The distribution patterns mapping of seawater intrusion in Kendari City, Southeast Sulawesi Province

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Abstract: The main purpose of this research is to determine the distribution pattern of seawater intrusion in Kendari City, Southeast Province by using direct observation method by measuring the value of electrical conductivity (EC). The electrical conductivity measurement was done at 140 points of groundwater wells owned by the communities. The EC result of electrical conductivity value varies and categorized in five groups that are: 541 - 2,650 μS/cm, 400 - 520 μS/cm, 240 - 374.4 μS/cm, and 208 - 224.4 μS/cm. Based on the EC values, indicated that several areas in Kendari City have experienced with high water sea intrusion within the region Tondunggeu, Puday, Kasilampe, Mata and Purirano with electrical conductivity values range from 541 μS/cm to 2,650 μS/cm.

1. Introduction

1.1. Background

Kendari City is the central region of the Southeast Sulawesi Province, geographically Kendari City is located on the South of the Equator line, and is between 3° 54’ 30” – 4° 3’ 11” South Latitude and 122° 23’ – 122° 39’ East longitude, most of Kendari City is in the mainland and surround Kendari Bay, at a glance about the location of Kendari City in the north, Soropia District, Regency of Kendari in the east, Moramo Subdistrict and Konda Subdistrict, in the west by Ranomeeto and Sampara Subdistrict [1][2]. Currently, Kendari City continues to increase population based on the 2000 population census of 205,240 people, then in 2005 increased to 226,056 inhabitants, in 2010 as much as 289,966 inhabitants and in 2013 of 314,126 people with uneven distribution [3]. The impact of this increase in population growth can lead to increased infrastructure development. Increasing the existing infrastructure development in Kendari City has an impact, one of which is the impact of the fulfillment of clean water needs, where the fulfillment of the community's clean water needs in Kendari is heavily dependent on the presence of surface water and groundwater. Groundwater is currently widely used for domestic, industrial, service and agricultural needs [3].

Hydrogeological conditions of Kendari City where the depth of shallow groundwater depth is highly variable. In the northern part of Kendari Bay has shallow groundwater depths ranging from 0.007 meters to
12.5 meters from the ground. In the western part of Kendari Bay has shallow groundwater depths ranging from 0.12 meters to 12.5 meters from the ground. In the southern part of Kendari Bay has shallow groundwater depths ranging from 0.18 meters to 9.81 meters from the ground level [4].

The main problems that occur in the area of Kendari City is the declining quality of water resources, especially groundwater in the coastal land of Kendari Bay, the decline in groundwater quality is caused by the intrusion of seawater into the aquifer layer of groundwater and the spread of water intrusion the sea has expanded so that the impact on the people who live around the coastal area of Kendari Bay consequently some people are very difficult to get clean water that can be used to meet the needs of his life.

The process of saltwater intrusion in a coastal area is caused by the hydrostatic imbalances of freshwater and saltwater, whereas when freshwater hydrostatic pressures are reduced the salt water will push into the freshwater aquifer layer and increase the salt content in the aquifer layer [5] other than that the intrusion of seawater is also caused by irregular land use where there has been a reduction of water catchment area resulting in the reduction of the amount of water entering the soil to fill the aquifer layer, when the aquifer layer has a large vacancy then a foreign fluid that is water the sea will infiltrate the filling of layers that have high porosity [6]. With the occurrence of seawater intrusion, this will become a problem in the use of groundwater in coastal areas because it will directly affect the quality of groundwater.

The identification of saltwater intrusion distribution occurring in an area has been developed by using chemical parameters of seawater intrusion level that is groundwater salinity level [5], beside that identification of salt intrusion dispersion zone can use geoelectric method based on change of type resistivity parameter, this geoelectric method is carried out by measuring the potential difference generated by the injection of an electric current into the earth [7][8], in addition to the above two methods in identifying the seawater intrusion distribution can also use the electrical conductivity (EC) value when compared to the seawater classification based on their electrical conductivity and the value of electrical conductivity (EC) can also be compared with the groundwater salinity classification [9][10][11][12].

This research activity using the method of electrical properties of the material based on electrical conductivity (EC) parameter measured by using electric conductivity meter with the unit used is micro Siemens per centimeter (μS/cm). The conductivity value is the value of a material's ability to conduct electricity, the conductivity will increase when more water will dissolve the salts to be ionized [11].

1.2. Geological Condition
Based on the geology condition of Kendari City Region included in the section of Geological Map of Kolaka and Lasusua Sheet, in Figure 1 is a regional geological map of Kendari City area which shows that Kendari City area is composed by several groups of rock formations namely: Meluhu Formation (TRJm), Formation Langkowala (Tml), Eemoiko Formation (Tmpe), Buara Formation (Ql) and Alluvium (Qa) [13][14].

Alluvium (Qa) consists of several types of lithology ie mud, clay, sand, gravel and crust. Mud is gray to reddish brown; contains a subtle coating that appears from several colors containing plant residues. The Langkowala Formation (Tml) is a part of Molasa Sulawesi and the rock formation consists of 3 (three) members namely Tolitoli Members, Sandstone Members, and Conglomerate Members. In the area of Kendari City is dominated by members of Sandstone and Conglomerate Members. In addition to the Langkowala Formation in Kendari City, the members of the Pohara Formation Eemoiko are also found where members of this formation form a low-topped hilly topography [15].

The Meluhu Formation (TRjm) is named by Rusmana & Sukarna 1985 [14] to rock units consisting of quartz sandstone, red shale, siltstone and mudstone at the bottom and black shale, sandstone and limestone patches at the top. This formation consists of 3 (three) members namely Toronipa, Watatalubonto and Tueteu members, in Kendari City, this formation is represented by the presence of Toronipa Members composed of sandstone, conglomerate, inset flakes, rocks, and claystone. Some thin inserts of lignite are found locally as in the small river near Nurul Huda Mosque, Kendari City [15].
1.3. Hydrogeological Conditions

Groundwater basin (CAT) in Kendari City consists of 2 (types) of CAT Ranomeeto and CAT Rawua, where CAT Ranomeeto has an area of 126 km$^2$ with lithology type constituent coral reefs, with graduation rate of medium to high water, the volume of groundwater depressed on this CAT Ranomeeto is around 71 million m$^3$/year. While CAT Rawua has an area of 256 km$^2$ with the lithology of alluvium, colluvium, and swamp sediments consisting of clay, sand, gravel, and crust with a low water pass rate, the amount of distressed groundwater present in CAT Rawua ranges 115 million m$^3$/year while the volume of groundwater is not depressed to reach 2 million m$^3$/year [16].

Potential groundwater in Kendari City spread in several areas, among others, high potential water area, medium, low and nil. For high groundwater potential area is an undisturbed groundwater type with static groundwater level between 0.0 m - 3.2 m and groundwater discharge 0.65 - 115 m$^3$/hour. Potential groundwater area is an unstressed soil type with static water level between 0.3 m - 3.0 m and a groundwater discharge of 0.5 - 0.63 m$^3$/hour. Low potential groundwater area is an undisturbed groundwater type with static groundwater level between 0.1 m - 12.7 m and groundwater discharge 0.2 – 200 liter/seconds. Whereas the zero groundwater potential area is a swamp and alluvial seawater deposited by Pre-Tertiary rocks with static groundwater levels between 0.5 and 7.5 m [17].

2. Method

Location of the research was conducted on the residential area of Kendari City which is located around the coast of Kendari Bay. This research uses a direct field observation method where direct observation of 140 dug wells and community bore wells comprise the groundwater level of groundwater temperature and the value of groundwater electrical conductivity (EC). The measurement value of electrical conductivity (EC) using an electric conductivity meter. In conducting data processing the value of electrical conductivity needs to be standardized water temperature, where the standard temperature used is 25$^\circ$C, therefore the value of groundwater electrical conductivity obtained will be standardized using the equation:
\[ DHL25 = DHL_t + (\Delta t + 0.02 \times DHL_t) \] (1)

After processing the DHL25 value after it was analyzed the level of intrusion of seawater that occurred by interpolation using Inverse Distance Weighted (IDW) method with the main parameter in interpolation is the classification of sea intrusion level based on the electrical conductivity (EC) value according to Davis and Wiest, 1996.

Table 1. Classification of seawater intrusion based on the value of Electrical Conductivity (EC) [9][10]

| No | Value of Electrical Conductivity/EC (μS/cm, 25°C) | Intrusion Level       |
|----|-----------------------------------------------|----------------------|
| 1  | ≤ 200.00                                      | Not intruded         |
| 2  | 200.01 to 229.24                              | Low intruded         |
| 3  | 229.25 to 387.43                              | Medium Intruded      |
| 4  | 387.44 to 534.67                              | Rather high intruded |
| 5  | ≥534.68                                       | High intruded        |

3. Results and Discussion
In figure 2 can be seen that the distribution of seawater intrusion that occurred in the area of Kendari City is divided into 5 groups of regions that are not intruded sea water, low intruded, medium intruded, rather high intruded and high intruded. The division of these five areas is based on the value of electrical conductivity (EC) of groundwater in dug wells and borehole of community, from the analysis result in a general level of intrusion of seawater which happened the biggest location at Kendari and Abeli sub-district.

Figure 2. Map of the distribution pattern seawater intrusion level in Kendari City area.
The areas of not intruded seawater are in the Southern Poasia Sub District, West and North Mandonga Sub-districts, and Western P uuwat Subdistricts. From the result of the analysis value of electrical conductivity (EC) got value equal to 30.60 – 200.00 μS/cm. The areas of low intruded seawater are in Kambu Sub-district in Mokoau and Kambu Subdistricts. The result of the analysis value electrical conductivity (EC) obtained the value of 208.01 - 224.40 μS/cm.

The areas of medium intruded seawater is located in the Eastern Abeli Sub-District of Nambo and Petoaha and Puday, North Poasia Subdistrict, North Kambu Subdistrict, Lalolara Subdistrict, Mandonga Sub District of Korumba and Mandonga, West Kendari Section South District, Watu-Watu, Tipulu, Pungguloba, Benu-Benua, Sodoha, and Sanua, as well as on the part of Bungkutoka Island have mostly experienced moderate seawater intrusion. The result of the analysis of electrical conductivity (EC) got value equal to 240.00 - 374.40 μS/cm.

The areas of seawater intrusion are rather high, mostly located in the northern part of Kendari, Purirano, Mata, Kasilampe, Kandai, Mandonga Sub-districts of Kelurahan Lahundape and Mandonga, North Abeli Sub-districts of Puday, Lapulu, Poasia, and Talia. Results of analysis electrical conductivity (EC) values obtained values of 400.00 - 520.00 μS/cm.

The areas of high sea intruded are mostly located in Southern Abeli District, Sambui and Tonddonggee Sub-districts, East Kendari Subdistrict, Kasilampe, Mata, and Purirano Subdistricts. The result of the analysis of electrical conductivity (EC) value obtained between 541.00 - 2,650.00 μS/cm.

| No | Value Electrical Conductivity/EC (μS/cm, 25°C) | Intrusion Level          |
|----|-----------------------------------------------|--------------------------|
| 1  | 30.60 - 200.00                               | No intrusion              |
| 2  | 208.01 - 224.4                               | Low intrusion             |
| 3  | 240.00 - 374.40                              | Medium intrusion          |
| 4  | 400.00 - 520.00                              | Rather high intrusion     |
| 5  | 541.00 - 2,650.00                            | High intrusion            |

4. Conclusion
Based on result of the research on the distribution pattern of seawater intrusion of Kendari City, Southeast Sulawesi Province conducted on 140 wells by using electrical conductivity (EC) method, there are 5 (five) groups of areas seawater intrusion which occurs in areas are not intruded seawater with the electrical conductivity (EC) values between 30.60 μS/cm - 200.00 μS/cm, areas low intruded seawater with the electrical conductivity (EC) values between 208.01 μS/cm - 224.40 μS/cm, areas medium intruded seawater with the electrical conductivity (EC) values between 240.00 μS/cm - 374.40 μS/cm, areas rather high seawater intruded are with electrical conductivity (EC) values between 400.00 μS/cm - 520.00 μS/cm, and areas high water intruded with electrical conductivity values between 541.00 μS/cm – 2,650.00 μS/cm.

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