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Sea Water Intrusion Analysis Using Electric Conduct Value And Hydrochemical Approach On Shallow Dug Wells In The Low Of Semarang City

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Abstract:
Background*: The lowland area of Semarang City is the center of Semarang City which has a high population density. As a result, the fulfillment of clean water needs continues to increase and the exploitation of underground water causes sea water intrusion. The sea water intrusion that occurred has penetrated into citizens's dug wells which are used to fulfill household water needs. This study aims to determine the distribution of salinity levels and sources of groundwater salinity in shallow wells.*
Materials and Methods*: The method used is by approaching the value of Electrical Conductivity (EC) to determine the pattern and distribution zone of the groundwater salinity. Furthermore, groundwater hydrochemical analysis is performed which is visualized on the Trilinear Piper diagram to determine the source of the groundwater salinity in shallow wells. The data collection of Electrical Conductivity which was carried out at 35 shallow well points in the lowland 9 sub-districts of Semarang City showed the value of Electrical Conductivity are 470 - 4.050 µS / cm.*
Results*: Based on the classification of the groundwater salinity level, most of the research areas are fresh groundwater and a small part is slightly brackish groundwater, namely at the points of Sambirejo, Kaligawe, and LamperLor. From the hydrochemical analysis with the Trilinear Piper diagram shows that the salinity of groundwater in the research area is due to sea water intrusion.*
Keywoards: *Seawater intrusion, Electrical Conductivity, Trilinear Piper diagram.*

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I. Introduction

Semarang City as the Capital of Central Java Province is growing as a metropolitan city. The total population according to in 2019 reached 1,814,110 people. Apart from a fairly high population, Semarang City also has quite a number of industries, companies, tourism, especially in the lower urban areas. This area is the center of government, trade and industrial activities so that the population distribution in the city of Semarang is concentrated in the lower areas.

The high population growth has resulted in not all components of society being able to enjoy clean water. This condition occurred in the city of Semarang. The need for clean water for residents of Semarang City reaches about 61.7 million m^3 per year or 170 thousand m^3 per day [1]. The increasing need for clean water results in depletion of surface water supplies. If this is the case, then underground water exploitation will result in negative impacts on the quality and quantity of groundwater, including a decrease in groundwater level and groundwater quality, as well as the occurrence of sea water intrusion in several areas of the lower city of Semarang. Even the intrusion that occurred has seeped into the dug wells used by the community [2]. The phenomenon of seawater intrusion is exacerbated by groundwater extraction and the potential for sea level rise as this process reduces the hydraulic gradient that promotes the discharge of fresh groundwater into the ocean. Contamination from seawater or salt water will affect the quality of groundwater reservoir water [3].

This study uses the parameter of the value of electrical conductivity (EC) to determine the distribution of the salinity level of groundwater in order to analyze shallow aquifers that have been intruded by sea water. Because the geological condition of Semarang City is a deltaic sediment, besides being caused by sea water intrusion, the salinity of the groundwater can also be caused by connate water. For this reason, it is necessary to determine the source of the salinity of groundwater by determining the chemical type of groundwater through hydrochemical analysis which is visualized using a piper trilinier diagram.

Previous research on seawater intrusion has been carried out including using the EC value approach and hydrochemical methods [4], using the Geoelectric resistivity method [5], [6], using the stable isotope approach and water chemistry [7], and using the geoelectricity method and hydrochemical [8]. Periodic studies may need to be carried out to show thedevelopment process of seawater intrusion that has occurred. For this reason, a re-research on sea water intrusion using the DHL value approach and hydrochemicals with the aim of knowing the distribution of the salinity of groundwater and the source of the salinity of groundwater in shallow wells in the city of Semarang below.

II. Material And Methods

Seawater intrusion is the infiltration of salt water into fresh groundwater areas in a coastal aquifer setting. Seawater intrusion is influenced by natural and anthropogenic processes [9].

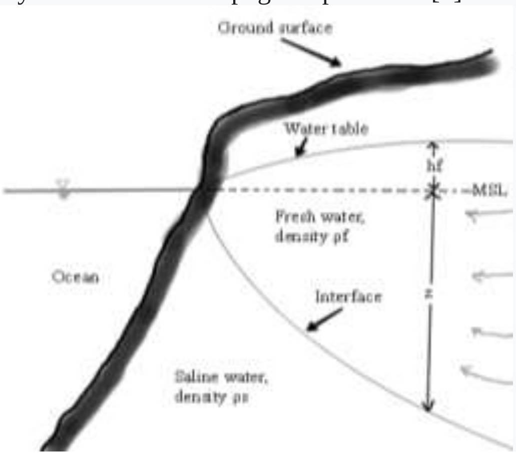

Figure 1.Illustration of groundwater events fresh and salty in aquifers free [11].

Excessive withdrawal of groundwater causes the groundwater level to be lower than sea level because there is a lot of empty space in the aquifer. The difference between the groundwater level and sea level causes sea water that contains salt elements such as chloride (Cl) to infiltrate groundwater, resulting in groundwater contamination [10].

The simplest conceptual model of seawater intrusion using the Ghyben-Herzberg approach of the hydrostatic balance between two liquids of different density (one-dimensional case) is given as [9]:

$$P_s = P_f \quad (1)$$

$$\rho_s g z = \rho_f g z + \rho_f g h_f \quad (2)$$

$$z = \frac{\rho_f}{\rho_s - \rho_f} h_f \quad (3)$$

where$P_s$is the hydrostatic pressure in seawater, P_f is the hydrostatic pressure in groundwater ρ_s is the density of seawater and, ρ_f is the density of groundwater. If the value of ρ_s is 1,025 kg /m^3 and the value of $\rho_f$is 1,000 kg / m^3, then we get:

$$z = 40\ h_f \quad (4)$$

where$h_f$is the height of the groundwater above sea level (m), and z is the level of sea water to the surface (m).

Groundwater (groundwater) is the amount of water below the earth's surface in the soil layer or subsurface rock [12]. Groundwater is an essential and vital resource in all countries. A number of factors can affect the quality of groundwater reservoirs such as contamination by intrusion of seawater or salt water [13].

An aquifer can be defined as a layer containing sufficiently saturated permeable material that can store and deliver or produce large amounts of water to wells and springs. Most aquifers have a large area and can be visualized as underground storage reservoirs. Water enters the reservoir from natural or artificial filling, mainly flows through gravity processes or is extracted by wells. There are 3 main types of aquifers, namely confined aquifer, unconfined aquifer, and leaky aquifer [11].

Electrical conductivity (EC) or conductivity is a numerical representation relating to a material's ability to conduct electric current. EC is an important parameter in assessing the quality of groundwater for drinking and irrigation. This measurement of electrical conductivity aims to measure the ability of ions (cations and anions) in water to conduct electric current [14].

According to [20] shallow groundwater generally has a price of 30 - 2,000 µS/cm. If the more ionizable dissolved salts, the higher the EC value. Therefore, EC can be used as one of the parameters to determine the salinity of groundwater.

Table 1. Classification of groundwater salinity based on the value of EC byCommittee for Ad Hoc Salt Water Intrusion (PAHIAA) Jakarta [16]

Water Properties	EC (µS/cm)
Fresh Water	<1500
Somewhat Brackish Water	1.500 – 5.000
Brackish Water	5.000 – 15.000
Salt Water	15.000 – 50.000
Brine	>50.000

Groundwater in natural systems generally contains less than 1,000 mg / l dissolved solids unless very soluble minerals such as gypsum are found, concentrated by evapotranspiration, and heated by geothermal heat [11].

The chemical composition of groundwater determines the chemical type of groundwater. To identify the chemical type of groundwater, the piper Trilinier diagram method is used. This method is based on the content of ions such as Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, HCO_3^{-}, CO_3^{2-}, and SO_4^{2-} [17]. The analysis of hydrochemicalfacies using the piper Trilinier diagram can illustrate the mixing of two types of water with different sources. The mixing of two different water sources will be drawn on a straight line connecting two points, namely freshwater points and sea water points, so that it can be used to detect sea water intrusion [8].

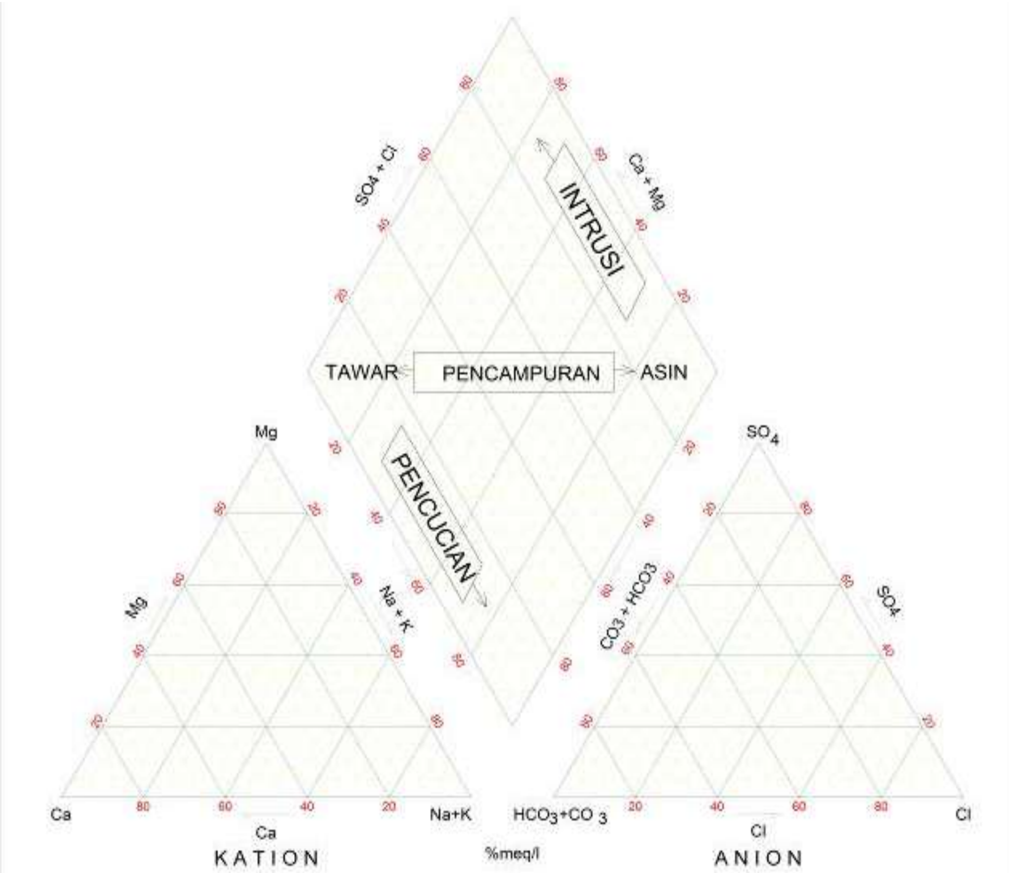

Figure 2. Piper's Trilinier Diagram [18]

Indication of seawater intrusion can also be done by calculating the chloride-bicarbonate ratio of the groundwater sample. The value of the chloride-bicarbonate ratio is in accordance with the equation.

If the value of R <1 and the value of EC<1,500 µS/cm, the salinity of groundwater is due to the dissolution of salt minerals found in aquifer rocks. Meanwhile, if the value of R> 1 and the value of EC> 1,500 µS/cm, then the salinity of groundwater is due to sea water intrusion [19].

The research was conducted in two stages, namely the analysis stage with the DHL value and hydrochemical analysis. The analysis phase based on the EC value begins with the collection of Electrical Conductivity data using the Electric Conductivitymeter which is carried out at 35 community dug well points in 9 sub-districts of Semarang City, namely Tugu District, West Semarang, North Semarang, Central Semarang, South Semarang, Gayamsari, East Semarang Pedurungan, and Genuk, as well as 2 points in Kebonbatur Village, Mranggen District, Demak. Based on EC data and point coordinates, aEC contour map was created using the Surfer 13 software.

The hydrochemical analysis stage is carried out to determine the source of the salinity of groundwater. The concentrations of cations (Na, K, Mg, Ca) and anions (Cl, CO_3, HCO_3, SO_4) which were determined by laboratory analysis were then visualized on a piper's trilinier diagram.

III. Result

The results of the measurement of the electrical conductivity of the measurement area in The Low of Semarang in the color gradation contour are shown in Figure 3. Based on the level of salinity of groundwater in Table 1, groundwater in the study area can be classified into 2 types, namely the distribution of fresh groundwater and slightly brackish groundwater.

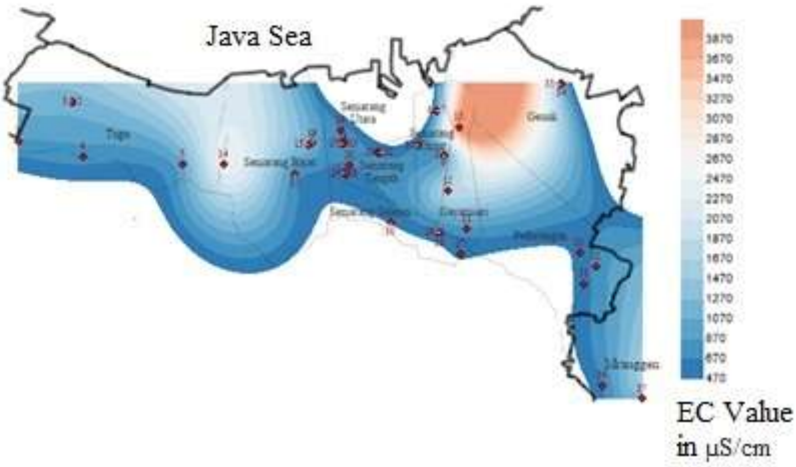

Figure 3. Contours of electrical conductivity (EC) in the research area

To determine the source of the salinity of groundwater, a hydrochemical analysis of groundwater was carried out. Water samples were taken from community dug wells which were estimated to be in one direction or one groundwater flow line. The direction of groundwater flow in the study area is estimated to be to the north. The well water samples were located at Sambirejo (T.12), Kaligawe (T.13), and LamperLor (T.28) locations. The concentrations of cations and anions are then plotted on a Piper's Trilinier diagram (Figure 4).

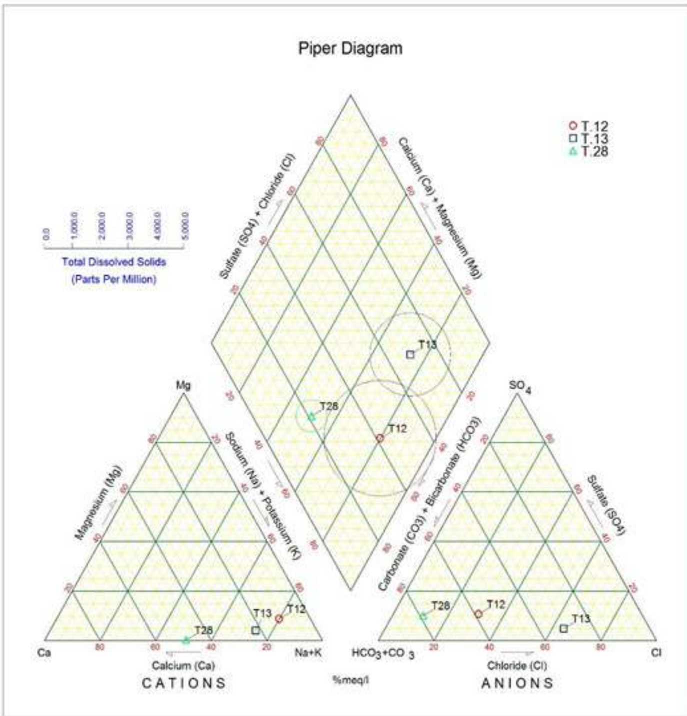

Figure 4. Piper Trillineardiagram resultsplotting groundwater samples shallow wells in the study area

IV. Discussion

In this study, the EC (Electrical Conductivity) values obtained for fresh groundwater ranged from 470 µS/cm to 1,400 µS/cm. The areas included in this classification cover most of the research areas, namely the fresh groundwater area of the lower Semarang region including Tugu District (MangkangKulon, MangkangWetan, Randugarut, and Tugurejo), West Semarang District (Tawangmas, Karangayu, and KalibantengKidul), Semarang District. North (Plombokan, BuluLor, and PanggungKidul), Central Semarang District (PendrikanKidul, PendrikanLor, Pandansari, and Pekunden), South Semarang District (Middle Lamper, LamperLor, and Pleburan), East Semarang District (Kemijen, Bugangan, and Kebonagung), Gayamsari (Gayamsari) District, Pedurungan District (PenggaronKidul, PedurunganLor, PedurunganKidul, TlogosariKulon and Tlogomulyo), and Genuk District (Trimulyo, Genuk Sari, and BangetayuWetan as well as 2 research points in Kebonbatur Village, District Mranggen.

The distribution of slightly brackish ground water, it can be seen that there is a closure pattern on the electrical conductivity contour. The DHL values obtained in the slightly brackish groundwater distribution ranged from 1,740 µS / cm to 4,050 µS / cm. The topography of this area starts from 3 meters to 8 meters above sea level. The research area included in this type is 3 points covering West Semarang District (Tambakharjo) and Gayamsari District (Sambirejo and Kaligawe).

Determination of the chemical type of groundwater based on the results in the piper Trilinier diagram. T.12 and T.28 are mixed types, while T.13 is a sodium chloride type whose chemical properties of groundwater are predominantly alkaline (Na^{+} + K^{+}) and strong acids (SO_4^{2-} + Cl^{-}). In the Piper Trilinier diagram, it can be seen that the samples T.12 and T.13 are in the mixing area between fresh water and salt water which is suspected as intrusion. Based on the calculation of the bicarbonate-chloride ratio, T.13 the ratio value (R)> 1 and the EC value> 1,500 µS/cm, it can be seen that the salinity of T.13 groundwater is due to seawater intrusion, while the groundwater sample is T.28 in a fresh condition because it has a value of R <1 and a EC value of <700 µS / cm.

The Cl content in T.12 was 132 mg / l, the Cl content in T.13 was the largest, namely 599.09 mg / liter so that it was included in the type of slightly brackish groundwater. Cl content in T. / l. Considering that the content and dominance of Cl ions is getting bigger to the north in the direction of groundwater flow which also flows north from the south, it can be indicated that the process of sea water intrusion has occurred.

V. Conclusion

The conclusions that can be drawn from this study include, based on the level of salinity of groundwater, the research area can be classified into two types. The distribution of fresh groundwater with EC 470 - 1,400 µS/cm includes Tugu District (MangkangKulon, MangkangWetan, Randugarut, and Tugurejo), West Semarang District (Tawangmas, Karangayu, and KalibantengKidul), North Semarang District (Plombokan, BuluLor, and PanggungKidul), Central Semarang District (PendrikanKidul, PendrikanLor, Pandansari, and Pekunden), South Semarang District (Middle Lamper, LamperLor, and Pleburan), East Semarang District (Kemijen, Bugangan, and Kebonagung), Gayamsari District (Gayamsari), Pedurungan District (PenggaronKidul, PedurunganLor, PedurunganKidul, TlogosariKulon and Tlogomulyo), and Genuk District (Trimulyo, Genuk Sari, and BangetayuWetan). While the distribution of groundwater is slightly brackish with a DHL value of between 1,740 - 4,050 μS/cm covering West Semarang (Tambakharjo) and Gayamsari (Sambirejo and Kaligawe) Districts. Based on hydrochemical analysis, it is concluded that in the research area the source of the salinity of groundwater is caused by the intrusion of sea water.

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