Study of seawater intrusion in coastal aquifer using total dissolved solid, conductivity and salinity measurement in Labuhan Kertasari Village, West Sumbawa

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Abstract. Indonesia is an archipelagic country that has a larger ocean area than land, many people live in coastal areas and still experience difficulties in obtaining springs that can be used for their daily needs. This study was conducted to see the extent of seawater intrusion into a coastal aquifer in Labuhan Kertasari Village. The method of measuring Total Dissolved Solids, Conductivity, and Salinity is used in studying seawater intrusion into a coastal aquifer. Coastal aquifer samples were taken from open wells and boreholes belonging to residents which are actively used on a daily basis. Analysis of the relationship between TDS, conductivity and salinity used simple linearity analysis, and distribution mapping using surfer 8. The highest TDS concentration, conductivity, and salinity were 5770 ppm; 8700 μS /cm; and 4600 ppm on S8. While the TDS concentration, conductivity, and salinity were the lowest consecutively were 836 ppm; 1258 μS /cm; 700 ppm on S26. In general, the coastal aquifer in residents' wells has experienced various intrusions and has decreased at a distance from the shoreline.

1. Introduction
Water is a natural resource that is essential and necessary for life. Water sources are water that are above and below the ground surface, including aquifers, springs, rivers, swamps, lakes, reservoirs, and estuaries [1]. This research was conducted in Labuhan Kertasari Village, Taliwang, West Sumbawa. This village is a fast developing area because it has a relatively dense population. The development of the coast and the sea in this area is marked by the large number of seaweed cultivation businesses. It is also a minapolitan area and a tourism area with many activities in it, such as plantations, seaweed processing industry, and local community activities. The development of this coastal area has an impact on the increasing need for clean water. The absence of surface water sources in this village impacts that the water supply for life support needs is not optimal. The water for drinking and cooking is met by buying processed water from a drinking water company. So, the community makes dug
wells to meet their daily needs. However, the dug well cannot be used optimally because it tastes brackish to salty.

Therefore, it is necessary to analyse the quality of the decomposition around the Labuhan Kertasari coastal area. One of them is the analysis of aquifers and seawater intrusion. Seawater intrusion is a problem for groundwater so that it can reduce the quality of groundwater and cannot be utilized optimally. Groundwater quality varies depending on the hydrological cycle components, monsoon and no monsoon season, local activities, and water consumption by people [2] [3].

Seawater intrusion is the process of entering seawater into a coastal aquifer, the main cause of seawater intrusion, namely excessive groundwater exploitation which causes a decrease in the surface of groundwater and forces seawater to enter the land. The relationship between subsidence and seawater entry into the land is described by the "Ghyben-Herzberg relationship" [4] [5]. Generally, to study seawater intrusion, TDS and salinity parameters are used. Seawater intrusion caused that increasing of TDS and salinity concentration compared to groundwater quality standards [6].

The purpose of this research is to determine the effect of sea water on water quality; the parameters measured are salinity, Total Dissolved Solid (TDS), and conductivity. So that the results of this study can be used as a benchmark in optimal groundwater utilization.

2. Method

2.1. Sampling location

This research was conducted in Labuhan Kertasari Village, Taliwang, West Sumbawa, it is at the latitude of 8°42'41.01" and longitude of 116°47'13.08". The sampling method was purposive sampling, namely determining the sampling point based on the research needs. Samples were taken from wells which were actively used for daily needs, such as washing, bathing and cooking.

![Figure 1. The map of research location](image)

2.2. Data collecting

Data were collected directly with in-situ measurements for each parameter. The number of sample points taken was 40 points.

2.3. Determination of the position of the sample point

Data were filled in based on SNI 6989.58: 2008 as well as direct interviews with well owners which were used as sampling points. The coordinates of the sampling point were determined using GPS, and the dimensions of the well were measured using a roll meter.
2.4. Measurement of TDS, Conductivity, and Salinity parameters
The measurement of the research parameters was carried out in situ using the Lutron WA 2017SD multiparameter tool. For open wells, 1 liter of well’s water is taken using a ballast pipe. Whereas for closed wells, the sample is taken from the faucet by first opening it for 2 minutes and then taking the water sample.

2.5. Processing and analysing data
For data processing and data analysis, Klaedagraph and surfer 8 software were used. Each value of each parameter was entered into the surfer program and interpolated to obtain TDS distribution modeling, conductivity and salinity. Meanwhile, linearity analysis was performed using Klaedagraph software.

3. Result and Discussion
In this research, measurements of the TDS, conductivity and salinity parameters were carried out to study the intrusion of seawater into a coastal water (coastal aquifer) in Labuhan Kertasari Village.

3.1. Coastal Aquifer Quality Parameter
The results of this research indicate that the quality of groundwater varies at each sample point. The highest TDS concentration, conductivity and salinity were found at sample point S8, respectively 5770 ppm, 8700μS / cm and 4600 ppm. The S8 sample point is 279.47 m from the shoreline. Based on Table 1, groundwater at sample point S6 is brackish [7] [8]. While the smallest TDS concentration, conductivity and salinity were found at sample point S26, namely 836 ppm, 1258 μS / cm and 700 ppm respectively, the distance of the S26 sample point from the shoreline was 1588.8 m. Based on Table 1. Ground water at sample point S26 is fresh [7] [8]. Based on Table 2. The quality of groundwater in the waters of the study location is still below the standards required by WHO [9].


| Table 1. Groundwater classification [7][8]. |
|---------------------------------------------|
| Parameters | fresh water | freshwater-brackish water | brackish water | salt water | very salt water |
| TDS (ppm)  | 0-1000 | 1001-3000 | 3001-10000 | 10001-100000 | >100000 |
| EC (μS/cm) | <1500 | 1500-5000 | 5000-15000 | 15000-50000 | >50000 |
| Salinity (ppm) | <1000 | 1000-3000 | 3000-35000 | >35000 |

| Table 2. Parameter of water quality at coastal aquifer sample |
|-------------------------------------------------------------|
| parameter | sample | min | max | mean | WHO[9] |
| TDS (ppm) | 40 | 836 | 5770 | 2428.425 | <1000 |
| EC (μS/cm) | 40 | 1258 | 8700 | 3628.35 | - |
| Salinity (ppm) | 40 | 700 | 4600 | 1912.5 | 250 |

3.2. Correlation of TDS, Conductivity and Salinity
TDS is an indicator of seawater intrusion which shows the amount of dissolved salt [8]. In addition to TDS, conductivity parameters were also used to identify the type of water, which indicates the presence of dissolved salts based on their conductivity values [10]. The next parameter used in identifying the type of water is salinity. Salinity indicates the level of salinity which is affected by dissolved salt [7].

To study the relationship between the three, it was analyzed using KaleidaGraph software, by making simple linear regression. The results of linear regression analysis of the relationship between TDS, conductivity, and salinity are shown in Figure 2, Figure 3, and Figure 4.
Figure 2 is a graph of the relationship between TDS and conductivity. From the figure it can be understood that the TDS to conductivity has a positive relationship, where the greater the TDS value, the greater the conductivity value. The coefficient of determination \( R^2 \) is 0.99612, which means that the TDS value greatly affects its conductivity.

![Figure 2. Correlation of TDS and conductivity](image)

![Figure 3. Correlation of conductivity and salinity](image)

Figure 3. is a graph of the relationship between conductivity and salinity. From the regression equation, the coefficient of determination \( R^2 \) is 0.99668, which means that the conductivity value greatly affects salinity. The greater the conductivity the greater the salinity, meaning that the level of salinity is greater. Likewise with Figure 4. which shows a graph of the relationship between TDS and salinity. The correlation between linear regression is positive with the coefficient of determination \( R^2 \) of 0.99395, which means that the TDS value greatly affects the salinity value. The greater the TDS value, the greater the salinity value.

![Figure 4. Correlation of TDS and salinity](image)

3.3. Correlation of TDS, Conductivity and Salinity to the distance from the coastline
Theoretically, the farther from the shoreline, the TDS concentration and salinity are getting smaller [7]. TDS is a chemical parameter that can be used in studying sea water intrusion. Where TDS is influenced by the number of dissolved chemical substances.
Seawater has a high TDS concentration, due to the high dissolved salt content. So, to find out whether an area is experiencing intrusion, it can be done by measuring the TDS concentration and salinity, because the high TDS and salinity concentration possibly caused by seawater contamination [12]. In this study, TDS concentration, conductivity, and salinity were measured starting from the closest distance to the shoreline, namely 79.34 meters to the farthest distance from the shoreline, namely 1588.8 meters. The measurement results can be seen in Table 1. In addition to distance, the type of rock formation and the lithological composition of the rock also affect the TDS concentration and salinity. Thus, there could be no correlation between distance and seawater intrusion [7].

From Figure 5, Figure 6, and Figure 7, it can be seen that the farther the distance from the shoreline, the TDS concentration, conductivity, and salinity are getting smaller. At a distance of 200 meters to 400 meters the TDS concentration ranges from 1000 mg/l to 4000 mg/l, only a few points reach almost 6000 mg/l. Likewise with salinity and conductivity, the farther the distance from the shoreline, the salinity and conductivity also getting smaller. In this research, the sample points are mostly found in residents that are related to the shoreline, only a small sample is taken in residential areas located far from the shoreline. In total, based on the R² value for the TDS parameter, conductivity, and salinity to the distance of the sample point from the shoreline were 0.07435,
0.026385, and 0.027814, respectively. This means that between TDS, conductivity and salinity against distance do not have a strong relationship.

3.4. Dispersion pattern of seawater intrusion
Contour maps of the distribution of TDS, conductivity and salinity were created using Surfer 8 software. The digitization process is carried out by entering the coordinates of latitude and longitude.

![Figure 8](image)

Figure 8. The map of research location lies between the latitude of 476197 to 477334 and longitude of 9035640 to 9038328 (a); TDS distribution contour map (b); Conductivity distribution contour map (c); and Salinity distribution contour map (d).

From the contour map of the TDS, conductivity and salinity distribution can be seen visually the extent to which the aquifer in Labuhan Kertasari village experiences an intrusion process. The green colour on the map in Figure 8.b. indicates a low TDS value, a blue colour indicates a moderate TDS value and a red colour indicates a high TDS value.

From the map, it can be seen that the farther from the shoreline, the colour becomes green which indicates the lower TDS value. Areas with high TDS values are due to the influence of the influx of seawater into large aquifers, as shown in the map, none of them obstruct the entry of seawater into aquifers such as mangroves. In accordance with the reality in the field that the area with the highest level of intrusion is the area directly opposite the pond. The conductivity and salinity distribution contour maps also have the same shape as the TDS distribution.

This research assists decision-makers in planning development in Labuhan Kertasari Village, such as drilling wells, developing water treatment industries, and making regulations in the utilization of coastal areas. The result obtained that the quality of groundwater is below the WHO standard for drinking water. However, groundwater can be used for daily needs such as washing, bathing, and irrigation purposes. Therefore, this research assists the community in managing groundwater so that it does not reduce groundwater quality, so that it can be used sustainably. Further studies are needed for the construction of new wells. One of the studies carried out is a geoelectric study for mapping the underground surface and founding groundwater sources (aquifer).

Research on seawater intrusion needs to be carried out using more innovative techniques and carried out periodically to determine the trend of seawater intrusion that occurs. Seawater intrusion caused by excessive use of groundwater. [11].

4. Conclusion
From this research it can be concluded that the groundwater conditions in Labuhan Kertasari Village are brackish. The average TDS, conductivity and salinity values were 2428,425 ppm, 3628.35 μS / cm and 1912.5 ppm, respectively. Based on WHO standards, the quality of groundwater is below the
required standards. The relationship between TDS, conductivity, and salinity has a very strong correlation. The relationship between TDS and conductivity, the relationship between conductivity and salinity and the relationship between TDS and salinity, respectively, has $R^2$ values of 0.99612, 0.99668 and 0.99395. In general, the distance from the shoreline does not have a strong correlation with the amount of TDS, conductivity, and salinity.

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