mystery. Elimination of existing scale or production of a softer and less yielded scale is its main effects. (Baker & Judd, 1996) reviewed that the efficiency of this treatment is still a controversial question and exact explanation of its mechanism does not exist yet. Various contradictory hypotheses have been proposed.

According to (Gholizadeh et al., 2008) magnetic treatment of water operates on the principle that a Lorentz force is

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experienced by each ion as the water is allowed to pass through a magnetic water softener. The frequency of collisions between ions increases due to redirection of the particles, positive and negative ions combine to form an insoluble compound. So, calcium carbonates dispatched from the solution as a mud which can be easily removed from the water. Water on applying magnetic field will show diamagnetism in which substances that are magnetized in a way opposite to the direction of field. As a result, water molecules are 'directed' to have certain orientation which reduces the chance of matched orientation as well as hydrogen bonds' percentage. In other words, larger water clusters are cut and broken down by external magnetic field to form smaller water clusters as observed by (Reddy et al., 2014). A strong magnetic field slightly increases the melting point of water was reported by Physicists in Japan. According to (Chang and Weng, 2006) water structure becomes more stable and the ability of water molecules to form hydrogen bonds is enhanced when magnetic field is applied. Magnetized water give rise to many phenomenon such as increase in compressive strength of concrete and precipitation process of calcium carbonate when it is magnetized reported by (Alimi et al., 2007).

Such a simple technology can have many beneficial impacts on industries utilizing water, truly motivates its deeps study. Thus in view of this, the present study was planned to see the effect of magnetic field on the electrical conductivity, total dissolved salts and pH of the $CaCl_2$ solution (hard water). The study of inherent properties of hard water such as electrical conductivity**,** TDS and pH give more insight to the concept of magnetic water treatment.

II. MATERIALS AND METHODS

The electromagnet used for this study consists of two pole pieces made from the material annealed soft iron with field strength up to 2.2 Tesla at 1 cm gap between pole pieces as shown in Fig.1. The dimensions of electromagnet are diameter 9.0 cm and length 27.5 cm with total number of turns 3000 per coil. The distance between poles of electromagnet is adjustable up to 7 cm. The magnetic field strength at different positions between the poles of electromagnet with varying current was measured by Digital gauss meter (DGM-102) to assure uniformity of field.

Different concentrations (0.05%, 0.10%, 0.15%, 0.20%, and 0.25%) of hard water were prepared in laboratory by using calcium chloride salt and distilled water. For preparation of 0.05% $CaCl_2$ solution, 0.05g of calcium chloride was dissolved in small volume of distilled water. Once the calcium chloride salt dissolved completely (after swirls the flask gently if necessary), water was added to make up the final volume as 100 ml of flask. In a similar way, other concentrations were prepared in laboratory by using distilled water.

Plastic beakers were used in the study due to low thermal conductivity as compared to glass beakers. At high magnetic field strength, poles of electromagnet get heated with time which ultimately affects the temperature of solution inside the beaker when placed between the poles of electromagnet. So, the best materials were the ones with the lowest thermal conductivity. In order to avoid external temperature effects, plastic beakers were further insulated by cotton because there are thousands of tiny air spaces between the fibres that slow or stop the transmission of heat from magnets to beaker when it was placed inside the magnets. The parameters electrical conductivity and total dissolved salts of hard water were measured with the help of waterproof HANNA probe 98311 with range TDS (0-2000 ppm) and EC (0-3999 µS/cm). The HANNA pH waterproof tester having pH range from -2.0 to 16.0 was used to measure pH of hard water.

Hard water of different concentrations was placed for 16 hours after preparation for stability of solution. After 16 hours, 40 ml of hard water was filtered with zero filter papers and placed in an insulated beaker in order to avoid external temperature effects. HANNA EC/TDS/pH/Temperature meter was then dipped into filtered solution to measure total dissolved salts (TDS), electrical conductivity (EC) and pH of hard water before the application of magnetic field. Now, the beaker with dipped EC/TDS/pH/Temperature meter was placed inside the electromagnets for 60 minutes. After each ten minute, the change in EC, TDS and Temperature were noted. Same procedure was repeated for different magnetic field strengths from (0.05T – 0.20T) and different concentrations of hard water (0.05% - 0.25%).

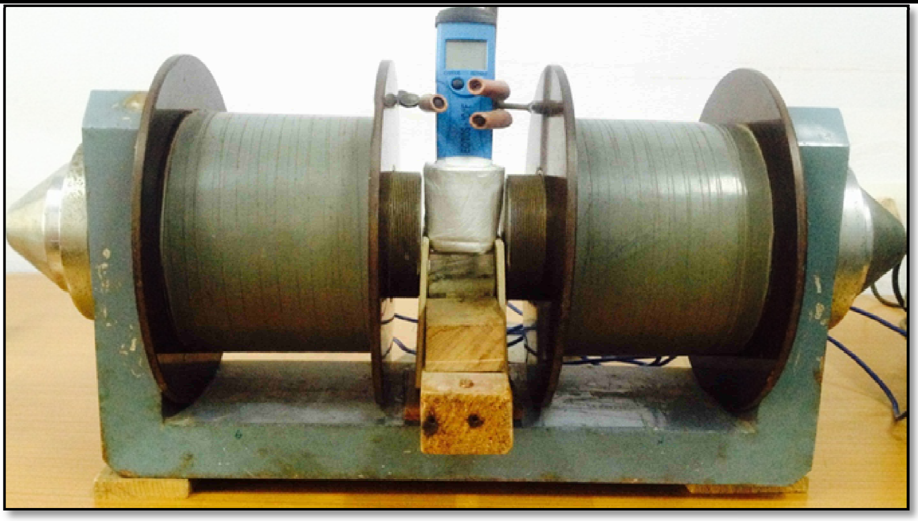

Fig.1: Experimental set up for measurement of EC and TDS

III. RESULT AND DISCUSSION

1. Effect of magnetic field strength and time on TDS and EC

Figure (2-3) shows the results of TDS in (ppm) and EC in (µS/cm) of calcium chloride solution as a function of magnetic field intensity and exposing time. It has been observed that the total dissolved salts and electrical conductivity of different concentrations increases with time as well as with magnetic field strength but this rise is highest for highest concentration and highest magnetic field strength. The effect of each magnetic field strength (0.05T, 0.10T, 0.15T, 0.20T) on total dissolved salts and electrical conductivity of different concentrations was found to be significant ($p < 0.01$). Similar types of variations were recorded by (Mousa & Hmed, 2008) and (Moosa et al., 2015).

It is believed that water will show diamagnetism, a property which magnetized the substances in a way opposite to the direction of applied field, after applying a strong magnetic field. These substances having pair-up electrons rotate opposite to each other in a pair due to which they cancel each other's magnetic moment. So, we can say that magnetic field forced the water molecules to have a particular direction due to which bond angle decreases from 104.5° to 103° which further reduces repulsion between electrons in bond pairs of H_2O and electrons in solute molecules. As a result, more solute can be packed in the same volume of water, thus increasing solubility (Reddy et al., 2014). However, TDS and electrical conductivity are in close connection**.** The more salts dissolved in the water**,** the higher is the value of electrical conductivity**.** So, higher is the value of magnetic field, higher will be the increase in TDS and electrical conductivity.

2. Effect of magnetic field on temperature of hard water with time

The experimentally observed values of temperature of hard water at different magnetic field strengths and different interval of time have been plotted in figure 4. Initially the hard water was taken at temperature of 31.0°C. It has been observed that the temperature of hard water increases significantly ($p < 0.01$) with magnetic field strength in an hour and rise in temperature is higher for highest magnetic field strength. For magnetic field strength 0.05T, the temperature of hard water increases from 31.0°C -31.2°C; for magnetic field strength 0.10T, the temperature of hard water increases from 31.0°C -31.6°C; for magnetic field strength 0.15T, the temperature of hard water increases from 31.0°C -32.8°C and for magnetic field strength 0.20T, the temperature of hard water increases from 31.0°C - 33.7°C, in an hour. Similarly, a slight increase in the water temperature by increasing the magnetic intensity from 0.05T – 0.15T during the preparation of dipole magnetized water was reported by (AL-Ibady, 2015).

When magnetic field is applied to hard water, dipoles (water molecules) get aligned which results in increase in the movement of water molecules, which slightly increases the temperature of hard water with time. Higher will be the magnetic field strength, higher will be rise in temperature as more and more dipoles get aligned.

3. Relationship between total dissolved salts and electrical conductivity

The values of electrical conductivity were found to be increase with the increase in values of total dissolved salts for different concentrations of $CaCl_2$ solution. Figure 5 shows the linear relationship between the total dissolved salts and electrical conductivity for different concentrations of hard water at constant temperature. Similar type of result was reported by (Hayashi, 2004), (Uwidia & Ukulu, 2013), (Ayeni, 2014) and (Iyasele & Idiata, 2015).

A high value of electrical conductivity indicates high total dissolved salt concentration. This implies that the ability of an electric current to pass through the water is proportional to the concentration of ionic solutes dissolved in the water. It therefore means that values of EC can be used to estimate the values of TDS in the water (Uwidia & Ukulu, 2013).

4. Relation between TDS and concentration

The values of TDS were found increased with increase in concentrations of $CaCl_2$ solution at constant temperature. Figure 6 shows the linear relationship between the total dissolved salts and different concentrations of hard water at constant temperature.

Concentration is a measure of how much solute is dissolved within the solvent. Higher concentration of salt means higher amount of solute in solution i.e. higher value of total dissolved salts. So, we can say that total dissolved salts and concentration are in direct relation.

5. Variation in pH of hard water with time at different strengths of magnetic field

The measured values of pH as a function of time and concentrations at selected magnetic field strength are expressed in the form of graph which is shown in Fig. 7. For highest concentration (0.25%), pH varies from 4.01-4.08 and 4.01- 4.08, in an hour for lowest (0.05T) and highest (0.20T) magnetic field strength respectively i.e. almost same change occur at different magnetic field strengths.

The effect of each magnetic field strength (0.05T, 0.10T, 0.15T, 0.20T) on pH of different concentrations was found to be significant ($p < 0.01$). Similar types of variations were reported by (Mousa & Hmed, 2008) and (Moosa et al., 2015). Increase in pH on applying magnetic field is probably due to the decrease in hydrogen ion concentration (Mousa & Hmed, 2008).

There is no significant difference between treatments i.e. different magnetic field strengths.

6. Variation of pH with different concentrations of hard water

The experimentally observed values of pH at different concentrations of hard water have been presented in the form of graph plotted between pH and magnetic field strength for different concentrations of hard water as shown in Fig. 8. It has been observed that as the concentration increases, pH of hard water decreases. As the calcium chloride salt is a lewis acid a compound that can accept an electron pair from a donor compound. It forms calcium hydroxide and liberates the hydrogen ions. So, as the concentration of salt increases, more and more hydrogen ions get liberated which makes the solution more and more acidic. In other words, we can say that as the concentration of salt increases, pH decreases.

IV. CONCLUSIONS

1. The changes in total dissolved salts, electrical conductivity and pH of hard water under the effect of magnetic field strengths have been observed significant at 1% level of significance.
2. The temperature of hard water changes significantly ($p < 0.01$) under the effect of magnetic field.
3. There is a linear relationship between total dissolved salts and electrical conductivity ($R^2 = 1.0$).
4. Total dissolved salts of hard water increases with concentration while pH of hard water decreases with concentration.

REFERENCES

[1] AL- Ibady Q A A K (2015) Influence of the Dipolar Magnetized Water on the Ecological Factors of Freshwater Ostracod Cypris laevis. *IOSR J Environ Sci Toxicol Food Technol* **9(9):**09- 15.

[2] Alimi F, Tlili M, Amor M B, Gabrielli C and Maurin G (2007) Influence of magnetic field on calcium carbonate precipitation. *Desalination* **206:** 163–168.

[3] Ayeni O (2014) A Preliminary Assessment of Phenol Contamination of Isebo River in South wester Nigeria. *GJPS* **4(2):** 30-37.

[4] Baker J S and Judd S J (1996) Magnetic amelioration of scale formation. *Water Res* **30(2):** 247-60.

[5] Chang K T and Weng C I (2006) The effect of an external magnetic field on the structure of liquid water using molecular dynamic simulation. *J App Phys* **100:** 0439171-76.

[6] Gholizadeh M, Arabshahi H, Saeidi M R and Mahdavi B (2008) The Effect of Magnetic Water on Growth and Quality Improvement of Poultry. *Middle-East J Sci Res* **3(3):** 140- 44.

[7] Hayashi M (2004) Temperature-electrical conductivity relation of water for environmental monitoring and geophysical data inversion. *Environ Monit Assess* 96: 119-28.

[8] Hozayn M and Qados A M S A (2010) Irrigation with magnetized water enhances growth, chemical

constituent and yield of chickpea. *Agric Biol J N Am* **1(4)**: 671-76.

[9] Iyasele J U, Idiata D J (2015) investigation of the relationship between electrical conductivity and total dissolved solids for mono-valent, di-valent and tri valent metal compounds. *Int J Eng Res Rev* **3(1)**: 40-48.

[10] Moosa G M, Khulaef J H, Khraibt A C, Shandi N R and Al Braich M S K (2015) Effect of Magnetic Water on Physical Properties of Different Kind of Water, and Studying Its Ability to Dissolving Kidney Stone. *J Nat Sci Res* **5(18)**: 85-94.

[11] Mousa A M and Hmed A S (2008) The Effect of Magnetic Water on Dissolving kidney Stones. *Eng Tech* 26**(5).**

[12] Reddy B S K**,** Ghorpade V G and Rao H S (2014) Effect of magnetic field exposure time on workability and compressive strength of magnetic water concrete. *Int J Adv Eng Tech* **4(3):** 120-22.

[13] Uwidia I E and Ukulu H S (2013) Studies on electrical conductivity and total dissolved solids concentration in raw domestic wastewater obtained from an estate in Warri, Nigeria. *GJPS* **3(3):** 110-14.

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TABLES

Table 1: Regression coefficient for total dissolved salts (TDS) at different concentrations

Concentration (%)	Magnetic field (0.05T)			Magnetic field (0.10T)		
	A	b	R^2	a	b	R^2
0.05	417.656	.047	.823**	418.044	.083	.928**
0.10	852.696	.093	.925**	852.476	.154	.908**
0.15	1157.875	.070	.751**	1157.648	.196	.950**
0.20	1545.806	.064	.868**	1545.385	.223	.972**
0.25	1897.934	.071	.785**	1896.670	.244	.888**
Concentration (%)	**Magnetic field (0.15T)**			**Magnetic field (0.20T)**		
	A	b	R^2	a	b	R^2
0.05	418.139	.187	.977**	418.073	.279	.975**
0.10	851.802	.273	.923**	850.048	.486	.922**
0.15	1155.231	.454	.952**	1151.092	.747	.905**
0.20	1543.220	.577	.973**	1539.623	1.004	.966**
0.25	1893.000	.821	.953**	1887.278	1.312	.940**

**** Significant at 1% level of significance ($p < 0.01$)**

Table.2: Regression coefficient for electrical conductivity at different concentrations

Concentration (%)	Magnetic field (0.05T)			Magnetic field (0.10T)		
	a	b	R^2	a	b	R^2
0.05	835.553	.111	.937**	836.388	.173	.950**
0.10	1705.784	.185	.964**	1705.344	.302	.916**
0.15	2316.132	.155	.818**	2315.553	.390	.955**
0.20	3092.300	.150	.950**	3090.919	.443	.973**
0.25	3796.059	.181	.951**	3793.890	.465	.918**
Concentration (%)	**Magnetic field (0.15T)**			**Magnetic field (0.20T)**		
	a	b	R^2	a	b	R^2
0.05	836.615	.364	.985**	836.205	.556	.975**
0.10	1703.652	.546	.924**	1700.165	.971	.922**
0.15	2310.542	.906	.952**	2302.264	1.491	.904**
0.20	3086.440	1.155	.973**	3079.245	2.008	.966**
0.25	3786.000	1.641	.953**	3774.476	2.629	.939**

**** Significant at 1% level of significance ($p < 0.01$)**

Table.3: Regression coefficient for temperature of hard water at different magnetic field strength

Magnetic Field (T)	a	b	R^2
0.05	30.952	.003	.541**
0.10	30.939	.012	.885**
0.15	30.831	.030	.944**
0.20	30.676	.045	.929**

**** Significant at 1% level of significance ($p < 0.01$)**

Table.4: Regression coefficient for pH at different concentrations

Concentration (%)	**Magnetic field (0.05T)**			**Magnetic field (0.10T)**		
	A	b	R^2	a	b	R^2
0.05	4.558	.001	.914**	4.561	.001	.847**
0.10	4.409	.001	.915**	4.411	.001	.888**
0.15	4.302	.001	.913**	4.304	.001	.897**
0.20	4.155	.001	.914**	4.154	.001	.922**
0.25	4.013	.001	.844**	4.009	.001	.845**
Concentration (%)	**Magnetic field (0.15T)**			**Magnetic field (0.20T)**		
	A	b	R^2	a	b	R^2
0.05	4.560	.001	.922**	4.561	.001	.847**
0.10	4.408	.001	.950**	4.410	.001	.908**
0.15	4.304	.001	.908**	4.299	.001	.940**
0.20	4.153	.001	.913**	4.153	.001	.932**
0.25	4.012	.001	.851**	4.014	.001	.909**

**** Significant at 1% level of significance ($p < 0.01$)**

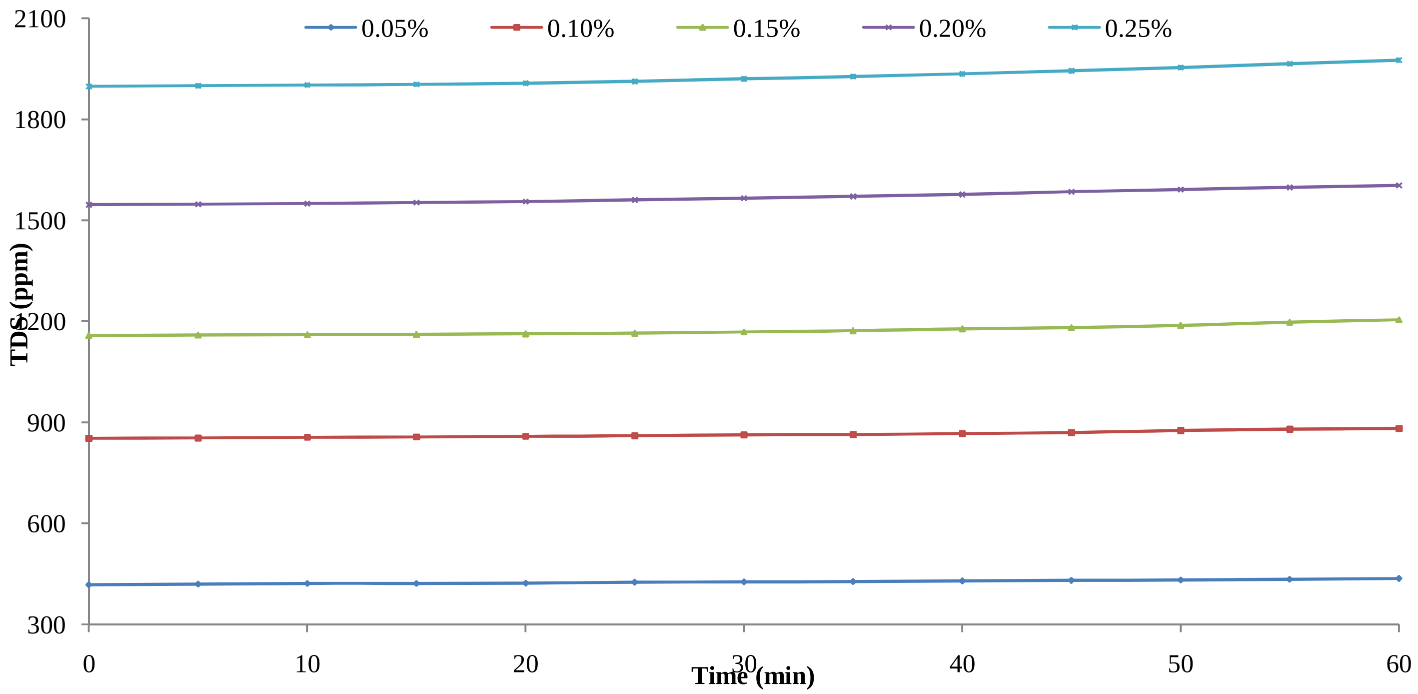

Fig. 2: Variation of total dissolved salts with time at magnetic field strength 0.20T

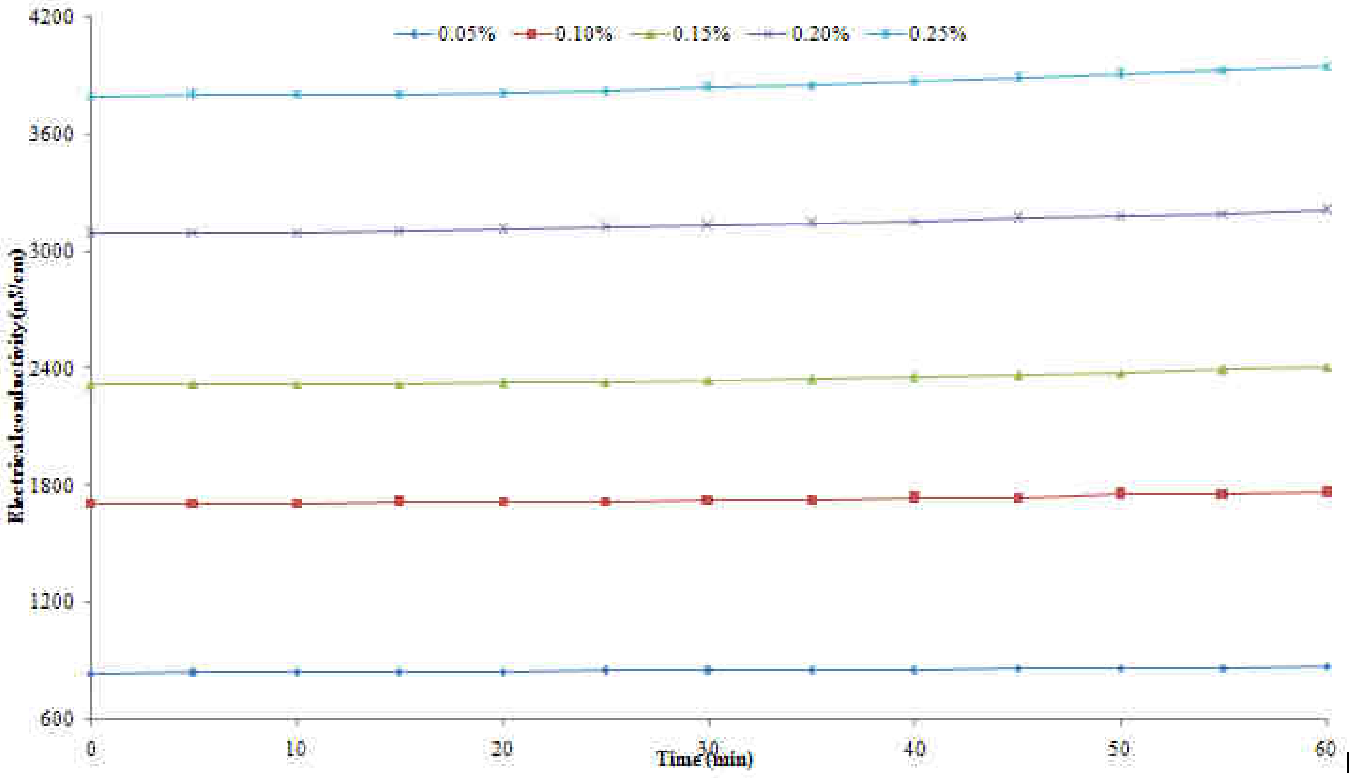

Fig. 3: Variation of electrical conductivity with time at magnetic field strength 0.20T.

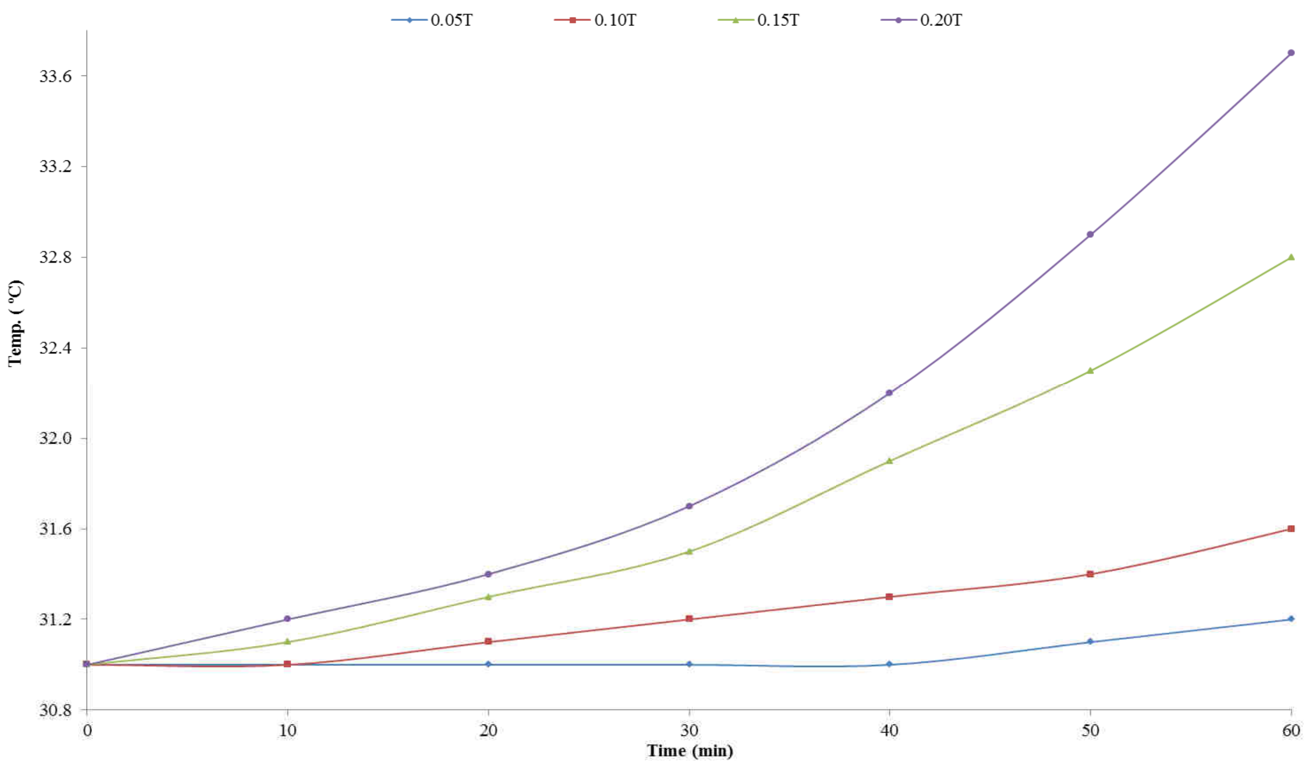

Fig. 4: Rise in temperature on applying different magnetic field strengths with time.

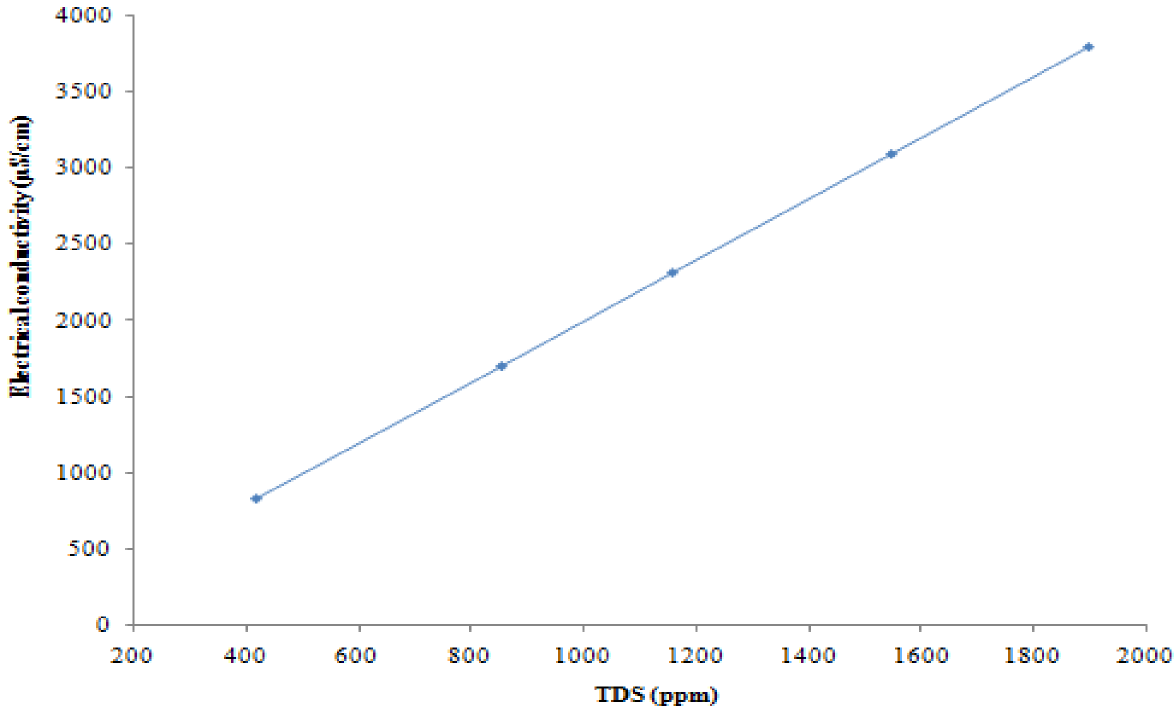

Fig. 5: Relationship between total dissolved salts and electrical conductivity at constant temperature.

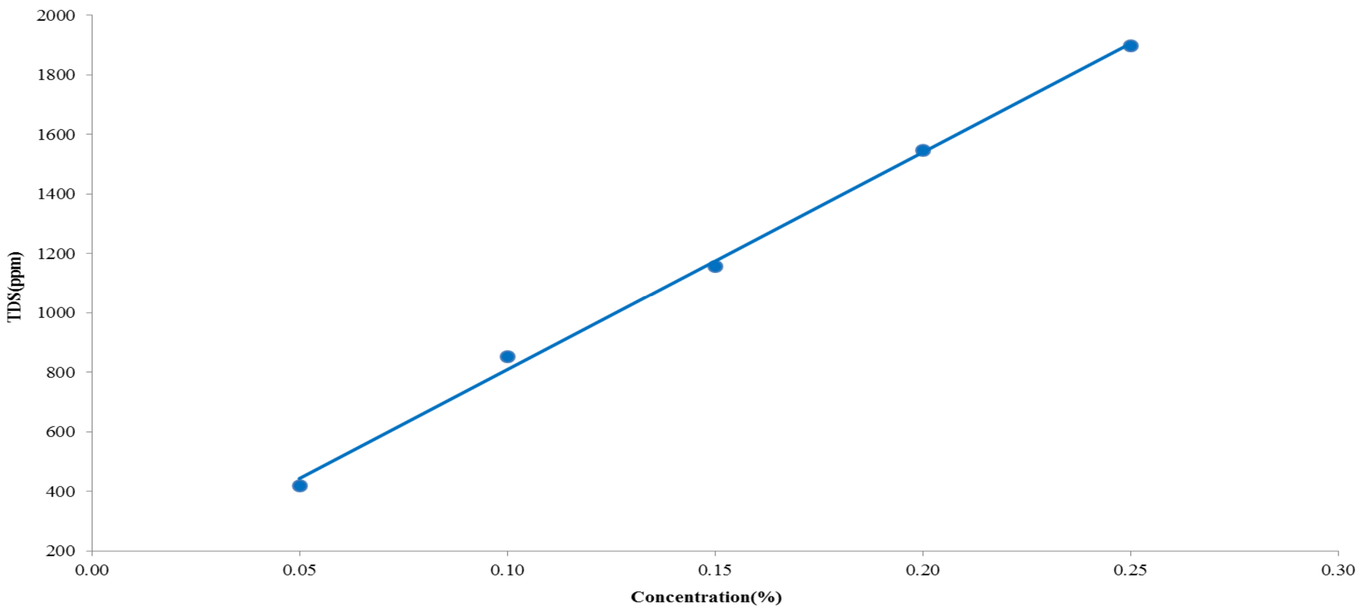

Fig. 6: Relationship between total dissolved salts and concentration.

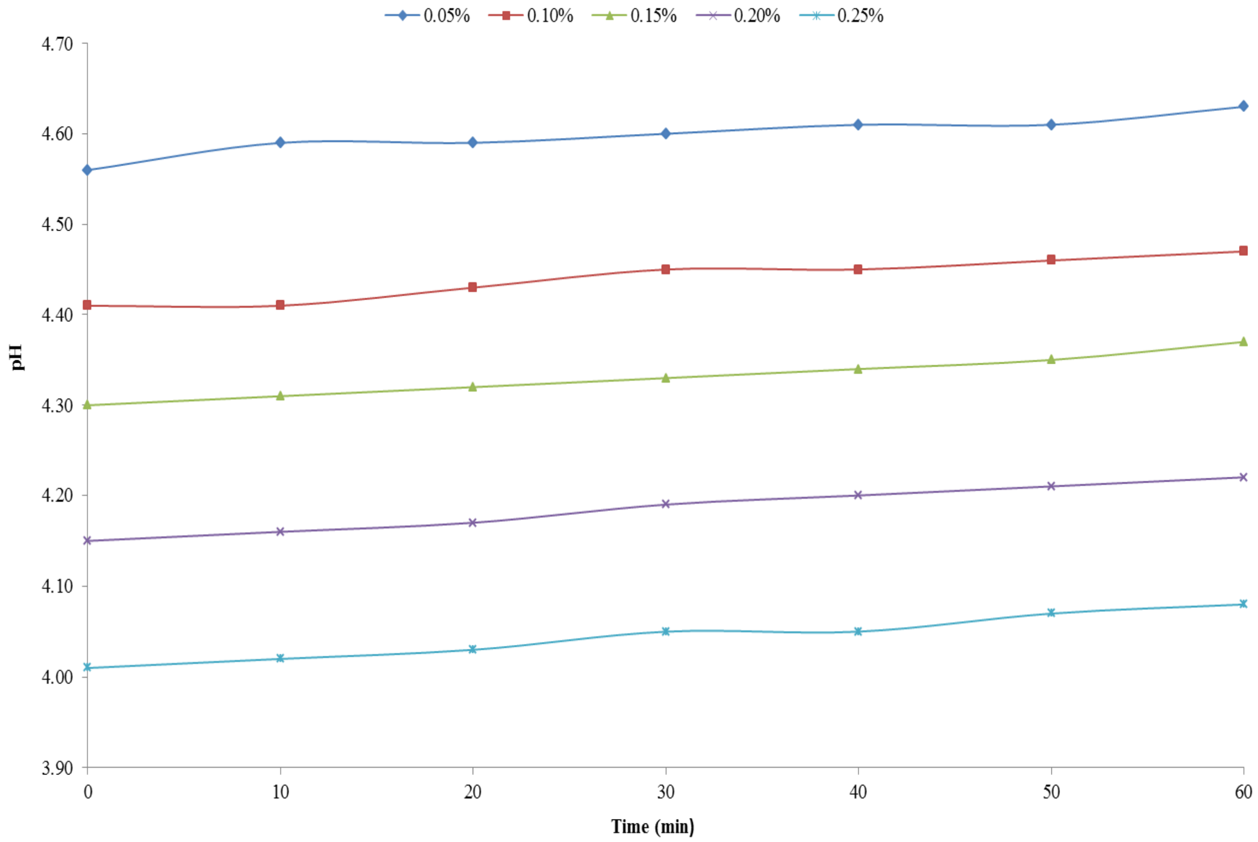

Fig. 7: Variation of pH with time at magnetic field strength 0.20T.

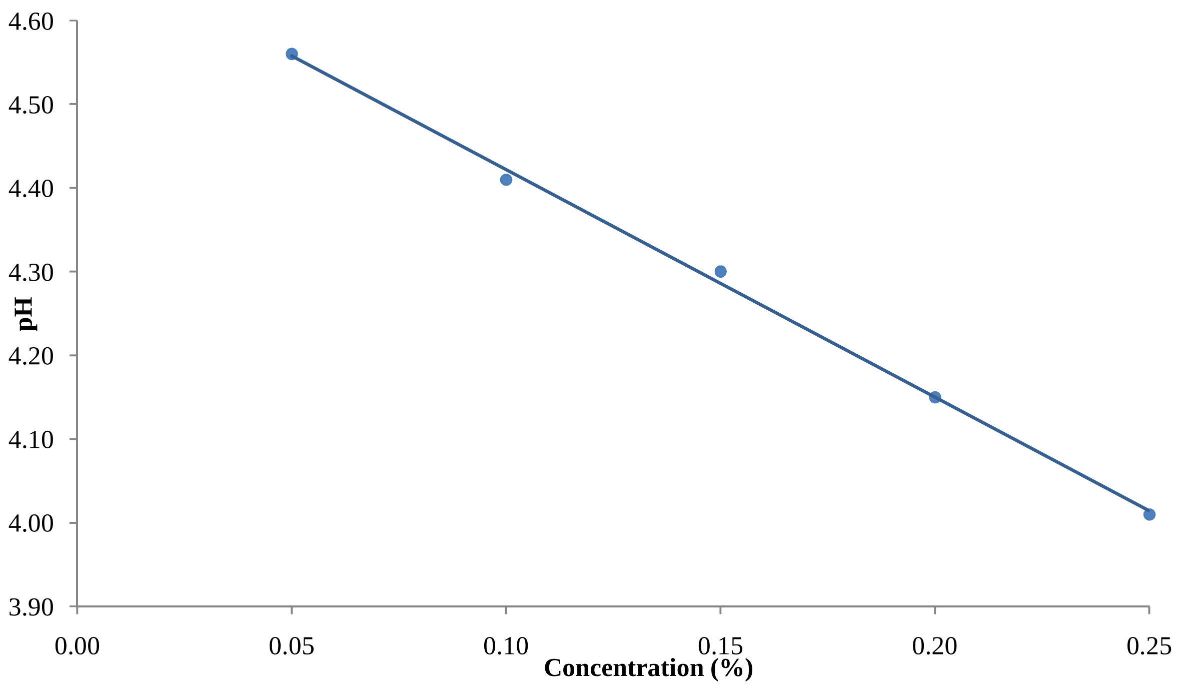

Fig. 8: Variation of pH with different concentrations of hard water.