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# Analysis of Groundwater Salinity Distribution Based on Electrical Conductivity (EC) and Hydrochemical Approaches to Deep Wells in Sayung Subdistrict, Demak Central Java

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***Abstract*— *In coastal areas, obtaining groundwater is not easy due to the lack of geological support conditions that cause water in the area to have poor quality such as groundwater that becomes salty. The coastal area of Sayung Subdistrict has geomorphological conditions whose surface tends to be flat with elevations 0-5 m higher than sea level and is dominated by alluvial material so that it can cause seawater infiltration to increase. The purpose of this research was to determine the distribution of salinity of groundwater in the coastal area of Sayung Subdistrict and to determine the cause of groundwater becoming salty. The method used in this research is the electrical conductivity (DHL) approach which is then classified based on the level of saltiness of groundwater. And then, well water from the sample points was tested using a hydrochemical test with the parameters used, namely the content of cations (Na, K, Mg, Ca) and anions (Cl, CO3, HCO3, SO4, NO3). This research was conducted at 33 well points spread across Sayung sub-district. The results of this study show that the electrical conductivity value obtained is between the range of 928-7,199 µS/cm which is divided into 3 classifications namely fresh water, fresh-brackish water, and brackish water. The analysis of the Trilinier Piper diagram shows that the saltiness of the groundwater is due to indications of seawater mixing characterized by a chloride (Cl) content that is increasingly greater towards the sea.***

***Keywords: seawater intrusion, electrical conductivity, trilinear piper diagram, ground water, mineral***

## I. INTRODUCTION

Geographically, Sayung sub-district is located next to the Java Sea on the north coast of Java. Due to the geomorphological conditions whose surface tends to be flat with an elevation of 0-5 m higher than sea level and dominated by alluvial material, the seawater infiltration will increase [1]. Sayung sub-district is an industrial area with geological conditions composed of rocks carried from the Rembang hills and Kendeng hills, so the possible cause of salinity of groundwater can also be caused by waste from industry or from minerals dissolved in aquifer rocks, so additional research can be done to find out the cause of groundwater becoming salty.

Seawater intrusion is the event of seawater entering the lower layers of groundwater. The occurrence of seawater instrusion is caused by a decrease in groundwater levels. Seawater intrusion is one of the causes of groundwater quality degradation [2].

 

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The electrical conductivity value can be interpreted as the power of water to transfer electricity. Consequently, as the electrical conductivity value increases, the amount of dissolved salts that can be ionized will increase [3]. The classification level of groundwater salinity based on the electrical conductivity value can be seen in **Table 1.**

**Table 1. Classification of Groundwater Salinity Based on electrical conductivity [4]**

| No | Characteristic of Water | DHL ($\mu S/cm$) |
|---|---|---|
| 1 | Fresh | <1.500 |
| 2 | Fresh-Brackish | 1.500 – 5.000 |
| 3 | Brackish | 5.000 – 15.000 |
| 4 | Salty | 15.000 – 50.000 |
| 5 | Briny | >50.000 |

TDS is an organic and inorganic substance dissolved in water and cannot pass a 0.45 µm diameter filter paper. However, in general, TDS is caused by inorganic compounds dissolved in water [5]. The classification level of groundwater salinity based on TDS can be seen in **Table 2.**

**Table 2. Classification of Groundwater Salinity Level Based on Total Dissolved Solids (TDS) [4]**

| No | Characteristic of Water | TDS (mg/l) |
|---|---|---|
| 1 | Fresh | <1.000 |
| 2 | Fresh-Brackish | 1.000 – 3.000 |
| 3 | Brackish | 3.000 – 10.000 |
| 4 | Salty | 10.000 – 35.000 |
| 5 | Briny | >35.000 |

Salinity indicates the level of saltiness or the amount of salt content dissolved in water. Salinity has a relationship with electrical conductivity where increasing electrical conductivity values will cause high salinity values [6]. The classification level of salinity based groundwater can be seen in **Table 3.**

**Table 3. Classification of Groundwater Salinity Levels Based on Salinity [4]**

| No | Characteristic of Water | Salinity (%) |
|---|---|---|
| 1 | Fresh | <0,05 |
| 2 | Brackish | 0,05 – 3,00 |
| 3 | Salty | 3,00 – 5,00 |
| 4 | Briny | >5,00 |

In general, water has a neutral pH of 7. The smaller the pH value <7, the water will be acidic and conversely the greater the pH value >7, the water will be alkaline. Acidic water contains CO2 and Fe. Alkaline water contains a lot of Ca or Mg salts [7].

Hydro-facies analysis using Piper's Trilinear diagram is one of the hydrochemical analyses that can be done to determine the cause of seawater intrusion. In this analysis, samples were tested to determine the composition of cations and anions to determine the genetics of groundwater and then plotted on Piper's Trilinear diagram which can be seen in **Figure 1 [8]**. The values tested for cation parameters were sodium (Na), magnesium (Mg), potassium (K) and calcium (Ca). The anion contents tested were sulfate (SO4), carbonate (CO3), bicarbonate (HCO3), sulfate (SO4), nitrate (NO3), and chloride (Cl) [9].

 

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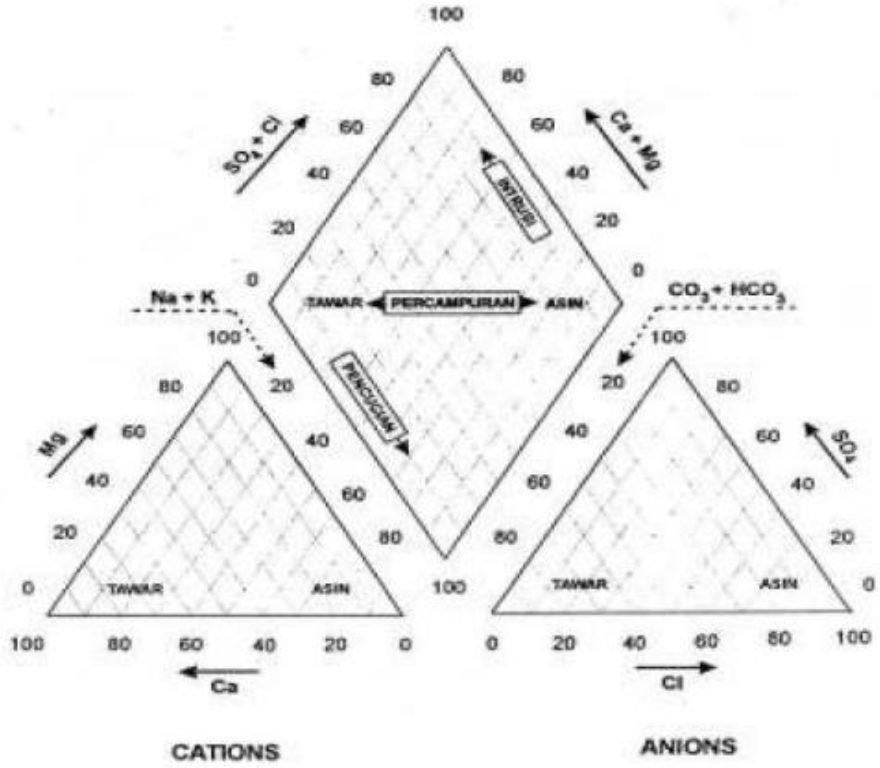


**Figure 1. Trilinier Piper Diagram**

In addition, the chloride-bicarbonate ratio method can also be used as a basic reference to determine the cause of seawater intrusion. Which can be expressed in the formula below:

$$R = \frac{Cl^-}{CO_3^- + HCO_3^-}$$

with units of meq/l for CL, CO3, and HCO3 [10]. From the calculation of the chloride-bicarbonate ratio, if the R value> 1 with an electrical conductivity value> 1500 µS / cm then salt water is caused by seawater infiltration. If the R value <1 with an electrical conductivity value >1500 µS/cm saltwater is caused by the presence of salt minerals dissolved in aquifer rocks [11].

**Table 4. Relationship between Seawater Intrusion Rate and R Value [4]**

| ***R*** | **The Level of Intrusion** |
|---|---|
| <0,5 | Fresh groundwater |
| 0,5 – 1,3 | Intrusion occurs in small amounts |
| 1,3 – 2,8 | Intrusion occurs in medium amounts |
| 2,8 – 6,6 | Intrusion occurs in high amounts |
| 6,6 – 15,5 | Intrusion occurs in very high amounts |
| 15,5 - 20 | Seawater |

The geomorphology of Sayung Sub-district has a flat surface with elevations 0-5 m higher than sea level and is dominated by alluvial material. The rock lithology is composed of soft firm clay and medium-rigid sand (alluvium) at a depth of 0-100 m, stiff-hard clay and medium-rigid sand 100-200 m, marl (Kalibeng Formation) 200-400 m and dominated by sandstone claystone (Kerek Formation) up to 600 m [12].

 

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## II. METHODS

The research was conducted in Sayung Subdistrict with 33 survey points used to determine the distribution of salinity of groundwater by approaching the value of electrical conductivity, TDS, salinity, and pH. For some areas in the south there are no water sample survey points because the area is dominated by ponds with no settlements. Then from the survey points, 3 samples were taken to determine the cause of groundwater becoming salty. The distribution map of survey points and samples for hydrochemical tests can be seen in **Figure 2. and Figure 3.**

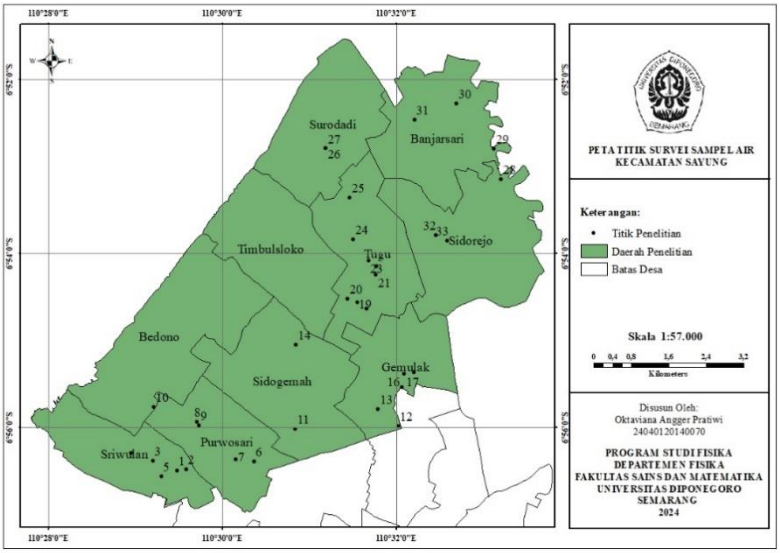


**Figure 2. Map of Water Sample Survey Points**

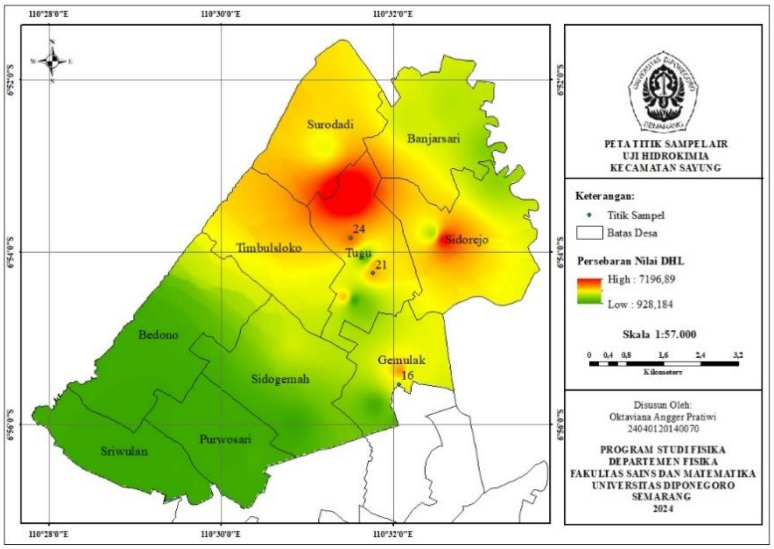


**Figure 3. Map of Hydrochemical Test Water Sample Points**

 

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## III. RESULT AND DISCUSSION

Based on the results of research that has been carried out at 33 points of deep wells obtained electrical conductivity values between 928–7199 µS/cm which indicates that the classification of the level of salinity of water is divided into three namely fresh water, slightly brackish water, and brackish water. Based on **Figure 4.** Sayung sub-district is dominated by the classification of groundwater salinity level is slightly brackish water. The classification of water salinity can be seen down below.

**Table 5. Research Data of DHL Value Based on Salinity Level Classification of Sayung Subdistrict Groundwater**

| Sample Point | DHL (µS/cm) | Village | Classification |
|---|---|---|---|
| 4 | 928 | Sriwulan | *Fresh* |
| 5 | 928 | Sriwulan | *Fresh* |
| 11 | 938 | Sidogemah | *Fresh* |
| 10 | 940 | Bedono | *Fresh* |
| 7 | 946 | Purwosari | *Fresh* |
| 19 | 946 | Tugu | *Fresh* |
| 3 | 952 | Sriwulan | *Fresh* |
| 2 | 992 | Sriwulan | *Fresh* |
| 8 | 1005 | Purwosari | *Fresh* |
| 1 | 1007 | Sriwulan | *Fresh* |
| 9 | 1039 | Purwosari | *Fresh* |
| 13 | 1133 | Gemulak | *Fresh* |
| 6 | 1155 | Purwosari | *Fresh* |
| 12 | 1344 | Gemulak | *Fresh* |
| 23 | 1535 | Tugu | *Fresh-Brackfish* |
| 18 | 1724 | Timbulsloko | *Fresh-Brackfish* |
| 29 | 1861 | Banjarsari | *Fresh-Brackfish* |
| 26 | 1901 | Tugu | *Fresh-Brackfish* |
| 28 | 2026 | Sidorejo | *Fresh-Brackfish* |
| 32 | 2332 | Sidorejo | *Fresh-Brackfish* |
| 30 | 2401 | Banjarsari | *Fresh-Brackfish* |
| 31 | 2596 | Banjarsari | *Fresh-Brackfish* |
| 14 | 2623 | Loireng | *Fresh-Brackfish* |
| 15 | 2775 | Loireng | *Fresh-Brackfish* |
| 16 | 2848 | Gemulak | *Fresh-Brackfish* |
| 27 | 2924 | Tugu | *Fresh-Brackfish* |
| 20 | 3585 | Tugu | *Fresh-Brackfish* |
| 22 | 3680 | Tugu | *Fresh-Brackfish* |
| 21 | 3686 | Tugu | *Fresh-Brackfish* |
| 17 | 3907 | Gemulak | *Fresh-Brackfish* |
| 24 | 4148 | Tugu | *Fresh-Brackfish* |
| 33 | 5204 | Sidorejo | *Brackfish* |
| 25 | 7199 | Tugu | *Brackfish* |

Based on the classification of groundwater salinity, freshwater has an electrical conductivity value of less than 1500 µS/cm, fresh-brackish water has an electrical conductivity value of 1500 to 5000 µS/cm, and brackish water has an electrical conductivity value of 5000 to 15000 µS/cm [4]. Based on the **table 4**, villages included in the freshwater classification are Sriwulan, Purwosari, Bedono, Gemulak, Sidogemah, and Tugu with electrical conductivity values of 928 to 1344 µS/cm. Freshwater-brackish are Sidogemah, Gemulak, Tugu, Surodadi,

 

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Banjarsari, and Sidorejo with electrical conductivity values of 1535 to 4148 µS/cm. Brackish water is in Tugu and Sidorejo with electrical conductivity values of 5204 to 7199 µS/cm.

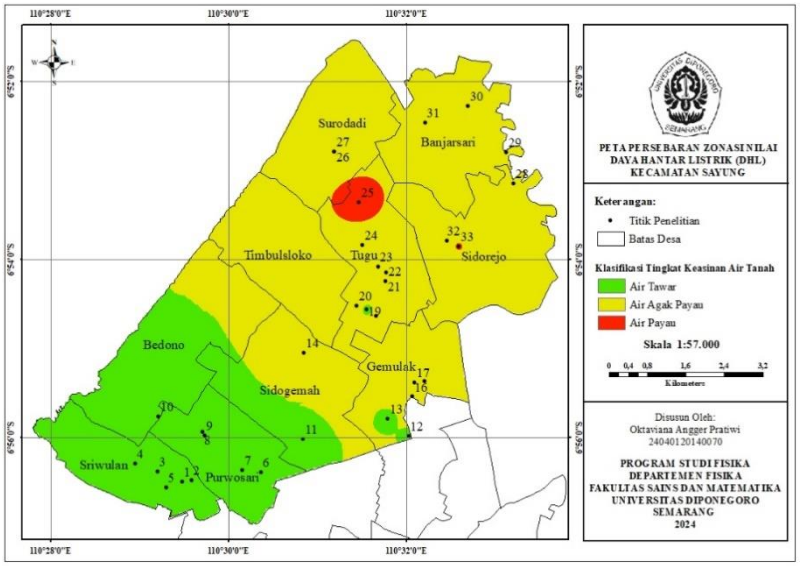


**Figure 4. The Map of Distribution of Electrical Conductivity Value**

Salinity is interconnected with the electrical conductivity value, salinity will be high if the electrical conductivity value is high. Based on the classification of groundwater salinity, freshwater has a salinity value of less than 0.05%, fresh-brackish water has a salinity value of 0.05 to 0.8% [4]. Based on this research, the salinity value for freshwater classification is 0.04% spread in Sriwulan, Purwosari, Sidogemah, and Tugu villages shown in green color in **Figure 5**. Freshwater-brackish classification is 0.05–0.8% spread in Sriwulan, Purwosari, Gemulak, Tugu, Sidorejo, Banjarsari, Loireng, and Timbulsloko villages shown in tosca green color in **Figure 5.**

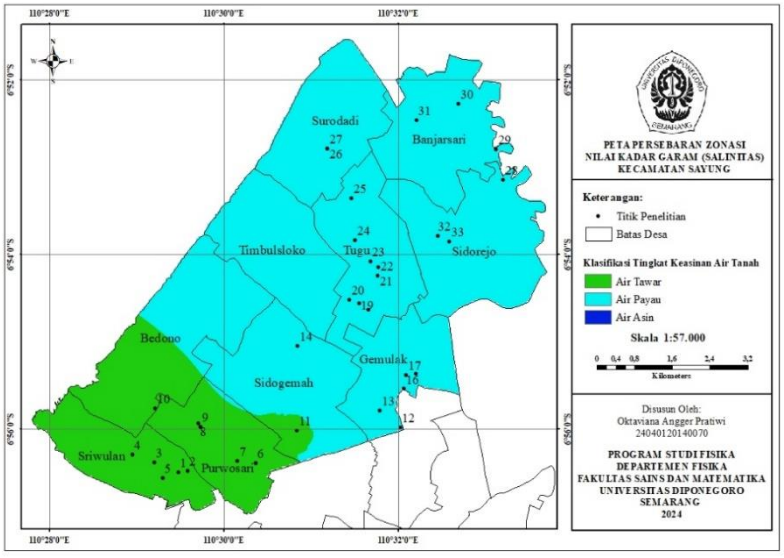


**Figure 5. The Map of Distribution of of Salinity Values**

TDS is the amount of substances dissolved in water. Based on the classification of groundwater salinity, freshwater has a TDS value of less than 1000 µS/cm, fresh-brackish water has a TDS value of 1000 to 3000 µS/cm, and brackish water has a TDS value of 3000 to 10000 µS/cm [4]. Based on this research, the TDS value for freshwater classification is 458.47–992.86 mg/l spread in Sidogemah, Sriwulan, Purwosari, Tugu, Gemulak,

 

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Timbulsloko, Banjarsari, and Sidorejo villages shown in light blue in **Figure 6**. The freshwater-brackish classification of 1195.63–2626 mg/l is scattered in the villages of Banjarsari, Loireng, Gemulak, Tugu, and Sidorejo shown in blue in **Figure 6**. And the brackish water classification of 3572.91 mg/l is in the village of Tugu shown in dark blue in **Figure 6**.

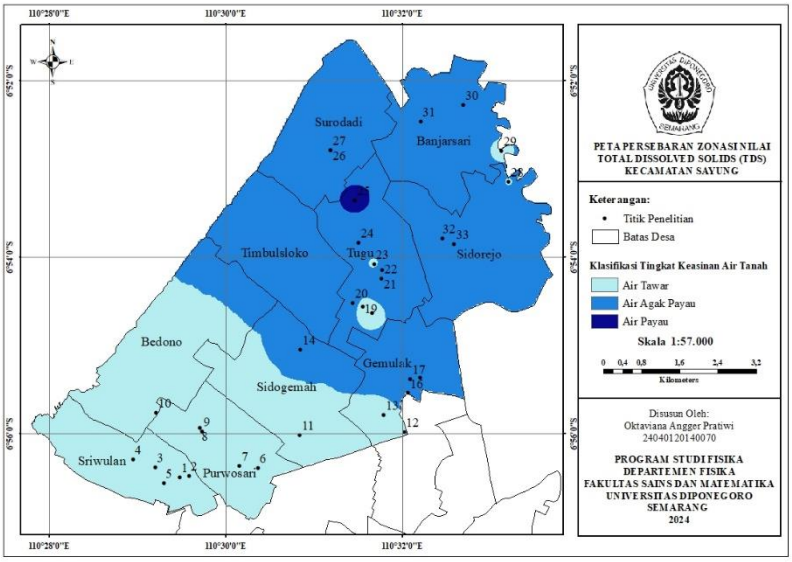


**Figure 6. The Map of Distribution of of TDS Values**

The degree of acidity (pH) is one indicator to show the balance between acids and bases. From **Figure 7**, the research area obtained a pH value ≥7, meaning that the groundwater in the research area is alkaline.

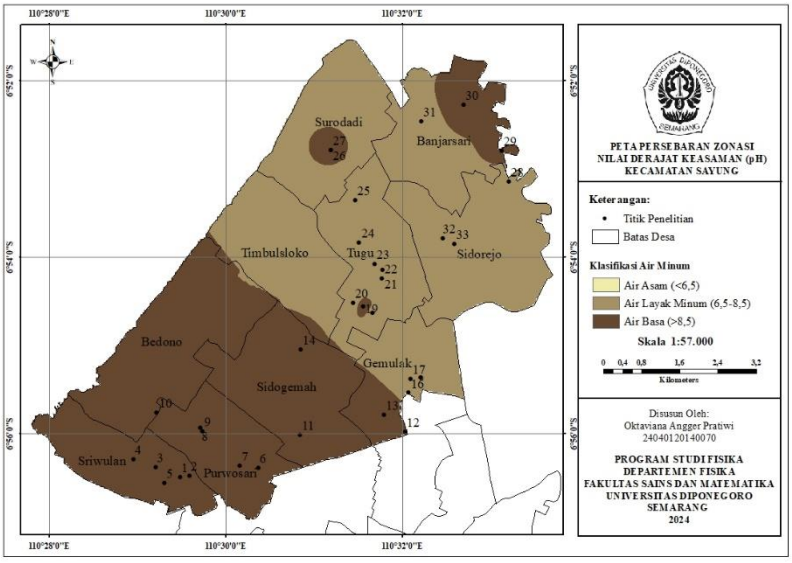


**Figure 7. The Map of Distribution of of pH**

From the hydrochemical test results of the piper trilinear diagram which can be seen in **Figure 8.** shows that sample points 16, 21, and 24 are in the freshwater area. This is reinforced by the chloride-bicarbonate ratio value at point 16 obtained an R value of 0.2308 with an electrical conductivity value of 2848 µS/cm. Point 21 obtained an R value of 0.2106 with an electrical conductivity value of 3686 µS/cm. And at point 24 obtained an R value of 0.2799 with an electrical conductivity value of 4148 µS/cm. The results of the 3 sample points show that the R value obtained is <1 with an electrical conductivity value of >1500 µS/cm, which means that

 

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salt water in the soil is not caused by seawater intrusion but due to the presence of salt minerals dissolved in aquifer rocks

**Table 6. Hydrochemical Test Research Results**

| Titik Sampel | Kation (mg/l) | | | | Anion (mg/l) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Na | K | Ca | Mg | Cl | $CO_3$ | $HCO_3$ | $SO_4$ | $NO_3$ |
| 16 | 2,35 | 0,56 | 70,84 | 67,12 | 62,30 | 156,78 | 145,68 | 42,35 | 5,60 |
| 21 | 3,41 | 0,62 | 84,56 | 71,34 | 56,87 | 140,82 | 178,30 | 28,90 | 3,89 |
| 24 | 3,82 | 0,73 | 91,10 | 74,56 | 67,93 | 132,56 | 148,18 | 32,40 | 4,30 |

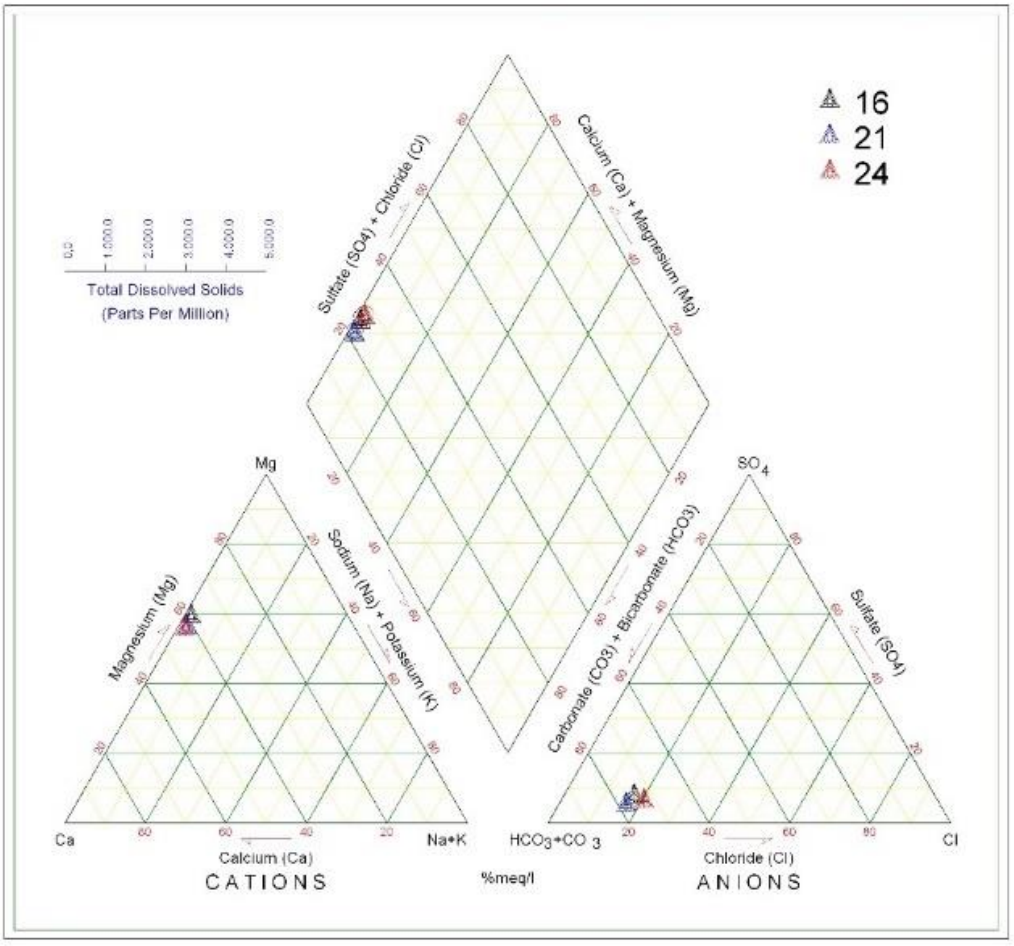


**Figure 8. Trilinier Piper Diagram of Groundwater in Sayung Sub-District**

In addition, from the piper trilinear diagram above, the hydrochemical facies can be interpreted. From the water hydrochemical test data, the anion type is chloride and the cation type is calcium and magnesium. The chloride content is indicated to be derived from seawater mixing characterized by the high chloride content pointing towards the sea. In addition, chloride content can be stored in sedimentary rocks such as clays. Meanwhile, the calcium and magnesium content comes from dolomite and limestone lithologies that form the same formation. These minerals show a picture of aquifer formation on the coast of Demak. This is because the material that forms on the coast of Demak comes from the Rembang hills and Kendeng hills which contain limestone and dolomite materials. Overall the groundwater in the study area belongs to the Mg(Ca)Cl(SO4) facies.

 

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## IV. Conclusions

Based on the classification of the level of saltiness of groundwater, Sayung Sub-district is divided into 3 classifications: freshwater, fresh-brackish water, and brackish water. Villages included in the freshwater classification are Sriwulan, Purwosari, Bedono, Gemulak, Sidogemah, and Tugu with an electrical conductivity value of 928 to 1344 µS/cm. Freshwater-brackish are Sidogemah, Gemulak, Tugu, Surodadi, Banjarsari, and Sidorejo with an electrical conductivity values of 1535 to 4148 µS/cm. Brackish water is in Tugu and Sidorejo with an electrical conductivity values of 5204 to 7199 µS/cm. The cause of groundwater becoming salty is due to indications of seawater mixing which is characterized by the chloride (Cl) content which is getting bigger towards the sea.

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