Spatial Analysis of the Groundwater Quality Based on Seven Physical Parameter—A case study in Meuraxa District, Aceh, Indonesia

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ABSTRACT

Water is one of the main sources for the needs of living things, which is indispensable in use for drinking, water and other industrial purposes. This study aim is to find out the condition of the well water in Meuraxa Sub-district of Banda Aceh city based on seven physical parameters that have been in test consisting of pH, TDS (Total Dissolved Solids), Total Hardness, DHL (Electrical Conductivity), Sulphate, Salinity, and Calcium. The function of these seven parameters are to find out the value of standard that has been set level and are considered the most influential of the other parameters in the measurement of clean water quality. Measurements in this study resulted in a form of classification rank or grade level classification and transformed in the form of spatial mapping. Through the spatial analysis technique of Geographic Information Systems (GIS), which serves as a spatial analysis, this study found the quality of well water in Meuraxa Sub-district of Banda Aceh varied. From the 3 rankings that shows Good zone, Average and Poor. Zone of each rank will be processed to be a display in the form of maps through the ArcGIS software.

KEYWORDS: GIS, Well Water, Spatial Variations Map, Water Quality, Banda Aceh

INTRODUCTION

Aceh is a province which is located on the northern end of Sumatra Island. Aceh's capital, Banda Aceh, is an area crossed by active fault that extends along the northern part of Banda Aceh to southern part of Lampung which is known as Fault Semangko Therefore, the area traversed by active faults is prone to earthquakes, landslides and tsunamis (BAPPEDA, 2013).

Banda Aceh is one of the cities which were destructed by the tsunami on 26 December 2004. Tectonic earthquake with a magnitude of 9.3 on the Richter Scale (SR) with the epicenter in the South of the city of Meulaboh which caused a tsunami capable of destroying ecosystems both on land and sea of Banda Aceh. The disaster's impact also resulted in severe damage to the city of Banda Aceh, especially in coastal areas and groundwater ecosystems.

Groundwater treatment is the process of checking the results of water samples which has standardization in the measurement. Therefore, the more value obtained from the measurement, the more accurate the data that will be obtained in a research process. Thus, it is necessary to look at the accuracy and yield levels good water in daily use (Marwan et al. 2015).

The sea water is pure water that includes some dissolved solids and gases. In 1.000g samples of sea water contained 35g soluble compounds called salts. (Thus, 96.5% are pure water and 3.5% is salt. The amount of solute or 3.5% of salt is called salinity or salt content (Kuncoro, 2004 ; Mulyani et al. 2012). The condition can affect patterns of the use of clean water in the future. Today, global warming effects and erratic weather in some regions, particularly in Banda Aceh itself can also affect groundwater ecosystems.

The purpose of this research is to map groundwater quality in Meuraxa District using Geographic Information System (GIS) technology and to provide the latest information the condition of the groundwater level in the area with more accurate and more efficient. The result of this study is expected to provide a comparison of the level of accuracy with the previous study (Zahrul, 2015). Furthermore, this study can be used as reference data for local government in Banda Aceh for reviewing clean water research Meuraxa District.

STUDY AREA

This Geographically, Banda Aceh is located in the coordinate of 05˚ 16 '15 "- 05˚ 36' 16" N and 95˚ 16 '15 "- 95˚ 22' 35" E. Banda Aceh is the capital and largest city in the province of Aceh, Indonesia. It is located on the island of Sumatra and has an elevation of 35 meters. The city covers an area of around 64 square kilometers and had a population of more than 200,000 people.

Meuraxa is one of the districts in Banda Aceh and consists of 16 villages. In general, Meuraxa district is an area where there are many ponds and residential land. Meuraxa is tsunami-affected areas with severe levels of damage. Proven by land area in 2003 before the tsunami 725.80 hectares with a population density of 30 532 inhabitants and after the tsunami 453.90 hectares with a population density of 3,917 inhabitants in 2007 (BAPEDDA, 2013).

Figure 1: Administrative map of Banda Aceh (BAPPEDA, 2013) and the red box is the location of the research.

Figure 2: Location of groundwater Survey.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Generally, Geographic Information Systems (GIS) is a specialized information system that manages the data that have spatial information. GIS is also a kind of software that can be used for entry, storage, manipulation, display, and output of geographic information following attributes (Prahasta, 2005).

The use of GIS increased since the 1980s. This trend is happening in government, academia, and business, especially in the regions forward. This is because the GIS technology is used as a tool of analysis. Utilization of GIS in digital image processing is to improve the classification results. Therefore, the role of GIS technology can be applied to the operation of remote sensing satellites (Arronof, 1989).

GIS is now growing very rapidly in the market. As the development of computer technology maps for planning and evaluation is no longer done manually, but now it is performed digitally by using computer software with a fairly high degree of accuracy. GIS provides facilities for storing, accessing and manipulating remote sensing data or information for scientific, commercial and policy-oriented information. Also, GIS has the facility to create and modify map, measure, monitor, modeling and management of data and analyze the spatial information, spectral, and temporal (Estes, 1992).

Remote sensing in simple words is a method to obtain information about an object without touching the object. Remote sensing has two aspects: (1) technology obtaining data via a device located at a distance from the object, and (2) data analysis to interpret the physical attributes of objects, both of these aspects are inextricably linked one another (Gupta, 2003).

METHODOLOGY

This study involves data acquisition of shape-file (primary data) and groundwater sample (secondary data) followed by data processing and data interpretation. The shape-file data was obtained from previous works of Laboratory of GIS and Data Spatial of Syiah Kuala University. The secondary data which is groundwater samples was acquired randomly from several locations in Meuraxa District.

Having recapitulated the data, then interpolation process was performed in ArcGIS software. According to Anderson (2001) interpolation is a method or mathematical functions that estimate the locations in which data are available. Spatial interpolation assumes that the data attributes are continuous in space and the attribute interconnected (dependence) spatially. Thus, the interpolation process is intended to represent some sample values of a scope.

Overlay technique was used for the final step where the latter to the four latest parameter map results will be combined with the three previous parameters map so it will be a map of the results of this study.

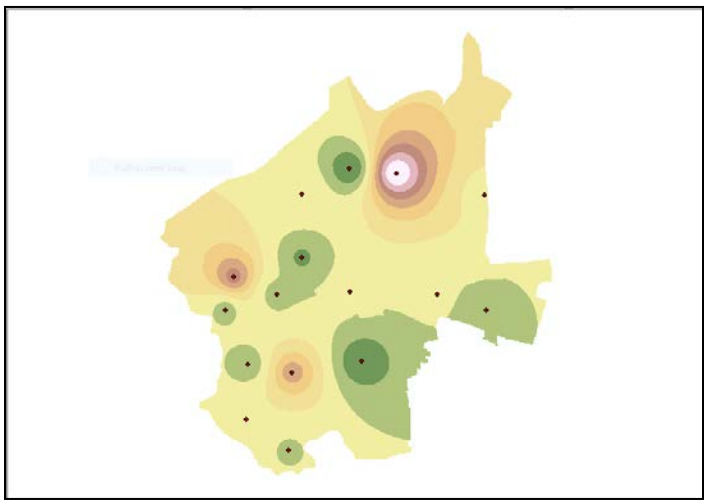

Figure 3: Interpolation results (only include territory).

RESULTS AND DISCUSSION

Analysis of groundwater quality in this study was based on seven physical parameters and was started in October 2015. The main method used is done by the ArcGIS software and field data in the form of four parameter data (Sulfate, DHL, salinity, calcium) content in the groundwater was received in December 2015 and data from previous studies in the form of 3 parameters (pH, Total Dissolved Solids, Total Hardness). The location of the four latest water sample data refer to previous research in which a water sample is taken directly from community wells in the same location with the location of previous studies (Fig.4).

Figure 4: Community wells for groundwater samples.

Spatial Analysis Results

Spatial analysis results in the mapping process were carried out by using ArcGIS software with IDW (Inverse Distance Weighting) interpolation method as a tool in a mapping. IDW Interpolation process was conducted with a scale of 1: 15,000. Physical parameters for the 7 analysis in the mapping are as follows.

1. pH

According to (Zahrul, 2015) pH is one of the indispensable parameters in water quality testing. Its characteristics have a limit level indicates the acidity or alkaline. Determination the level of acidity can be obtained from the test results that show the value of pH <7 (acidic) pH = 7 (neutral), and pH> 7 (alkaline). From the spatial analysis results (**Fig.5**), it can be analyzed that the quality of water for pH measurement in Meuraxa is still quite excellent.

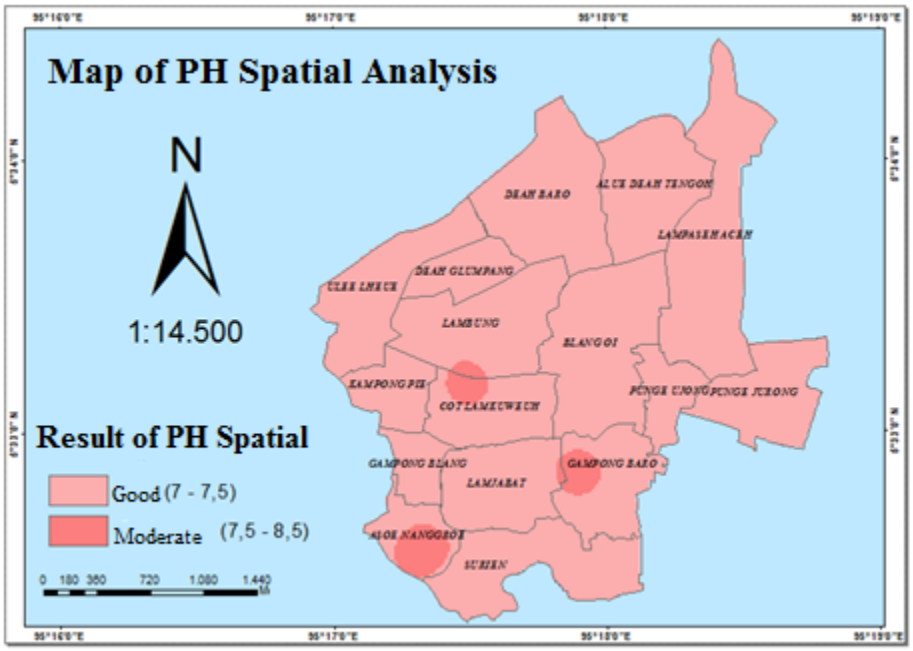

Figure 5: Spatial analysis results of pH.

2. TDS (Total Dissolved Solids)

Total dissolved solids TDS (Total Dissolved Solids) was dissolved materials (diameter <10-6 mm) and colloidal (10-6 mm diameter - 10-3 mm) in the form of chemical compounds and other materials, which do not filtered on a 0.45 µm diameter filter paper (Rao, 1992). TDS which shows the value of 0-500, can be categorized as Good, the value of 500-1000 can categorized as Medium and the value > 1000 can be categorized as Poor (Zahrul, 2015). The following map display TDS parameter distribution that was processed by using the boundary of Meuraxa. From TDS analysis in Meuraxa (**Fig.6**), the water quality is classified as Medium. Only in a few areas have good TDS. TDS is usually caused by inorganic materials in the form of ions. It is commonly found in the waters and sea water and they also have a high TDS value because it contains a chemical compound that also results in a high value of salinity and electrical conductivity (Effendi, 2003).

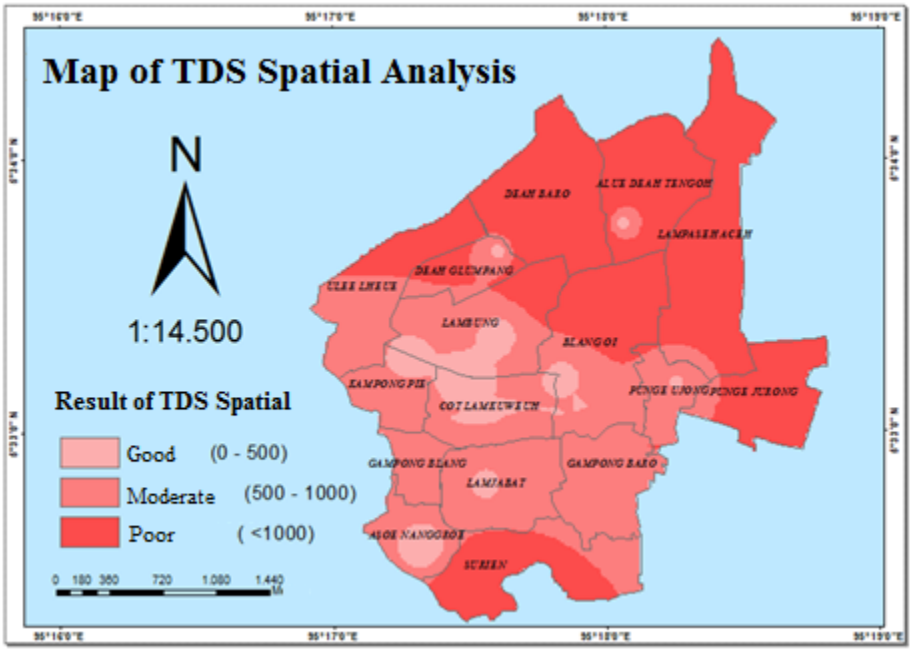

Figure 6: Spatial analysis results of TDS.

3. Total Hardness

Hardness in water is caused mainly by the presence of Carbonate and Calcium and magnesium bicarbonate, sulfate, chloride and nitrate. Total hardness is classified in three ranges (0-300 mg / l, 300-600 mg / l and> 600 mg / l) (Karthikeyan, 2013). From Total Hardness spatial analysis (**Fig.7**), it can be seen that the water quality in Meuraxa is classified as moderate. Also, it can be analyzed that only a few areas that have a high concentration of Total Hardness, namely Lampaseh and some parts of Deah Baro. This happens because the area Lampaseh and Deah Baro rivers are located close to the sea.

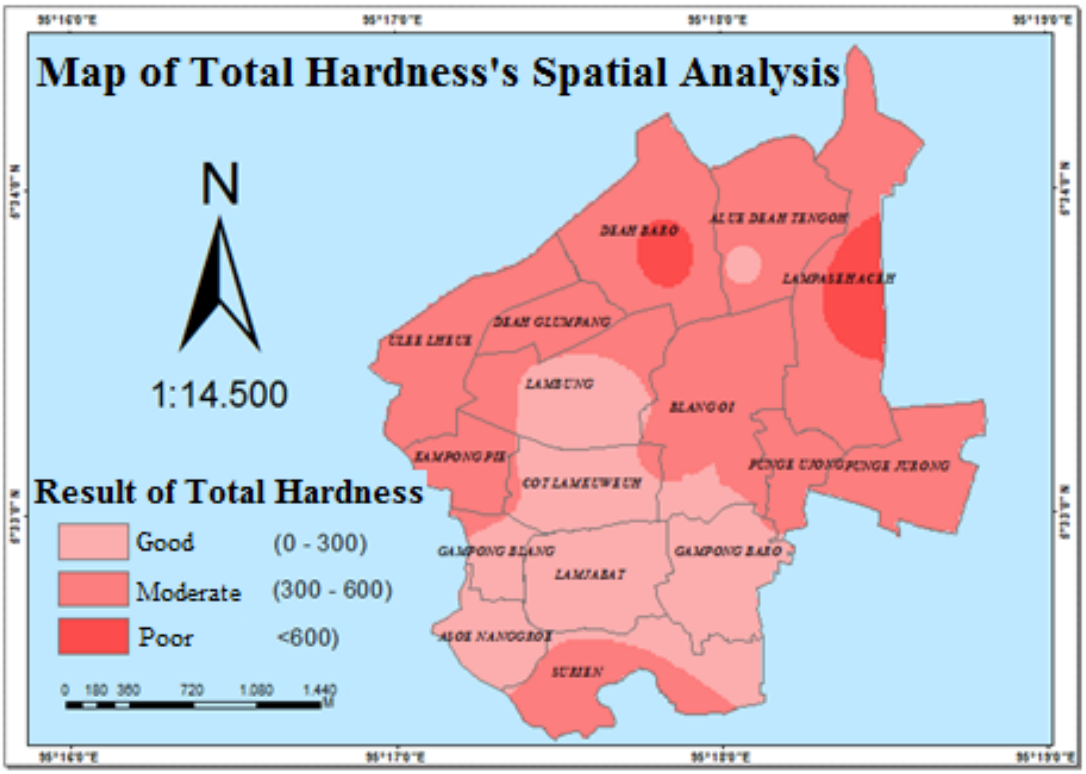

Figure 7: Spatial analysis results of Total Hardness.

4. DHL (Electrical Conductivity)

DHL, which refers to electrical conductivity, is a numerical representation of the ability of the water to continue the flow of electricity. Therefore, the more dissolved salts which can be ionized, the higher the value the DHL (Effendi, 2003). DHL is classified in three ranges (0-2250 µmhos / cm, 2250-3000 µmhos / cm and> 3000 µmhos / cm) (Karthikeyan, 2013). Fig.8 shows that the water quality in Meuraxa, which was analyzed from DHL measurement, is still quite excellent.

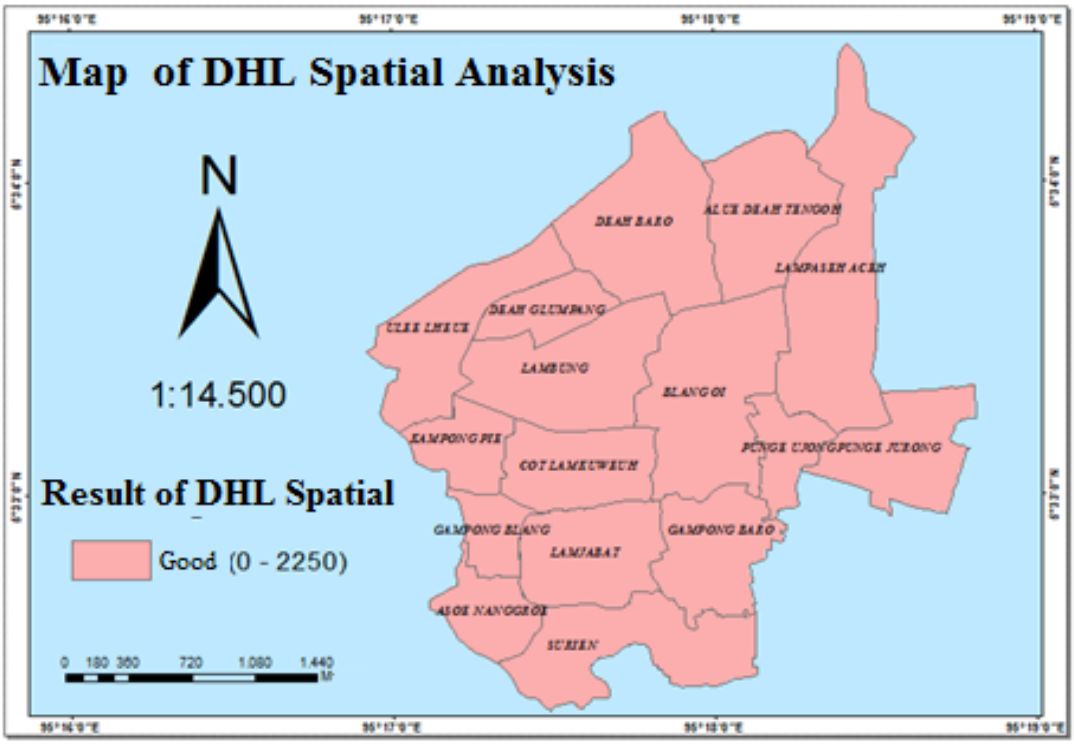

Figure 8: Spatial analysis results of DHL.

5. Sulfate

Sulfate is an ion from sulfur that has been bonded to oxygen. Sulfate compound easily found in nature, such as in the rain. A sulfur compound also comes from the mill effluent (waste) paper, textiles (due to the manufacturing process or staining wearing sulfuric acid) and other industries. Spatial analysis results of Sulfate (**Fig.9**) shows that the water quality parameter in Meuraxa is relatively excellent. This happens because the results of laboratory tests do not show the value of Sulfate above 200 mg / l.

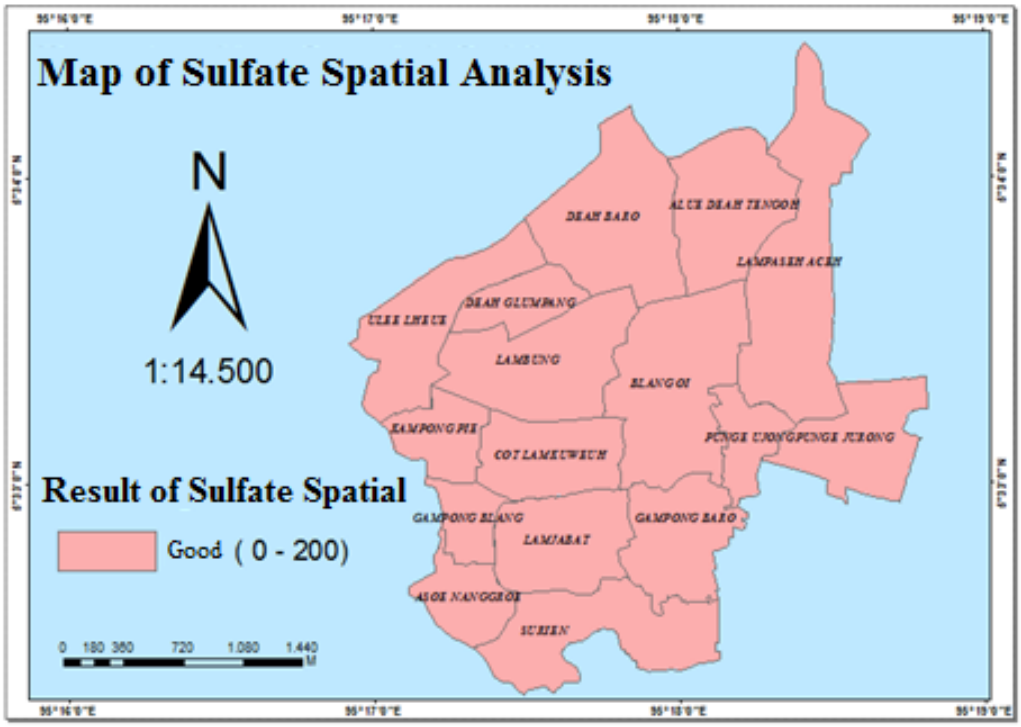

Figure 9: Spatial analysis results of Sulfate.

6. Salinity

Salinity is the concentration of all the salt solution obtained in seawater. The concentration of salt is relatively equal to every instance of water or sea water, though their extraction is done in different places (Purnomo, 2013). From spatial analysis results (**Fig.10**), it can be analyzed that the water quality, derived from Salinity measurements in Meuraxa, is quite good. There are several places that are classified as places having moderate water quality such as Gampong Pie, Alue Deah Tengoh, Baro village, Asoe Nanggroe, Ulee Lheue, Lambung and Cot Lamkuweuh. This happens because the region has a pond where the water activity classified as acidic and there is also a river that connects directly with seawater.

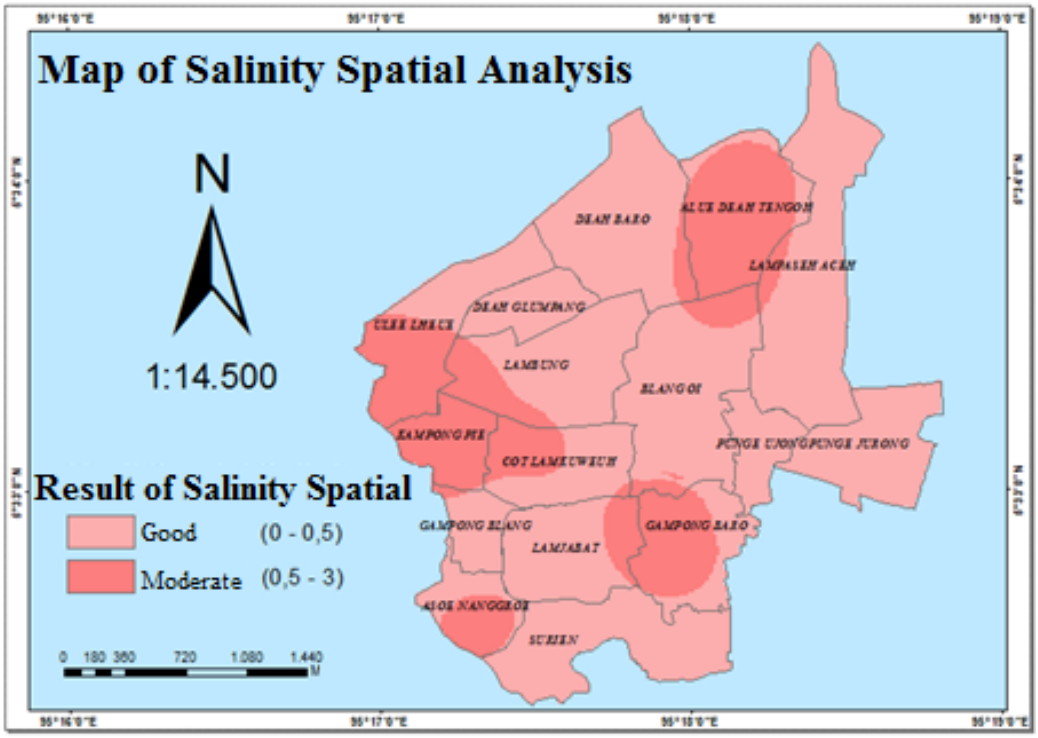

Figure 10: Spatial analysis results of Salinity.

7. Calcium

Calcium occurs in water, especially for their limestone, gypsum and dolomite minerals (Karthikeyan, 2013). Calcium is classified into three ranges level which are Good (0-75 mg / l), Medium (75-200 mg / l) and Poor (> 200 mg / l). Spatial analysis results of Calcium (**Fig.11**) shows that the quality of the water in Meuraxa still quite excellent. There is only one place that has good water quality. This happens because the laboratory testing result does not show the value above 75 mg / l. Also, the calcium is only obtained from limestone, which is mostly found in the mountainous area, whereas Meuraxa area is located far from mountain. Therefore, from spatial analysis of Calcium, it can be derived that the quality of water in the area is quite good.

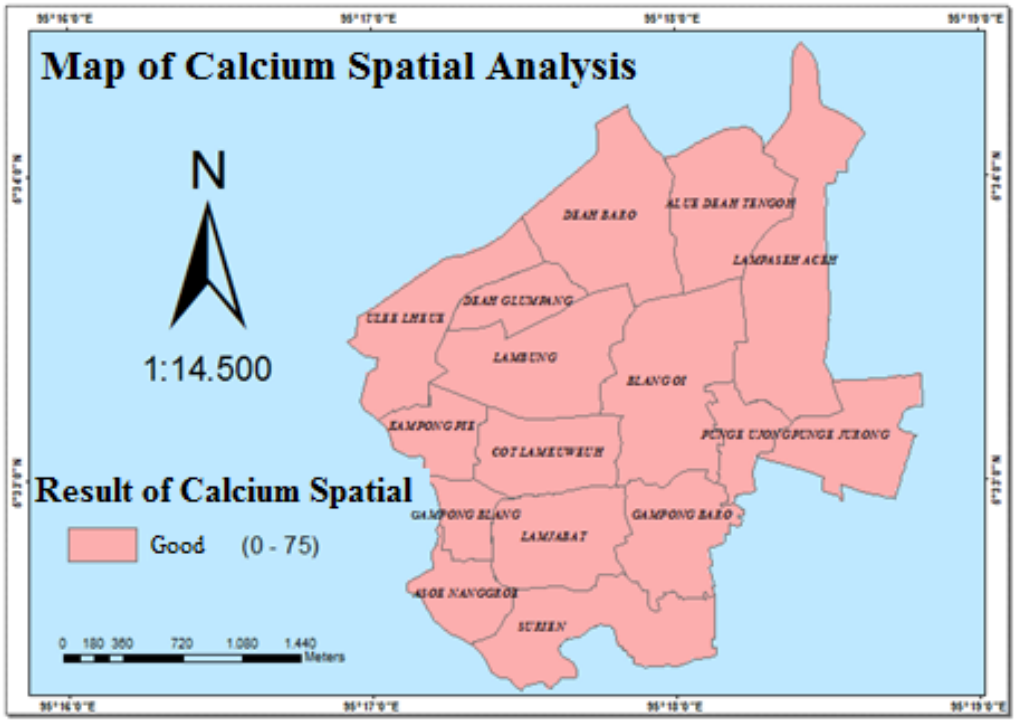

Figure 11: Spatial analysis results of Calsium.

7. Overall Spatial Analysis

From the test results of all 7 parameters, then a final map of overall results analysis was constructed. The final map is based on combination results of seven physical parameters. It only displays two levels of water quality which are good and moderate. In contrast to previous studies results that have qualities of the three categories. It is inferred that in the additional sample testing (4 parameters) has a good sample results, where only salinity contains good and moderate value. Other parameters such as DHL, Sulfate and Calcium have good value only. This proves that the levels of well water for Meuraxa is already categorized quite good (moderate), where only a few locations that have excellent water content is in the area of Hull, Cot Lamkuweuh, Lamjabat and a small part of Blang Oi areas were previously categorized as poor in previous studies.

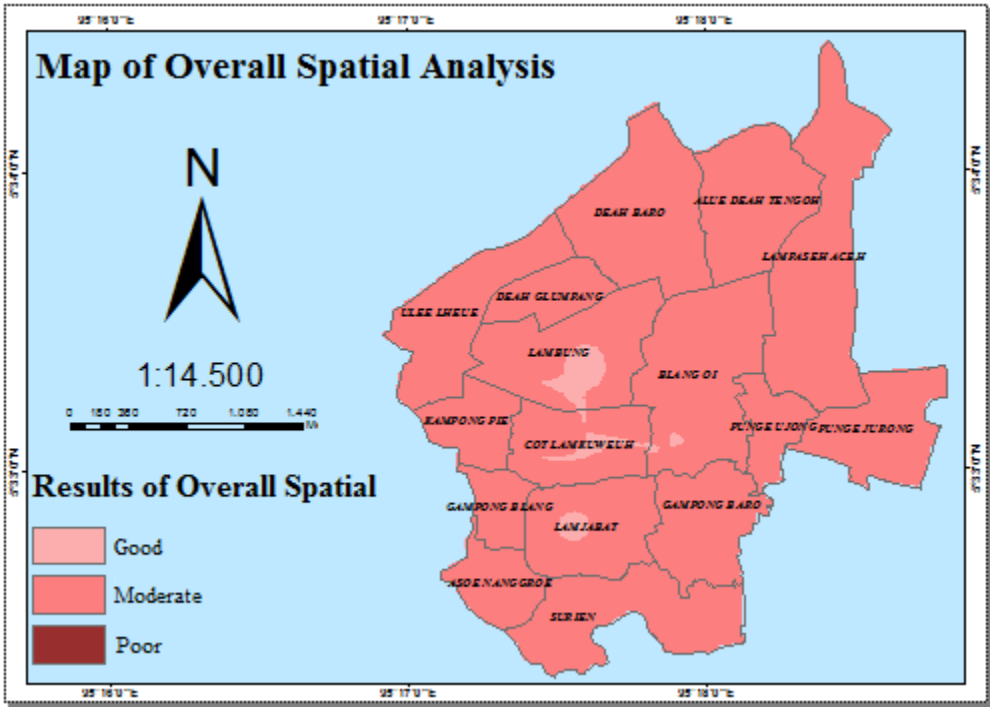

Figure 12: Results of overall spatial analysis.

CONCLUSIONS

This research has demonstrated the utility of GIS combined with analytical data to assess and mapping of groundwater quality. The spatial distribution map of pH, Electrical Conductivity, Total Dissolved Solids, Total Hardness, Sulfate, Salinity and Calcium shows that, these parameters were not within the permissible limit throughout the study area uniformly. The spatial distribution map of pH, DHL, Salinity, Sulfate, Calcium and Total Hardness concentration shows that Meuraxa has good water quality. Only the spatial distribution map of TDS concentration illustrates that Meuraxa has poor water quality. Thus, spatial distribution maps of various quality parameters are used to distinguish the locational distribution of water quality in a comprehensive manner and help in suggesting groundwater suitable for domestic purposes.

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