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The Effect of Groundwater Quality towards Resistivity

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Abstract: Electrical Resistivity Method (ERM) is widely used as a geophysical method in groundwater investigation. This study evaluates the effect of groundwater quality towards resistivity by focusing on acidity (pH) and dissolved iron (Fe) content. The variation of pH and dissolved iron values were tested using Electrical Resistivity Method (ERM) to determine its resistivity values. In this study, the contaminated groundwater is simulated via varied its pH and dissolved iron concentration. This study was set three different pH values from neutral to extremely acidic and alkaline groundwater as well as three sets of dissolved iron concentrations for each pH value. This study was conducted in the laboratory using an electrical soil box to contain the contaminated groundwater sample and Miller 400A to measure the resistivity. The study began with testing the water resistivity with pH without iron solution and followed by pH with the iron solution. The resistivity values without iron solution show the neutral water pH7 has the highest resistivity compared to pH3 and pH10. The resistivity value increased along with the pH level. However, after the pH level exceed the neutral level, the resistivity values decreased drastically. When the iron solution was added from acidic to alkaline water, it indicates the water resistivities drastically decreased in alkaline waters. It shows that the iron solution is effectively in alkaline water for reducing the resistivity value. This study can be concluded that the resistivity responds with the different pH levels and iron concentrations.

Keywords: Resistivity, pH, Fe

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1. Introduction

Groundwater is a part of the natural water cycle located in the subsurface of the earth. It is commonly located between loose gravel or sand and fractured rock. Fractured rock formation or an unconsolidated granular layer transports water along the planar breaks normally has limited storage capacity and is called an aquifer. Unconsolidated granular layers, such as gravel, sand, and silt with porosities ranging from 15% to 50% and containing 1.4 to 3.7 gallons of water, will make suitable aquifers. Aquifers are porous medium that allows water to move quickly through them. Examples of permeable and porous aquifers are sandstone, broken limestone, and unconsolidated sand and gravel. Groundwater may also be drained from a well or come to the surface as a spring. Both of these types of aquifers are normally suitable source for usable natural water apart from the surface water that are normally collected from rivers. Groundwater provides around half of our municipal, domestic, and agricultural water supply. It is often used as the supply of drinking waters as it is less polluted than surface water [1]. This makes the treatment of the groundwater process more accessible and cheaper than surface water. Study done by [2] and [3] shows the resistivity value for groundwater are 30 – 150 Ohm.m and 10 – 100 Ohm.m respectively. Electrical resistivity and Induced Polarization (IP) are methods that can be used for groundwater exploration [4]. The resistivity value shows how the condition of the soils can adversely affect the current flow, whereas the chargeability value tells how the material retains the electrical charges [5]. Both approaches are non-destructive ways for groundwater investigation.

Groundwater is often time used as mineral water for drinking purposes. Hence the quality of the water is one of the upmost important aspects of the water to be considered for safe drinking condition. One of the important parameters that needed to be considered for drinkable water quality is the Ph value. The water quality will be determined whether it is safe to drink by comparing it with the standard value of pH and Fe^{2+} in drinking water. However, there is no detailed research on how pH and Fe^{2+} will affect the value of electrical resistivity. This research aims to investigate the effect of pH and Fe^{2+} concentration in water by using electrical resistivity method in a controlled environment. The resistivity values are compared to the resistivity values obtained from an original groundwater. The water used for this testing was controlled using distilled water to ensure the effects of pH and Fe^{2+}.are established. Electrical Resistivity Method (ERM) was used to conduct the electrical resistivity of the testing.

2. Testing methods and materials

The Electrical Resistivity Method (ERM) is a geophysical method employed as the first step in any groundwater investigation. A geophysical tool provides a very appealing methodology for characterizing subsurface profiles over a vast area. ERM has been used in groundwater investigation in various ways [6]. ERM is also a method that does not change the nature of the ground as it only applied electrical current instead of drilling or destructing the nature of the ground. ERM plays a significant role in groundwater exploration as it has significant advantages compared to conventional groundwater exploration technique. It is also suitable and capable of investigating groundwater pollution, contamination, saltwater intrusion, and not limited to one cluster of investigation. It also refers to a survey that is carried out to present an image of the sub surface's electrical properties by conducting an electrical current via various routes and measuring the voltage [7]. ERM is based on the interaction between the earth and the flow of electrical current. Therefore, it is sensitive to changes in the sub surface's electrical resistivity, as measured by Ohm meters [8]. **Figure 1** shows the soil box used to put in the sample before measuring the resistivity of the materials. The distance between the electrodes on the soil box determines the electrical resistivity of the samples. 4 pin methods are employed in this experiment, where C1, C2 are the current electrodes which the direct current are injected whilst P1 and P2 are the potential electrodes in which the resistivity of the materials are measured.

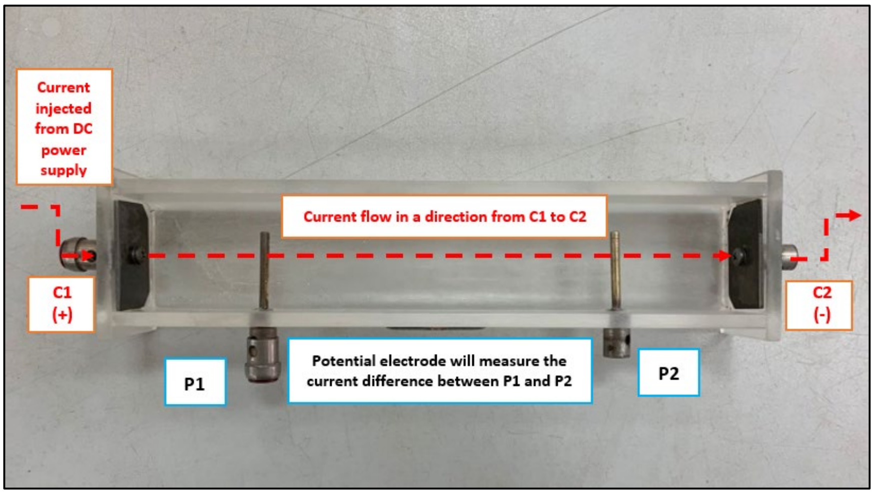


Figure 1: Soil box used to put the sample

2.1 **pH and Iron (Fe)**

pH is one of the chemical parameters, functioning as a measurement of acidity and alkalinity of water. There are several factors effecting the level of pH in groundwater. One of the factors is the heavy metals that dissolve in the groundwater which indicate high acidity that lowers pH. value. High pH value also might affect aquatic plants and animals. As the pH value increased, water with a strong alkaline presence, such as ammonia, became dangerous [9]. Therefore, it is essential to control and observe this presence in water to ensure it does not harm any organism. According to the National Drinking Water Quality Standard (NDWQS), the safe pH level should be between 6.5 and 9 [10].

Iron (Fe) presence in potable water is a natural thing as it is an element that is required by living organisms [11]. The type of metal often identified in groundwater solution is ferrous (Fe^{2+}) ion. This iron provides a bitter taste to drinking water and will not cause any health problems [12]. The principal sources of concern in the aquatic environment are ferrous Fe^{2+} and ferric Fe^{3+} ions. Other types of bacteria can be found in both organic and inorganic wastewater streams. The ferrous form Fe^{2+} can exist in water devoid of dissolved oxygen, and it commonly comes from pumped or drained groundwater or mines. Laundry and porcelain are often stained by iron in-home water supply systems [13]. When Fe was added into a strong acid solution, ions in the solution might decreases as it deduced from its spectral similarity to the octahedral species in the acid solution [14]. The study shows that 75% of the Fe ion in neutral pH solution was deduced in the condition of acid solution.

3. Testing and sample preparation

The samples of different pH levels were analyzed to ensure the samples of acidity and alkalinity used are according to the needs of this research. For this study, the pH values were varied into pH 3, pH 7, and pH 10 within a controlled distilled water where the resistivity value was measured. The distilled water was obtained from the UTHM Micropollutant Research Centre (MPRC) Lab, FKAAB UTHM.

A sodium hydroxide solution (NaOH) was first prepared by diluting the sodium hydroxide pellets with distilled water. Then, three different pH level was created by diluting acid sulphuric and sodium hydroxide solution with distilled water. Three samples were created for each pH level. A frequent pH test was done to ensure the pH level was consistent. About three reading of the pH test was taken, and the average reading was used as the final pH level for the sample. Lastly, Fe solution was prepared for 80 mg/L, 120 mg/L, and 160 mg/L and added to each pH level solution. All of the samples were labeled to avoid human error. **Figure 2** shows the three pH readings were taken to obtain the sample's final pH level. The pH electrode was washed and calibrated using distilled water after each usage to ensure data accuracy.

The pH testing was conducted based on ASTM 1293 – 18 which was the standard test method for water pH. This test was conducted by using the laboratory pH meter. Several other methods were used to test the pH value, such as the glass electrode and reference electrode methods. However, to ensure the credibility of the pH value, the pH test method by using the laboratory pH meter was chosen as it shows the highest accuracy compared to other methods.

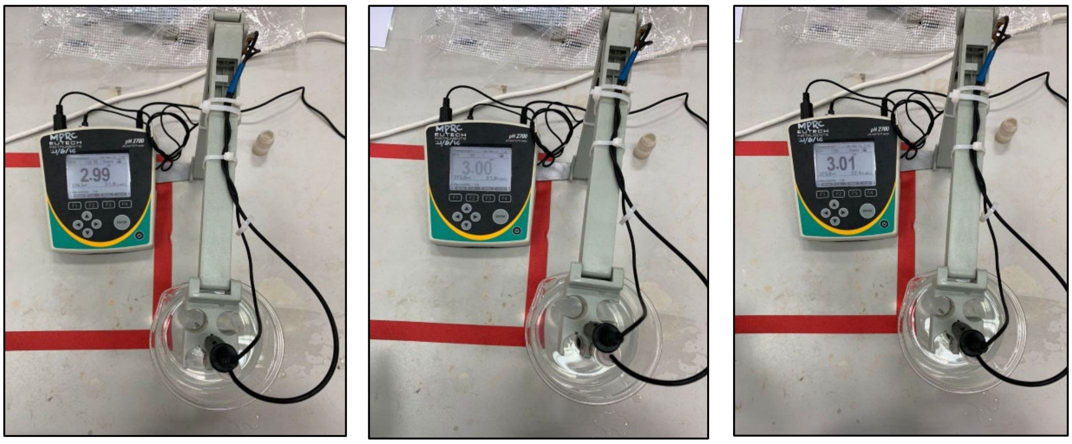


Figure 2: Frequent pH reading taken

4. Results and Discussion

This study acquired the parameters of resistivity towards groundwater quality which is pH and Fe. The study phase starts with the acidity measurement (pH) to ensure the pH of the samples obtained complies with the pH level needed as in the study. The next phase of the study was measuring the resistivity of the samples. ERM was used in this phase using Miller 400A as the measurement equipment following the ASTM G187 standard.

4.1 Acidity Measurement (pH)

All of the samples were tested for their acidity using a pH test. Several pH readings were taken to ensure the consistency of the data, and the average pH reading was taken as the finalized pH level of the solution. Calibration of the equipment was done before the data reading to minimize the error that might occur. Temperature also influences the pH value results as chemical reactions and pH values are temperature-dependent. Therefore, to minimize the temperature factor influencing the pH value, the testing was conducted indoor and temperature sensor was used to ensure the sample has constant temperature over the period of testing. The temperature was observed to be constant before the pH reading was taken at 25°C. **Table 1** shows the pH data obtained by using the pH test.

Table 1: pH readings obtained

pH level (needed)	Reading of pH level obtained			Average of pH level obtained
3	3.01	3.00	2.99	3
7	6.91	7.11	7.04	7.02
10	10.03	9.80	10.24	10.02

4.2 Resistivity Measurement

Resistivity value was taken using Miller 400A connected with the soil box that holds the sample. Results were taken focusing on how pH and Fe affect the resistivity value. The results were first taken without Fe solution added to observe the effect of pH values towards the resistivity values. The results were then taken for three different pH values and three different concentrations of Fe solution.

This study focuses on three different pHs: pH 3, pH 7, and pH 10, representing high acidity, neutral and high alkalinity, respectively. **Figure 3** shows the graph of resistivity against pH level without Fe solution.

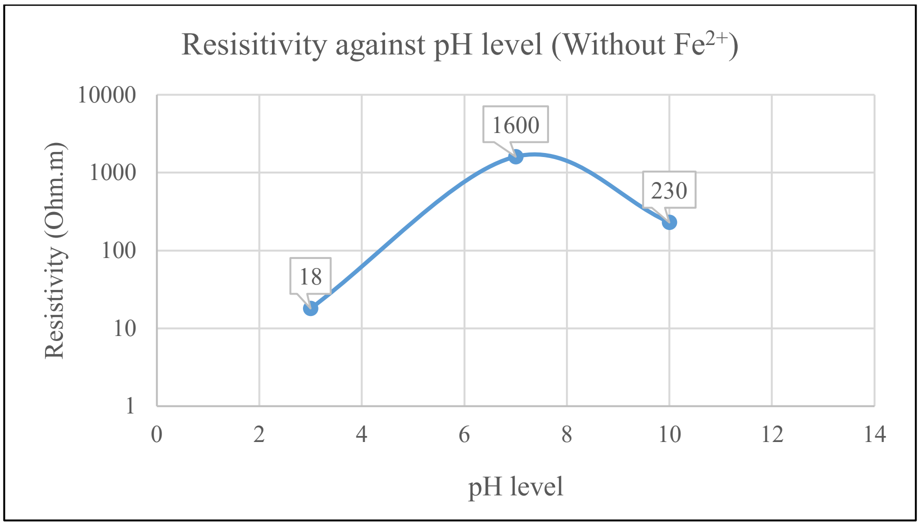


Figure 3: Resistivity against pH level (Without Fe^{2+})

Based on the results obtained, it was observed that water with neutral pH had higher resistivity value compared to lower and higher pH value. Furthermore, the graph indicates that the resistivity values increased dramatically once the pH level increased. However, the data obtained shows that the resistivity values decreases once again once the pH level becomes alkaline. It is important to note that the solution used is a buffered solution that contains Acid Sulphuric and Sodium Hydroxide in creating the desired pH.

4.2.2 Resistivity against pH level and Fe Solution

Resistivity value was taken for three different pH levels and three different Fe^{2+} concentrations. Each pH level (pH 3, pH 7 and pH 10) was added with Fe^{2+} solution with 80 mg/L, 120 mg/L, and 160 mg/L concentration respectively. **Figure 4** shows the resistivity value of the different pH and Fe solution. The resistivity values obtained showed a similar pattern throughout the difference in pH value. The resistivity decreases when the Fe concentration increases. Fe^{2+} solution is an acidic solution as it is highly corrosive. When Fe^{2+} concentration was poured into the water, a chemical reaction happens. Whenever a chemical reaction happens, energy was transferred. As Fe^{2+} was considered acidic, Fe^{2+} might give a chemical reaction such as temperature release. This chemical reaction might affect the water condition, increasing the temperature of the sample. The sample rise in temperature is notable through the flask from physical touch after Fe^{2+} was added into the solution. Therefore, temperature change will also affect the resistivity value based on previous study done by [15]. A constant time interval between each resistivity test after e Fe^{2+} was added to the solution was fixed to retain the consistency of the reaction within the solution.

Figure 4 shows that an increment of Fe^{2+} presence decreases the resistivity values. For example, the pH 3 acid solution shows higher resistivity values than the neutral and base solution with pH 7 and 10, respectively. Therefore, the resistivity results might also occur due to the buffer solution reaction with the added Fe^{2+}.

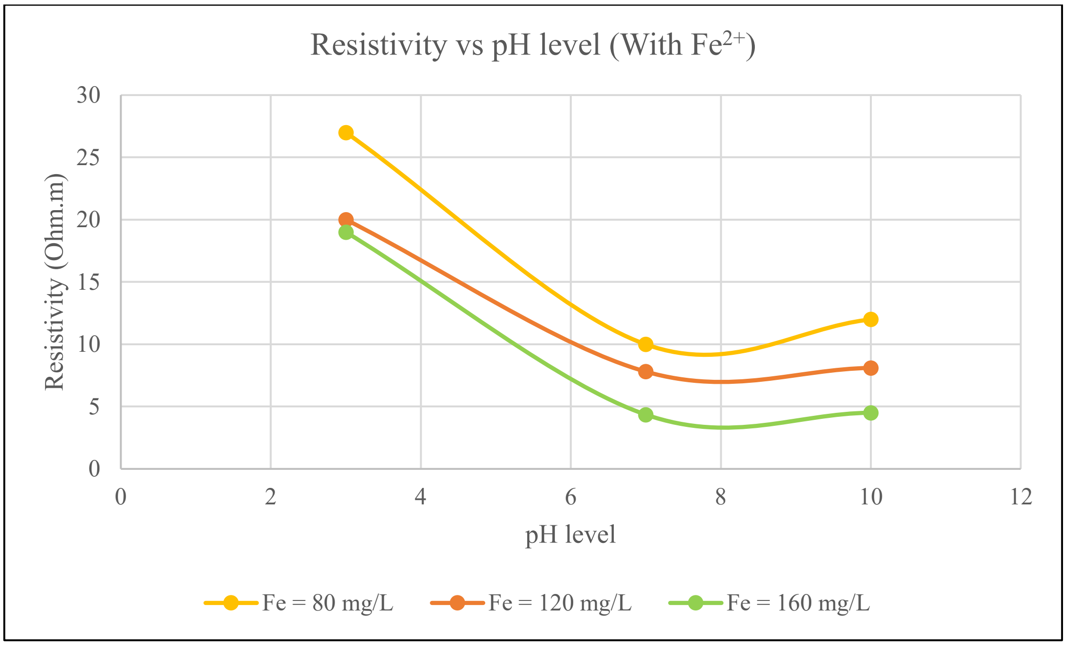
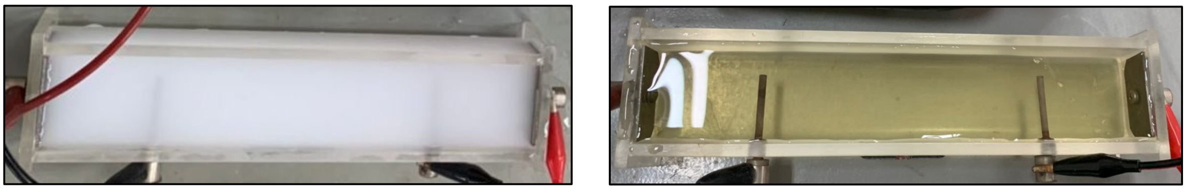


Figure 4: pH level vs Resistivity (With Fe^{2+})

4.3 Discussion

Miller 400A and soil box is one equipment that can be used to obtain resistivity. The Miller 400A equipment was equipped with three pieces of C 1.5V battery, providing the energy to read the resistivity value. Solution without Fe^{2+} concentration at the neutral level of pH shows that the reading of resistivity obtained have an increment of resistivity value along with pH level. However, the resistivity value obtained decreased once the pH level passed the neutral level, which is pH 7.

It can be seen that the mixture solution with Fe^{2+} concentration influence the resistivity obtained. Once the Fe^{2+} solution was added, the resistivity varied and showed a similar pattern between the nine samples of three different pH solutions. The acidic solution showed higher resistivity values for all three different Fe concentrations added. Observation during the laboratory work shows that acidic pH level shows a cloudy solution condition when added with Fe^{2+} solution. Meanwhile, for neutral and base pH levels, pH 7 and 10 the solution only turns yellowish-colored when influenced by the color of the Fe^{2+} solution. **Figure 5** shows the difference of the sample color between acidic pH level and base pH level.



(a) **(b)**

Figure 5: Difference of sample color after Fe^{2+} was added

Figure 5 (a) shows the acidic sample condition when Fe was added into the solution. Cloudy solution condition was observed. **Figure 5 (b)** shows the base sample condition when added with Fe. A yellowish-colored solution was observed influencing by the color of Fe solution. As shown in **Figure 5**, the resistivity value for pH 7 were 10 Ohm.m, 7.8 Ohm.m and 4.35 Ohm.m for Fe concentration of 80 mg/L, 120 mg/L, and 160 mg/L, respectively. The results obtained with the control of pH and Fe^{2+} had showed that the resistivity value for acidic and alkaline solution are lower compared to the neutral pH solution.

5. Conclusion

This study shows that resistivity values respond with water pH and the presence of dissolved iron solution. The resistivity values without iron solution shows the neutral water pH7 has the highest resistivity compared to pH3 and pH10. The resistivity value increased along with the pH level. However, after the pH level exceed the neutral level, the resistivity values decreased drastically. When the iron solution was added from acidic to alkaline water, it indicates the water resistivities drastically decreased in alkaline waters. It shows that the iron solution is effectively in alkaline water for reducing the resistivity value. This study can be concluded that the resistivity responds with the different pH levels and iron concentrations. For further study, it is recommended to adding more groundwater quality indicator parameters to understand the resistivity respond.

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