THE ASSESSMENT OF SEAWATER INTRUSION ON THE NORTH COAST OF ACEH BESAR: A SURFACE WATER AND WELL WATER STUDY

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Abstract: Groundwater that is used excessively in coastal areas will have an impact on the entry of salt water into groundwater so that groundwater becomes salty, a process called seawater intrusion. This study aims to determine the spatial distribution of seawater intrusion on the north coast of Aceh Besar. The method used in this study is a random and purposive sampling method on resident well water and surface water in both high and low tide conditions. The collected data was visualized using ArcGIS in the form of a spatial map. The results of the study show that the north coast of Aceh Besar in the eastern part has experienced seawater intrusion, while in the west it has the potential for seawater intrusion. Meanwhile, the salinity level for well water used daily is brackish, so it cannot be used for drinking water and other hygiene needs. The result of the correlation test between salinity and distance shows that salinity is not influenced by distance with a value of 4.17%. However, it is influenced by other factors such as land subsidence due to aquaculture activities and the nature of the rocks that make up the aquifer with a value of 95.83%.

Keywords: seawater intrusion; spatial distribution; brackish aquiver; surface water; well water

Abstrak: Air tanah yang dimanfaatkan secara berlebihan di daerah pesisir akan berdampak pada masuknya air asin ke dalam air tanah sehingga air tanah menjadi asin yang disebut dengan intrusi air laut. Penelitian ini bertujuan untuk mengetahui sebaran spasial intrusi air laut di pantai utara Aceh Besar. Metode yang digunakan dalam penelitian ini adalah metode *random* dan *purposive* sampling pada air sumur penduduk dan air permukaan baik pada kondisi pasang maupun surut. Data yang terkumpul divisualisasikan menggunakan ArcGIS dalam bentuk peta spasial. Hasil kajian menunjukkan bahwa pantai utara Aceh Besar di bagian timur telah mengalami intrusi air laut, sedangkan di bagian barat berpotensi terjadi intrusi air laut. Sementara tingkat salinitas untuk air sumur yang digunakan sehari-hari adalah payau sehingga tidak dapat digunakan untuk air minum dan kebutuhan kebersihan lainnya. Hasil uji korelasi antara

salinitas dan jarak menunjukkan bahwa salinitas tidak dipengaruhi oleh jarak dengan nilai 4,17%, namun dipengaruhi oleh faktor lain seperti penurunan muka tanah akibat kegiatan budidaya dan sifat batuan penyusun akuifer dengan nilai 95,83%.
Kata kunci: intrusi air laut; distribusi spasial; akuifer payau; permukaan air; air sumur

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Introduction

The north coast of Aceh Besar is an area where many people use groundwater because of the difficulty of obtaining fresh water. With these conditions, people have to use groundwater to meet their daily lives. It is very possible that groundwater or well water close to the coastal area mixes with sea water or is intruded by seawater (Yuwandari et al. 2020; Irham et al. 2021a). Excessive groundwater extraction in coastal areas can make the space between grains in the aquifer layer a storage medium to be filled by salt water in the soil (Herlambang & Indriatmoko 2018; López-Alvis et al. 2019).

Groundwater will be a problem if it is overexploited, especially if the exploited area is close to the sea. As a result, seawater will enter the pores of the rock, thus affecting the condition of groundwater (Irham, et al. 2021; Rusdi et al. 2021). The space below between the rocks is a gap for seawater to enter the aquifer which causes seawater intrusion in coastal areas (Rahmadani & Juliani 2019). Differences in groundwater level and sea level will also cause seawater to seep into the soil pores and pollute groundwater so that groundwater becomes brackish and even salty (Smrzka et al. 2019; Stein et al. 2020). The infiltration of salt water into groundwater is caused by continuous groundwater extraction, generating a decrease in the groundwater level (Sun et al. 2018; Sefati et al. 2019). Naturally, groundwater that is on land will flow into the sea through coastal aquifers that are connected to the sea. However, the condition experienced by coastal areas is that seawater enters groundwater through aquifers in the lower layers which turn the water into brackish due to the high influence of salinity (Cheng et al. 2021). As a result, groundwater cannot be directly used in daily life, such as for drinking, bathing, washing and others (Aladejana et al. 2021). The impact of seawater intrusion is to remove soil fertility elements from the subgrade to become salty. Other impacts are health, soil fertility and damage to buildings (Hussain et al. 2019). The impact of intrusion in terms of environmental aspects has the potential to change the chemical, biological, and physical properties and content of groundwater (Cahyadi et al. 2017).

Several studies examining seawater intrusion have been conducted by (Cahyadi et al. 2017) regarding seawater intrusion on Pramuka Coral Island which has an impact on the difficulty in obtaining decent (not salty) water because the

pores occupied by freshwater have mixed with seawater due to excessive use of groundwater (Akshitha et al. 2021). The study of seawater intrusion by (Nirmala et al. 2020) in the city of Semarang concluded that the quality of fresh water is decreasing because the mineral salt content has replaced the content of decent groundwater. Research on seawater intrusion into groundwater in East Surabaya concluded that more than 50% of the area has experienced seawater intrusion which has an impact on declining water quality (Wardhana et al. 2017). Furthermore, the seawater that pollutes groundwater cannot be reused by the community because the east coast area in Surabaya City has a high level of seawater intrusion (Herdyansah & Rahmawati 2017). From the two studies, it can be said that the impact of seawater intrusion is felt by the community the most because it is used to meet daily needs which are not suitable for consumption (Kete et al. 2020).

One of the parameters used to detect groundwater intrusion is to measure salinity or salt content. Besides the salinity parameter which is the main point of this study, other parameters such as temperature and pH were also recorded to determine the environmental properties of the sampling. Justification regarding the presence or absence of seawater intrusion in this area needs to be proven with accurate data. Therefore, this research is important as basic information must be known by the community, especially the northern coastal community of Aceh Besar. The study aims to determine the spatial distribution of seawater intrusion that occurred on the northern coast of Aceh Besar.

Method

Place and Time

This research was conducted from November 2020 to March 2021, located on the north coast of Aceh Besar (Figure 1). A sampling of resident wells, groundwater and water body was carried out in two stages, namely at high tide and at low tide. Water sample analysis was carried out at the Marine Chemistry Laboratory, Faculty of Marine and Fisheries, Syiah Kuala University.

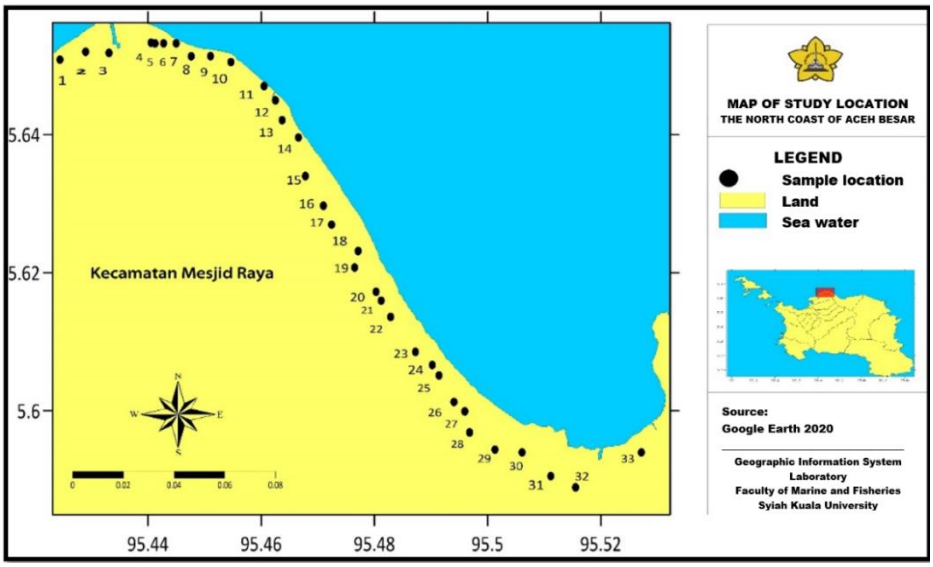

Figure 1. Location of the research map.

Procedure

Determination of Research Location

Determination of the location of water sampling used a random sampling method by looking at the characteristics of the sampling area. It is a way to select a sample from the population at simple random so that each member of the population has an equal chance of being taken as a sample.

Research Sampling

Sampling was done by purposive random sampling method. The number of samples taken was 30 sampling points along the location with 3 repetitions. Sampling also refers to the tidal and ebb conditions in the sampling area. Tidal data was obtained on the web of http://tides.big.go.id/pasut/index.html (BMKG 2020).

Sample Analysis

Water samples were analyzed using a salinity refractometer 0 - 10% ATC. In addition, data collection was also carried out on the distance between point to point and the coastline using Global Positioning System (GPS). Then the temperature and pH data were taken using a temperature and pocket pH meter EW-35423-01 indicator as a supporting parameter. The results of the next analysis are used to see the extent to which salt water enters the study area. Software used to process research data using ArcGIS.

Result and Discussion

Water Quality

The results of the research on water quality in the case of seawater intrusion are based on three parameters: temperature, water acidity (pH) and salinity. The following are the results of the water quality analysis and presented discussion.

Temperature

The results of the temperature analysis are shown in Figure 2 which is the result of the distribution of surface water and the temperature of resident wells in the study area. The temperature at each station is different with temperature values ranging from 28-35. The highest temperature was obtained at station 6 and the lowest temperature of 28℃ was at station 27. The difference in temperature values in the water samples at each station was due to the environment and time of sampling that was not carried out in the same period.

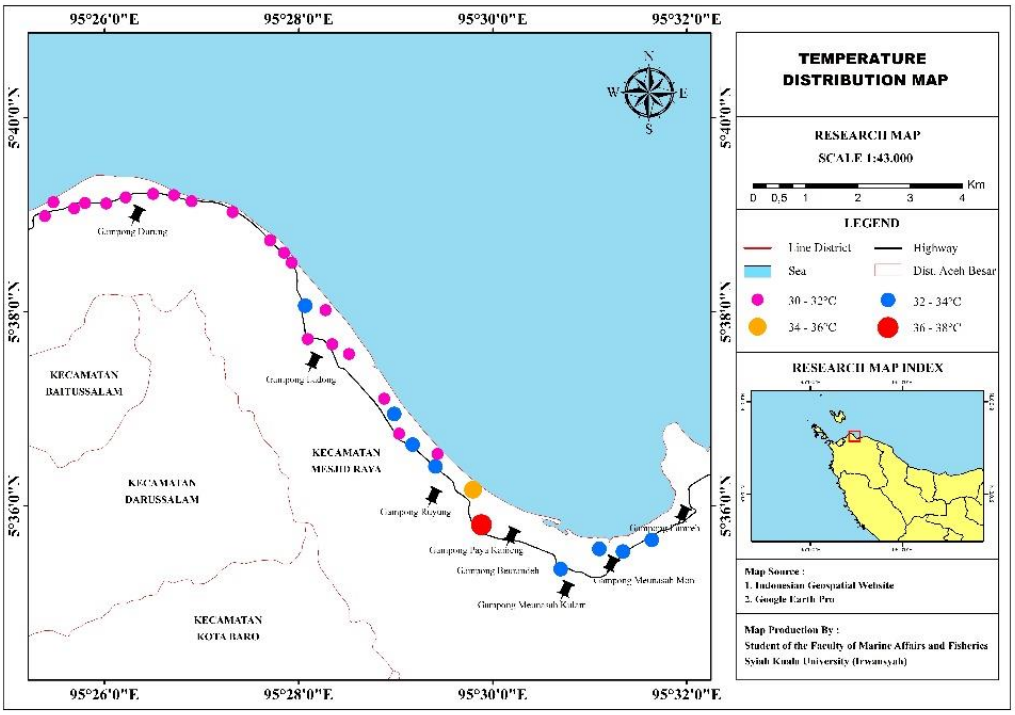

Figure 2. Map of average temperature (^{o}C) distribution

Generally, low temperatures of surface water and well water are located in residential areas with dense vegetation (land cover). These areas are relatively populated areas and the penetration of sunlight is reduced by the obstruction of trees and houses. Meanwhile, areas with high temperatures are open land areas and are not residential areas. These areas are aquaculture extents or fisheries cultivation areas.

pH

The degree of acidity (pH) is a good indicator of acid-base waters (Hamuna et al., 2018). Based on a map of the distribution of pH on the north coast of Ache Besar, the pH ranges from 6.4 to 8.1 in both high and low tide conditions. This pH value indicates that surface water and well water on the north coast of Aceh Besar are still relatively good. However, at some points, the pH value exceeds 7.79 which exceeds the drinking water quality standard value of 6.8 - 7.7 (Figure 3).

(Qudus & Setyowati 2010) explained that the pH value above the drinking water quality standard could not be used because it had been intruded by seawater.

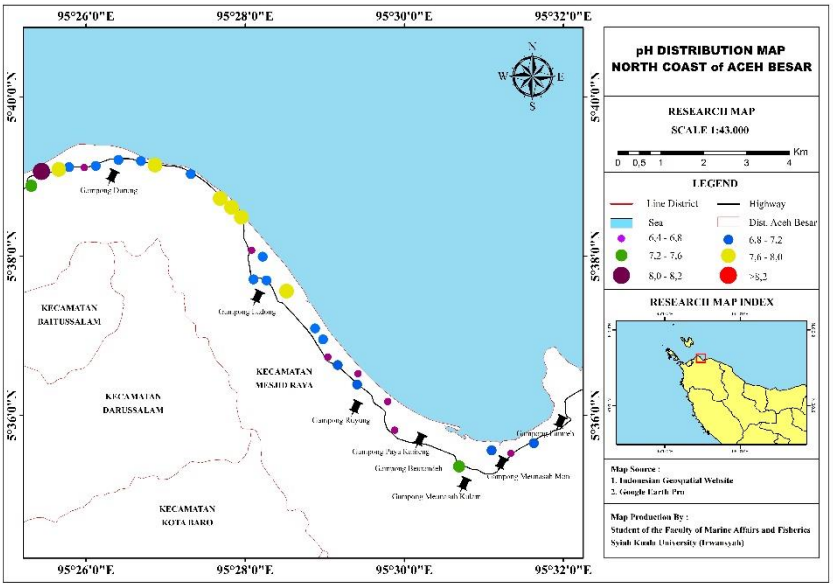

Figure 3. Map of average pH distribution

The results of the pH analysis of water are generally neutral to alkaline. On the north coast of Aceh Besar, which is partly an open area, gets a lot of heat intensity from the sun, therefore the surface temperature will rise. When the surface temperature of the water rises, the solubility of carbon dioxide will decrease so that the pH will increase and the water will become alkaline. Next, the factors that affect pH are carbonate and bicarbonate ions which are classified as bases. If the water has a high enough concentration of carbonate and bicarbonate ions, the pH will certainly change. From the initial neutral, the water will turn alkaline. In addition, there is not much decomposition of organic matter and the process of dissolving CO_2 does not occur so the acidity of the water does not exist in the study area.

Salinity and Sea Water Intrusion

The results of salinity analysis in high and low tide conditions are shown in Figures 4 and 5. For well water, the overall salinity at the study site ranges from 0.67 - 9, this indicates that the sample belongs to the category of brackish water, while groundwater and surface water ranges from 3 - 35 which are categorized as brackish water to salt water (Ayoub et al. 2019). The results of the distribution of salinity show that at high tide the salinity value is very low in the west and high salinity value in the east. These values indicate that the eastern part of the north coast of Aceh Besar has been intruded by seawater compared to the western side. Even so, the potential for seawater intrusion in the western part is very possible due to the presence of salinity values above the permissible threshold (below 0.05) according to the national standard of Ministerial Regulation No. 32 of 2017 for

decent water. At some points, there is a distribution of groundwater with different salinities in the brackish and salty groundwater groups. This is caused by the composition of the sediment in the form of muddy sand sediment which is an alluvial deposit with generally low permeability and flat topography of the land surface, making it very susceptible to seawater intrusion. (Herlambang & Indriatmoko 2018; Irham et al. 2021a) who said that the differences in rock systems that make up the aquifer are the cause of differences in the level of salinity of groundwater.

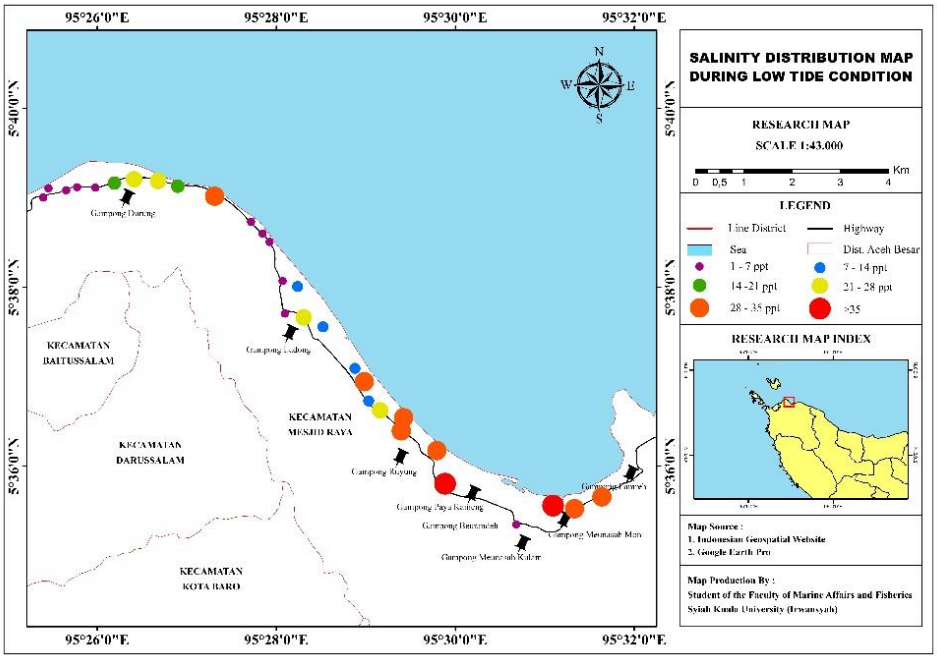

Figure 4. Map of salinity distribution during low tide condition

Overall well water, surface water and groundwater on the north coast of Aceh Besar have been contaminated with seawater at the stage of crew intrusion on the west side and large on the east side of the study area. One of the causes of high seawater intrusion is aquaculture in coastal areas and excessive use of groundwater for both the daily needs of the population and for aquaculture. The creation of shrimp and fish ponds provides a great opportunity for the entry of seawater deep into the mainland caused by the traditional water drainage pattern that is not environmentally standard (Aurilia & Saputra 2020). Judging from the soil texture in the study area which has the characteristics of a flat and sandy beach. Such beaches are porous or have pores between rocks in large numbers so that they have a high ability to absorb and pass seawater into the ground, causing the mixing of groundwater with seawater (Santosa 2021).

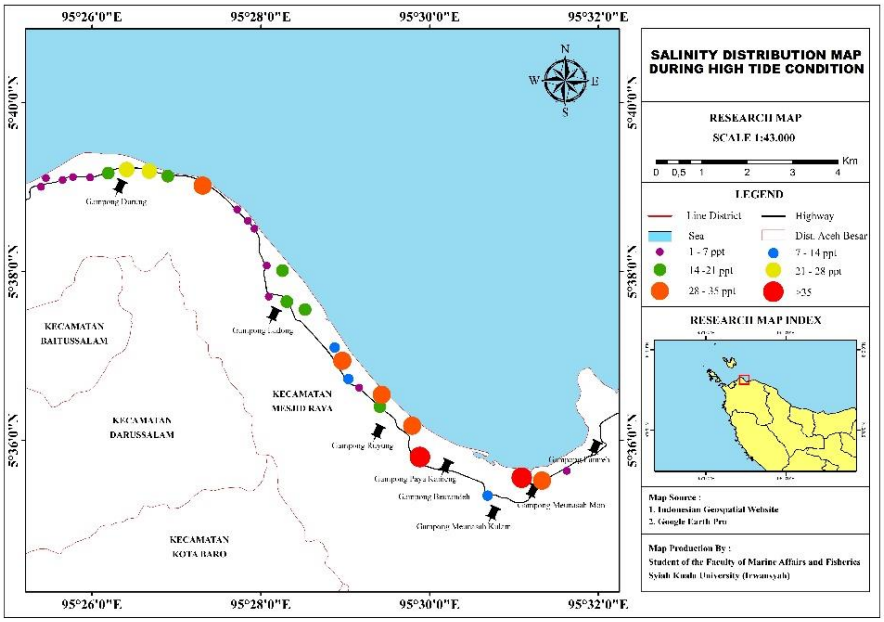

Figure 5. Map of salinity distribution during high tide condition

The Relationship between Salinity and Coastal Distance

The difference in salinity and distance from the shoreline to the land can be seen on the salinity distribution map (Figures 4 and 5) where the highest salinity is at station 3 which has a distance of 530 m from the shoreline with a salinity value of 9, while the lowest salinity is at station 16 which has a distance of 430 m from the shoreline with a salinity value of 0.67. These two stations have a distance difference of 100 m but the difference in salinity values is very large. Stations that are closer to the shoreline have a smaller salinity value than stations that are farther away from the shoreline.

Therefore, the relationship between the distance from the shoreline to the land with the salinity value of the water is carried out by analyzing the strength and weakness of the relationship between the two variables using simple linear regression analysis. The results of the analysis of the relationship between distance and salinity levels in the well can be seen in Figure 6.

Figure 6 shows that there is a negative slope trend between distance and salinity which indicates that the farther the distance between the well and surface water from the shoreline will make the salinity value lower. However, the correlation value between distance and salinity has a very low correlation with a determinant value (R^2) of 0.0417. This value of 4.17% indicates that salinity is not strongly influenced by the distance from the shoreline to the land. It can be said that 95.83% of salinity in the study area is influenced by other factors.

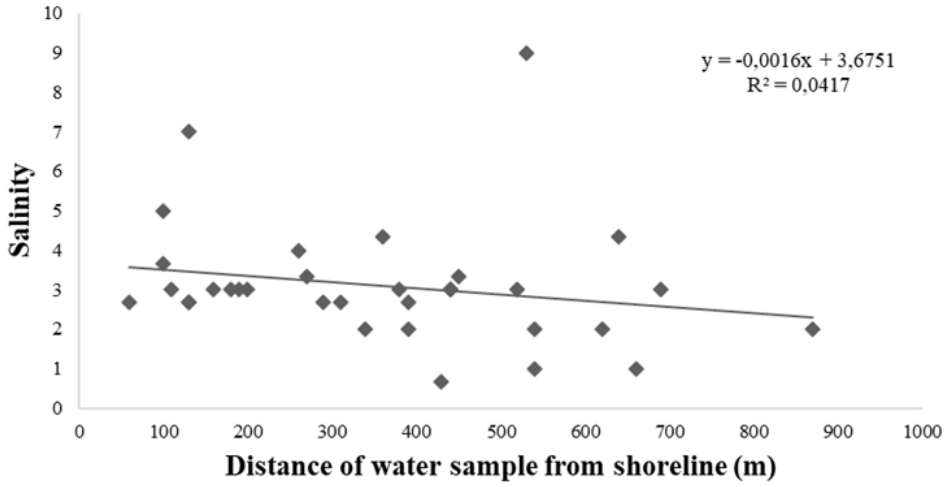

Figure 6. The graph of the relationship between salinity and the distance of the water sample from the shoreline

Conclusion

The results of the study concluded that based on the salinity value of the sample of water bodies, surface water and well water were classified as brackish, this indicates that the water in the area has been intruded by seawater. The results also inform that the average distance of seawater intrusion on the north coast of Aceh Besar from the coastline to the mainland is more than 500 m. Based on the correlation test between salinity and distance, a correlation value of 0.204 is obtained which has a low correlation between the two variables. Meanwhile, the determination value states that only 4.17% of salinity is influenced by distance and 95.83% is influenced by other factors. The factor causing this intrusion itself is due to human activities related to the manufacture of shrimp and fish ponds, land subsidence and the shape of the rocks that make up the aquifer.

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