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Impact of Seawater Intrusion on Freshwater Quality in Coastal Area of South Kalimantan

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***Abstract*—*Climate change and sea level rise as both have the potential to affect saltwater intrusion into the coastal area. The aim of this study is finding seawater influence on coastal area freshwater. To this purpose, it is conducted study of groundwater aquifer as freshwater and its electrical characteristics by electrical resistivity survey in the coastal area of Muara Asam-Asam Village, South Kalimantan. It channeled from three different positions to find its impacts on the well water quality. The data interpreted and analyzed based on the two-dimensional mapping of the distribution of subsurface resistivity values. At a distance of 100 m from the shoreline, it experienced intrusion at a depth of 1.24 – 9.68 m with a thickness of 8.44 meters with resistivity values 1.17 – 4.20 Ωm. Furthermore, at a distance of 200 m from the shoreline, it experienced intrusion at a depth of 0.80-5.14 m with a thickness of 4.34 meters with a resistivity value of 0.26-4.70 Ωm. Finally, at a distance of 300 m from the shoreline is free of seawater intrusion. Meanwhile, the physical parameter of well water as freshwater and water consumption conducted to monitor water quality for the settlement around the area. Mean value of physical parameter of well water for TDS, level of turbidity and pH are 124.03 mg/L, 5.80 NTU and 6.80 respectively. Both TDS and pH are meet health requirements, but it is not for turbidity level value.*

***Keywords*— Seawater intrusion, coastal area, freshwater, electrical resistivity, physical parameter, water quality.**

I. INTRODUCTION

Global warming impacts in Indonesia with surface temperatures increasing from 0.2 to 0.3 ºC/decade (Case et al., 2007) (Prinz, 2009) and its rise estimated at 0.9 to 2.2°C by the 2060s and 1.1 to 3.2 °C by 2100 (Ministry of Foreign Affairs of the Netherlands, 2018). Groundwater withdrawals from coastal aquifers are vulnerable to climate change and sea level rise as both have the potential to affect saltwater intrusion and hence groundwater quality depend on hydrogeological settings.(Rasmussen et al., 2013). Seawater intrusion (SWI) as a global issue, exacerbated by rising demands on freshwater in coastal areas and predisposed influencing the rising of sea levels and the climate change (Werner et al., 2013) (Paul & Rashid, 2017b). SWI degrades groundwater quality through enormous pumping activities or natural phenomena such as tidal waves (Sahana & Waspodo, 2020). The climate change influences seawater intrusion by seeing both Sea Level Rises and freshwater recharge rates (Chun et al., 2018) (Paul & Rashid, 2017a).

The study of groundwater aquifer and its electrical characteristics had been carried out by electrical resistivity survey with the pole–pole configuration (Wahab et al., 2021). The gap of electrical resistivity using geophysical techniques between seawater (0.2Ωm) and freshwater (> 5Ωm) is able to map the subsurface groundwater salinity distribution (Werner et al., 2013). The research by (Chen et al., 2018) showed that Electric Resistivity Tomography could detect the front edge of the seawater intrusion and means of time-lapse observed a delay effect existing between seawater intrusion and tidal action.

Water quality criteria are used to assess risk and establish or revise water quality standards (Zhao et al., 2018). Each country develops their water quality criteria to reflect country-specific human exposure patterns and ambient water environmental conditions before incorporating water quality criteria into water quality standards such as USA (USEPA, 2022), Singapore (PUB Singapore's National Water Agency, 2019), Indonesia (Permenkes RI, 2010), Malaysia (Ministry of Health Malaysia, 2000) and Japan (Wakayama, 2004). Road salt (mainly NaCl) is commonly used during the winter to ensure road and pavement safety; however, the long-term application of NaCl has negative consequences on soil and the water environment (Szklarek et al., 2022).

Saline water play an important factor for hypertension or high blood pressure in the coastal areas (Shammi et al., 2019). Red Sea coast in Saudi Arabia. the influence of seawater intrusion and heavy metals are contaminating groundwater quality (Alshehri et al., 2021). In particular country such as Bangladesh, groundwater quality is a serious environmental concern for sustainable development specially in the southeast coastal region to guarantee drinking water safety (Islam et al., 2021).

The objective of this study is finding seawater influence on coastal area freshwater. To this purpose, it is conducted study of groundwater aquifer as freshwater and its electrical characteristics by electrical resistivity survey in the coastal area of Muara Asam-Asam Village, South Kalimantan from three different positions. The outcome of this study is providing the baseline data of the seawater impact for sustainable groundwater management and human health protection in the coastal region of Muara Asam-Asam Village, Tanah Laut Regency, South Kalimantan. Specifically, it provides:

- Seawater intrusion into the coastal area up to 200 m from the shoreline at a depth of 0.80-5.14 m with a thickness of 4.34 meters with a resistivity value of 0.26-4.70 m.
- Measurement at 300 m from the shoreline is free of seawater intrusion.
- For the settlement around the area, average value of physical parameter of well water for TDS, level of turbidity and pH are 124.03 mg/L, 5.80 NTU and 6.80 respectively. Both TDS and pH are meet health requirements, but it is not for turbidity level value.

II. MATERIAL AND METHODS

The research was conducted on the part of coastal region of Muara Asam-Asam Village, Tanah Laut Regency, South Kalimantan (as seen in Fig. 1). The data collection process consists of two parts that are resistivity data collection and well water sampling. The well water are representing ground water of the certain area.

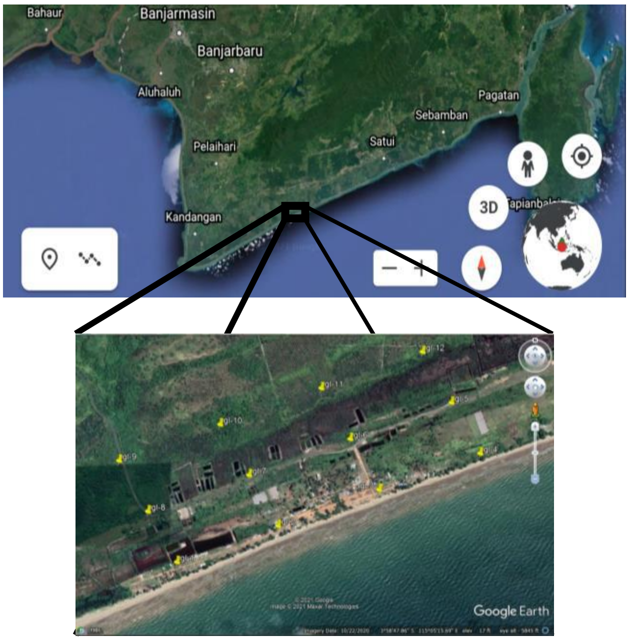


Fig.1: Map of measurement locations on the coast of South Kalimantan (above) and the research location of coastal area (below)

Resistivity data retrieval was carried out on 12 tracks with a length of 200 m each. The shortest electrode spacing as (a) is 5 m. Data collection in the field is carried out with the following steps:

• Spread the meter along the 200 m on a track that has been determined starting, middle and end points.

• Arrange a series of resistivitymeter and install electrodes according to Wenner's configuration, namely C_1-P_1-P_2-C_2. For the first layer (n_1=1), the space is na=a.

• Clamp the electrode so that it is connected to the resistivitymeter wire.

• Turn on the resistivitymeter with the battery and record the measured resistance value, potential difference and current.

• Move the electrode a with distance a, then re-measure the value of the resistance potential difference and current.

After obtaining field data in the form of measured resistivity data from each datum point in the measurement path, the data multiplied by the geometric factor to obtain the apparent resistivity value. The data processed using

Software Progress to obtain a subsurface vertical layer. The results obtained from data processing are interpreted and analyzed. Data interpretation and analysis was carried out based on the interpretation of the two-dimensional mapping of the distribution of subsurface resistivity values. Furthermore, it can be seen the layer of soil / rock on each measurement path.

Sampling of well water was carried out to analyze physical parameters including odor, color, TDS, turbidity, taste and temperature as well as the content of Sodium (Na) and Chloride (Cl). Sampling was carried out as many as five 1.5 liters glass bottles.

Odor parameters were measured directly with organoleptic assistance, which was carried out by two respondents to smell the water sample, then gave smell's opinion. The color parameter is measured directly with the help of the sense of sight, which is done by two respondents to see the color in the water sample, then give an opinion about the color or not (Sari & Huljana, 2019), (Hapsari, 2015). The pH value was measured using a universal indicator, namely inserting the universal pH meter into a beaker containing a sample of dug well water and inserting it for 2 seconds (Sari & Huljana, 2019); (Hasrianti & Nurasia, 2016).

The basic principle of TDS is evaporation. Well water that has been filtered with 2 μm porous filter paper and then dried to dry. Then weighed until the weight remains (Hapsari, 2015). Testing for water turbidity uses a tubidimeter and materials that include distilled water, well water samples, 200 ml sterile plastic bottles (Parera et al., 2013). The taste parameter is measured directly with the help of the sense of taste. Two respondents feel the water sample, and then give an opinion related to the water tastes. Good water has a normal temperature, approximately ±3° from room temperature (27 °C). Water temperatures that exceed normal limits indicate that there are dissolved chemicals in large enough quantities or that the process of decomposition of organic matter by microorganisms is taking place. The standard regarding drinking water quality requirements as follows: TDS is 500 mg/L, the maximum turbidity level is 5 NTU, the pH level is ranging from 6.5 – 8.5, the temperature has a value of ± 3° from the air temperature, the taste is tasteless, water color is colorless and the smell is odorless (Permenkes RI, 2010).

Elemental sodium (Na) using atomic absorption spectrophotometry (ASS), in addition to testing the element sodium can also use the flame photometric method and analyze sodium using flame emission spectroscopy testing in isotonic drinks. Testing the content of chloride (Cl) in water samples in the research area using the national standard Argentometry method (SNI 6989.19, 2009). In the Regulation of the Minister of Health of the Republic of Indonesia concerning the sodium content is a maximum of 200 mg/L and Drinking Water Quality Requirements, the maximum level of chloride in drinking water is 250 mg/L (Permenkes RI, 2010).

III. RESULTS

Resistivity data collection

Field data acquisition was carried out on 06 – 08 April 2021 with measurements of 12 points. The coordinates of the geoelectrical measurement point are as shown in Table 1.

Table 1. Geoelectric measurement point

No.	Code	Coordinates	
		South Latitude	East Longitude
1	GL-1	3° 59′ 00″	115° 04′ 26″
2	GL-2	3° 58′ 55″	115° 04′ 40″
3	GL-3	3° 58′ 50″	115° 04′ 54″
4	GL-4	3° 58′ 45″	115° 05′ 08″
5	GL-5	3° 58′ 38″	115° 05′ 04″
6	GL-6	3° 58′ 43″	115° 04′ 50″
7	GL-7	3° 58′ 48″	115° 04′ 36″
8	GL-8	3° 58′ 53″	115° 04′ 22″
9	GL-9	3° 58′ 46″	115° 04′ 18″
10	GL-10	3° 58′ 41″	115° 04′ 32″
11	GL-11	3° 58′ 36″	115° 04′ 46″
12	GL-12	3° 58′ 31″	115° 05′ 00″

In the GL-1 point area, the types of lithologies that make up are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 1.82 Ωm which is at a depth of 4.48 – 9.68 m and with a layer thickness of 5.20 m. In the GL-2 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a specific resistance value of 4.20 Ωm which is at a depth of 7.87 – 17.01 m and with a layer thickness of 9.14 m.

In the GL-3 point area, the lithological types of the constituents are sand and clay. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 1.17 and 2.02 Ωm which is at a depth of 3.01 – 6.77 and 17.80

– ∞ m, with a layer thickness of 3.76 and ∞ m. In the GL-4 point area, the lithological types of the constituents are sand and clay. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 5.96 and 3.24 Ωm which is at a depth of 1.24 – 2.32 and 9.25 – 14.90 m, with a layer thickness of 1.08 and 5.65 m.

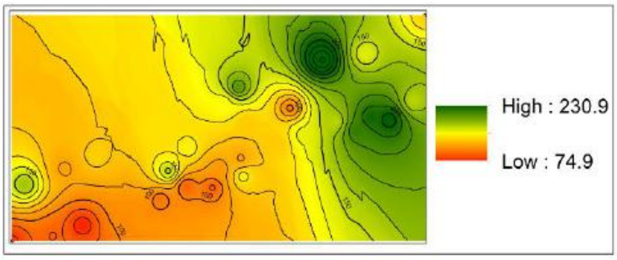
In the GL-5 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has resistivity values of 4.01 and 1.95 Ωm at a depth of 0.80 – 1.43 and 4.09 – 6.25 m, with a layer thickness of 0.63 and 2.16 m. In the GL-6 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a specific resistance value of 0.26 Ωm which is at a depth of 11.56 –∞ m and with a layer thickness of ∞ m.

In the GL-7 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 4.70 Ωm which is at a depth of 4.16 – 7.37 m and with a layer thickness of 4.68 m. In the GL-8 point area, the types of lithologies that make up are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 3.38 Ωm which is at a depth of 4.47 – 6.47 m and with a layer thickness of 2.00 m.

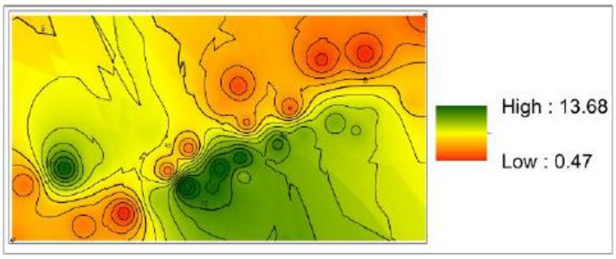
In the GL-9 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). The intrusion layer has a resistivity value of 3.80 Ωm which is at a depth of 3.17 – 5.14 m and with a layer thickness of 1.97 m. In the GL-10 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). At this point there is no seawater intrusion. In the GL-11 point area, the types of lithologies that make up are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). At this point there is no seawater intrusion. In the GL-12 point area, the types of lithological constituents are sand, clay and sandy loam. Seawater intrusion is thought to have a value of 0.2 – 6 Ωm (Astutik et al., 2016). At this point there is no seawater intrusion.

Well water data collections

The distribution of the value of the amount of dissolved solids (TDS) in the study area is 74.9 – 230.9 mg/L as shown in Figure 2a. The amount of dissolved solids (TDS) in the water samples in the study area on average is 124.03 mg/L. The test results from water samples can be concluded that the amount of dissolved solids (TDS) in the study area still meets health requirements. The distribution of the turbidity level in the study area is 0.47 – 13.68 NTU as shown in Figure 2b. The average turbidity level in water samples in the study area is 5.80 NTU. The test results from water samples can be concluded that the level of turbidity in the study area does not meet health requirements.



(a)



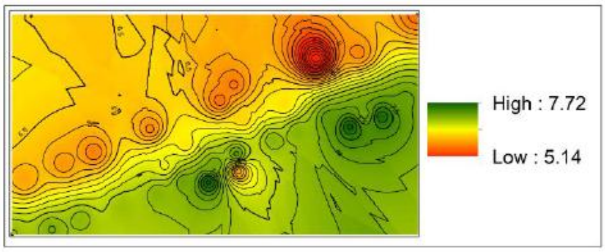
(b)

Fig.2: Contour of (a) TDS level and (b) turbidity level on this research

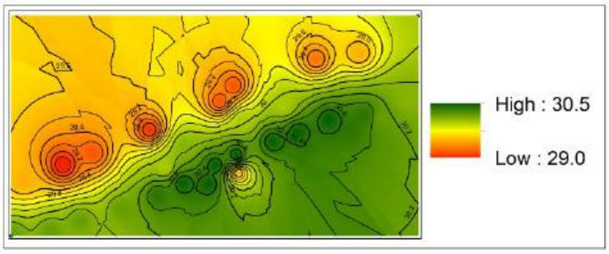
The distribution of pH values in the study area is 5.14 – 7.75 as shown in Figure 3a. The average pH level in water samples in the study area is 6.80. The test results from water samples can be concluded that the level of turbidity in the study area still meets health requirements. The distribution of temperature values in the study area is 29.0 – 30.5 as shown in Figure 3b. The average temperature value of water samples in the study area is 29.98 ± 2.5. The test results from water samples can be concluded that the temperature in the study area still meets the health requirements.

The taste assessment of water samples in the study area was 30% of the water samples still tasted salty. The test results from water samples show that the odor in the research area still meets health requirements. The color assessment of the water samples in the research area is 6.67% of the water samples still look colored. The test results from water samples indicate that the color in the research area still meets health requirements. The odor assessment of the water samples in the study area was that

30% of the water samples still smelled. The test results from water samples are still meets health requirements.

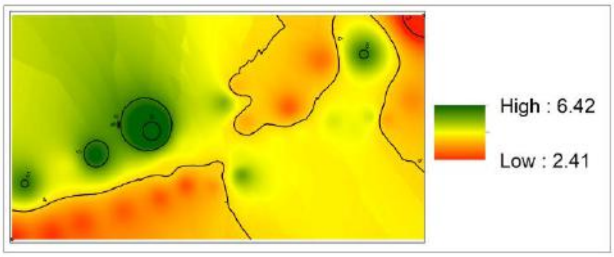


(a)

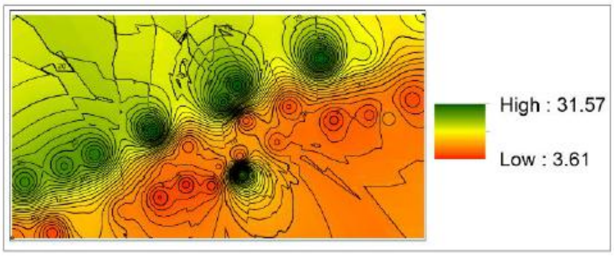


(b)

Fig.3: Contour of (a) pH level and (b) temperature level on this research



(a)



(b)

Fig.4: Contour of (a) sodium content and (b) chloride content on this research

IV. CONCLUSION

In conclusion, this research shows that seawater intrusion in the coastal area of Muara Asam-Asam Village, Tanah Laut Regency, South Kalimantan from three different positions has several impacts on the well water quality. At a distance of 100 m from the shoreline, it experienced intrusion at a depth of 1.24 – 9.68 m with a thickness of 8.44 meters with resistivity values 1.17 – 4.20 Ωm. Furthermore, at a distance of 200 m from the shoreline, it experienced intrusion at a depth of 0.80-5.14 m with a thickness of 4.34 meters with a resistivity value of 0.26-4.70 Ωm. Finally, at a distance of 300 m from the shoreline is free of seawater intrusion. Meanwhile, the physical parameter well water as water consumption was also conducted to monitor well water quality for the settlement around the area. The amount of dissolved solids (TDS) are 74.9 – 230.9 mg/L with an average of 124.03 mg/L, so it is still meet health requirements. The level of turbidity is 0.47 – 13.68 NTU with an average of 5.80 NTU, so it does not meet the health requirements. The pH value is 5.14 – 7.75 with an average of 6.80, so it still meets health requirements.

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