Phys. Comm. 3 (2) 2019 : 94 - 100

Physics Communication

http://journal.unnes.ac.id/nju/index.php/pc

Conductivity of Groundwater In Semarang City

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Article Info

Article History :
Received June 2019
Accepted July 2019
Published August 2019

Keywords:
TDS (Total Dissolved Solid), groundwater conductivity, electrode, water sources

Abstract

Semarang is the capital of Central Java Province and is the most developed city in Java island. This city is one of the most important cities in the north coast of Java. Most of Semarang's landscape consists of lowland areas that become floodplain of the large rivers that flow through the city. Water is not only used for drinking but also for other necessities such as bathing, washing, agricultural and industrial needs, electricity generation, etc. The objective of this study was to determine the conductivity value of groundwater from several locations in Semarang as the conductor of electricity. This study used groundwater samples from seven locations in Semarang. The tests conducted including TDS (*Total Dissolved Solid*) test by inserting TDS meter into the water and recorded the value after 3 seconds of observation. The conductivity test was done by water electrolysis using a buzzer circuit. The test was conducted by inserting the electrode into the water for 3 seconds, then observed the buzzer sounding (soft or loud). Afterward, the water temperature was recorded using the thermometer. Results of this study showed the different water conductivity of groundwater collected from different locations. The lowest conductivity was obtained from S-1 sample with TDS value of 50 ppm, while the highest conductivity was obtained from S-7 sample with TDS value of 549 ppm. The higher the TDS and temperature value, the higher the electrical conductivity.

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p-ISSN 2528-5971
e-ISSN 2528-598X

INTRODUCTION

Semarang is the capital city of Central Java province and is the fifth biggest metropolitan city in Indonesia. It is also one of the most developed city in Java island. Semarang has an area of 373.70 km^2 located on the north coast of Java. West Semarang has a width of 4 km from the coastline that gets wider on the east side reaches 11 km from the coastline. This low-lying area is the floodplain of the large rivers that flow through the city (BPS, 2018). Water is not only used for drinking but also for other necessities such as bathing, washing, agricultural and industrial needs, and electricity generation (Irwan & Afdal, 2016). Groundwater and river are the most used water sources to fulfill the daily needs (Ezewali et al., 2014).

Water quality has become a problem related to the public health since water contamination can cause several health problems. Especially in the West and East Semarang as a huge industrial area, water contamination can occur both directly and indirectly. The contamination will decrease the water quality, along with the changes in physical, chemical, and biological characteristics of the water (Paul & Sen, 2012).

The characteristics of groundwater vary due to the different number of particles contained (Syetiawan et al., 2014.). Ions dissolved in water affect the chemical characteristics of water such as its acidity level. Acids, bases, and salts can be broken down into positive and negative ions called electrolyte (Sehah & Cahyanto, 2009). This electrolyte can be used to generate the electricity.

One factor that affects the electricity produced from water is the type of water electrolyte contained. Water is an electrolyte with chemical and physical properties that can produce electricity by means of electrochemical (Sitorus, 2010). Water has several characteristics i.e. water temperature, metal content, Total Dissolved Solid (TDS), and the amount of electrical conductivity (Pinandita et al., 2015).

Measurement of dissolved solid concentration can be carried out by using gravimetric analysis, a standard method with high accuracy. However, this analysis must be conducted in a laboratory and takes a lot of time. Therefore, an alternative method by using electrical conductivity to measure the dissolved solid concentration in water was needed (Herlambang, 2016).

Electrical conducitivity is the measurement of solution's ability to carry electrical current. Electrical current is carried by the dissolved ions (Irzaman, 2010). The amount of ion dissolved in a solution is also affected by the dissolved solid content. The more dissolved solid content will probably increase the amount of ions and therefore generate the higher value of electrical conductivity. There is a relationship between the number of total dissolved solid (TDS) with the electrical conductivity (Irwan & Afdal, 2016).

Based on the explanation above, it is important to know the influence of TDS and temperature on electrical conductivity. There had been no report of water quality in Semarang City. Therefore, a study on groundwater conductivity in Semarang was needed to be carried out. The objective of this study was to analyze groundwater electrical conductivity from various water sources in Semarang by considering the influence of TDS and temperature. This study can provide information of water quality especially for people living in sampling site areas.

METHODS

Samples of water were taken from seven locations in Semarang. The locations were spread over the highland (300-311 m asl), midland (11-150 m asl), and lowland (2-6 m asl) areas. The highland was represented by Mijen (S-1) and Gunungpati (S-2) with altitudes of 311 and 300 m asl respectively. Gajah Mungkur (S-3), Tembalang (S-4), and Ngaliyan (S-5) represented the midland with altitudes of 150, 125, and 11 m asl respectively. The lowland was represented by Pedurungan (S-6) and North Semarang (S-7) with altitudes of 6 and 2 m asl respectively (Badan Pusat Statistik Kota Semarang, 2018).

Measurement of Total Dissolved Solid (TDS)

Measurement of TDS was conducted by initially preparing and cleaning the beaker glass, then filling it with the water sample. Digital TDS meter was then inserted into the beaker glass and eventually displayed the TDS value in ppm unit.

The process of measurement was carried out 7 times for water samples from 7 different locations in Semarang. Measurement steps used in this study were following a method by Munfiah (2013), where initially the water sample was prepared, then the TDS meter was inserted into the water and the TDS value can be observed after three seconds. Results of measurement were recorded and the water samples were collected since the measurement using TDS meter did not affect the water condition.

Electrolysis test

The water electrolysis test was conducted on each groundwater sample. A total of 300 cc of each water sample was taken for measuring the initial temperature. Subsequently, the water was then electrolyzed for 90 seconds. The water was then left for 60 minutes, and recorded for its changes in color, temperature, and as well as precipitates formed.

Water conductivity

Electrical conductivity is a numerical description of water's ability to carry a current. Accordingly, the more salts dissolved and ionized, the higher the water electrical conductivity. Buzzer and electrode that was put into the water were used to measure the water conductivity (Mentari, 2016). The measurement was conducted qualitatively. If the buzzer sounds loud, then it indicates a high water conductivity, but if the buzzer sounds soft, the water conductivity is low (Pramana, 2018).

RESULTS AND DISCUSSION

Groundwater samples obtained from various locations in Semarang showed the presence of different color changes, precipitate formation, and increased temperature (Figure 1) after 90 seconds of electrolysis followed by settling for several minutes.

Figure 1. Results of electrolysis of groundwater from several locations

The results of examination showed that the groundwater TDS values ranging between 50-549. This condition occurred due to the difference in types of solid that dissolved in the groundwater. There were three colors of precipitation (orange, green, and brown) obtained in this study. According to (Munfiah & Setiani, 2013), the changes in color of water can be caused by the presence of organic and inorganic materials such as plankton, humus, and metal ions (iron and manganese), as well as the other materials. The presence of iron oxide will make the water turning red, while the presence of manganese oxide will make the water becomes brownish or blackish color. The results of groundwater analysis is presented in Table 1.

Table 1. Results of groundwater TDS, conductivity, precipitation color, and temperature analysis

Water samples	TDS (ppm)	Conductivity	Precipitation color	Temperature (initial/final) (^{0}C)
S1	50	✓	Yellow	25/31
S2	244	✓✓	Orange	25/51
S3	268	✓✓✓	Orange	25/66
S4	271	✓✓✓	Orange, Green	25/58
S5	440	✓✓✓✓	Green	25/92
S6	495	✓✓✓✓✓	Orange, Green	25/84
S7	549	✓✓✓✓✓	Green	25/95

Note: the more check (✓) mark indicates the louder buzzer sound.

The results of Table 1 showed that the lowest TDS value was found in Gunungpati (S-1) by 50 ppm. Gunungpati is located in the highland with many trees and no pollution. Groundwater from North Semarang (S-7) showed the highest TDS value by 549 ppm. This condition is thought to be caused by the pollution from sea water and industrial waste. According to Thirumalini & Kurian (2009), TDS value of sea water is high because it contains small amount of organic matters such as silica, magnesium, aluminium, strontium, boron, etc. It is in line with a study by (Ezewali et al., 2014) that showed that the quality of water is correlated with human and industrial activity. Moreover, Niekerk et al., (2014) also stated that the difference in geographical location also affects the TDS value that affects the water quality.

Water with low TDS value will produce a soft buzzer sound while tested, and it is indicated that the water conductivity is very low. The water color will change from clear to yellow without any precipitation after the electrolysis. Water with high TDS value will produce a loud buzzer sound which means that the water conductivity is very high. The water color will change from clear to greenish-orange color with precipitation. That condition occurs due to the high TDS value that means that there is a large amount of solute dissolved. There are two types of solute i.e. organic and inorganic (metal compound). The more metal compound dissolved, the easier the solution to conduct electricity, so the buzzer sound will be louder. Results of groundwater conductivity test (Table 1) showed that the less check mark (✓) indicates the softer sound, while the more check mark (✓✓✓✓✓) indicates the louder sound of buzzer.

According to WHO, water with high inorganic minerals is not good for health because that minerals cannot disappear after boiling (Nurrohim et al., 2012). There are five categories of water based on their TDS value as follows,

a. TDS < 300 ppm : excellent
b. TDS 300-600 ppm : good
c. TDS 600-900 ppm : fair
d. TDS 900-1200 ppm : poor
e. TDS > 1200 ppm : unacceptable

WHO standard for TDS of drinking water that can be consumed is below 1000 ppm (WHO.1996).

Table 2. WHO standard for water TDS value

TDS Value (mg/L)	Salinity
0 – 1.000	Non-saline/fresh water
1.001 – 3.000	Slightly saline / brackish water
3.001 – 10.000	Moderately saline / brackish water
10.001 – 100.000	Highly saline
> 100.000	Severely saline

The conductivity of potable water ranges from 42-500 µmhos/cm. Conductivity of more than 250 µmhos/cm ppm is not recommended for consumption because the precipitation can occur and damage the kidney stones (Gasim, 2015).

In addition to changes in color, temperature also changes in electrolyzed water (Juniarti & Jumarang, 2017). The longer the electrolysis time, the higher the water temperature compared to the initial state (Figure 2). Figure 2 also shows the equation between time of electrolysis and water temperature using 2nd order polynomial model with correlation coefficient (r) closest to 1 as shown in figure 3.

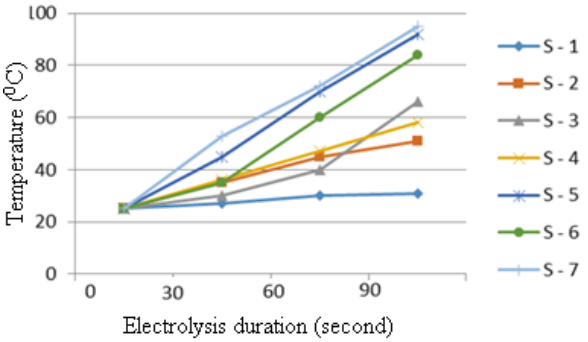

Figure 2. Relationship between electrolysis duration and water temperature

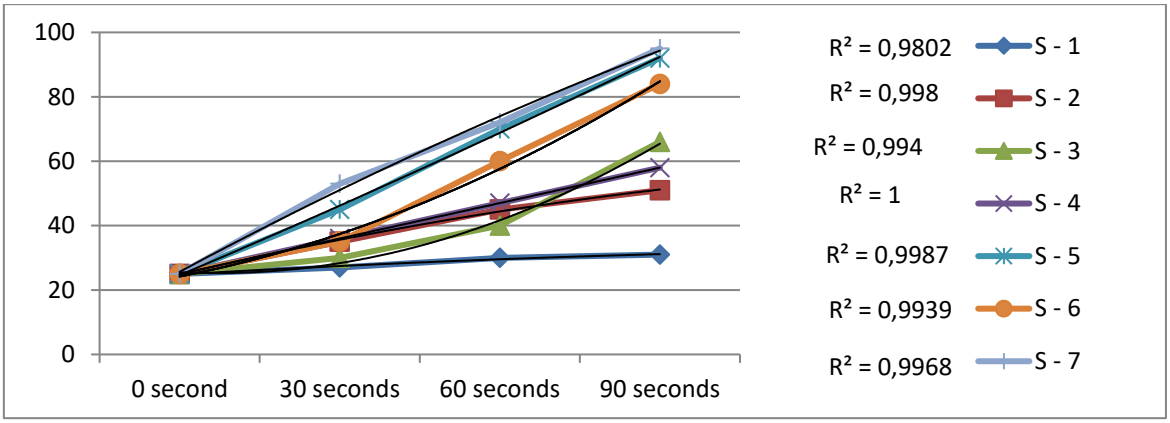

Figure 3. Value of correlation coefficient (r) from 2nd order polynomial equation model

Relationship between electrolysis time and groundwater temperature is linear at short electrolysis time and starts to be non-linear at long electrolysis time (Efendi, 2013). The best model for relationship between electrolysis time and groundwater temperature is 2nd order polynomial model with correlation coefficient (r) closest to 1. Figure 3 represents the linear relationship between the length of electrolysis time and the increase in water temperature of 7 water samples obtained from 7 different locations in Semarang.

Electrolysis testing caused changes in water temperature. The results showed that there is a tendency of water with higher TDS value to generate higher temperature after the electrolysis. The initial temperature of S-1 with TDS value of 50 was 25^{0}C, while after the conductivity test for 90 seconds it became 31^{0}C. In addition, the temperature of water with high TDS value (549) can increase up to 95^{0}C (Table 1). According to Sitorus (2010), a higher dissolved solid content is able to produce more electricity because the ions dissolved in the water have more density and make the electrons move faster from negative to positive, therefore water with higher TDS seems to heat faster than the one with lower TDS. Water with higher TDS has more and denser metal ions so if it is heated, it will heat up faster in a short time. Otherwise, the temperature of water with lower TDS will not change significantly if the water is heated in a short time because of low heat conductivity due to the smaller amount of dissolved ions (Choo-in, 2019).

Figure 2 shows the relationship between temperature and electrical conductivity. It shows that the higher the temperature, the higher the electrical conductivity. This condition is caused by the movement of ions that is faster due to an increase in temperature, resulted in the higher electrical conductivity (Jemily et al., 2019).

Temperature also affects the chemical properties of water. Chemical reaction rate commonly increases at a higher temperature. Especially for groundwater, the higher temperature can dissolve more minerals from surrounding rocks resulted in the higher electrical conductivity as well (Rusydi, 2018). This water conductivity measurement is able to show that an area with low groundwater conductivity has higher water quality, while it will be lower in an area with high groundwater conductivity.

The benefit of this study is to provide a reference that the difference in water conductivity is dependent on the location, TDS value, the height of a land, and water temperature.

CONCLUSION

The lowest water conductivity was found in sample from S-1 with TDS value of 50 ppm and the highest was from S-7 with 549 ppm. The higher the groundwater TDS value, the higher the water conductivity. According to the data on correlation coefficient (r) closest to 1, there is a linear relationship between the length of electrolysis time and the increase in water temperature of 7 water samples obtained from 7 different locations in Semarang. Therefore, it is known that the higher TDS value will accelerate the time of electrolysis resulted in higher water temperature and higher water electrical conductivity.

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