Indonesian Physical Review

Volume 6 Issue 3, September 2023

P-ISSN: 2615-1278, E-ISSN: 2614-7904

Distribution Analysis of Clean Water Quality Using Hydrophysical Data in Marsela Village, Masela Island District, Southwest Maluku Regency, Maluku Province

Matheus Souisa[1,2,3,4*], Sisca M. Sapulete[1], Raras F. Waimalaka[1]

[1] *Department of Physics, Faculty of Mathematics and Natural Sciences, University of Pattimura, Ambon, Indonesia*

[2] *Landslides Laboratory, Faculty of Mathematics and Science, University of Pattimura, Ambon, Indonesia*

[3] *Disaster Mitigation Laboratory, Faculty of Mathematics and Science, University of Pattimura, Ambon, Indonesia.*

[4] *Geosciences Center, Faculty of Mathematics and Science, University of Pattimura, Ambon, Indonesia*

Corresponding Authors E-mail: thos.phys@gmail.com

Article Info

Article info:
Received: 05-07-2023
Revised: 06-08-2023
Accepted: 09-08-2023

Keywords:
Hydrophysical parameters; Water zoning; Water quality; Distribution pattern

How To Cite:
M. Souisa, S.M. Sapulete and R.F. Waimalaka "Distribution Analysis of Clean Water Quality Using Hydrophysical Data in Marsela Village, Masela Island District, Southwest Maluku Regency, Maluku Province", Indonesian Physical Review, vol. 6, no. 3, p 324-333, 2023.

DOI:
https://doi.org/10.29303/ipr.v6i3.254

Abstract

In situ measurements of hydrophysical parameters have been carried out in groundwater in dug wells, drilled wells, and reservoirs related to temperature, electrical conductivity, degree of acidity, salinity, and total dissolved solids (TDS). This study aims to analyze the characteristics of hydrophysical parameters in water samples and create a water quality distribution model based on hydrophysical data in the study area. The results showed that water zoning based on air temperature and water temperature is included in the mesothermal zone category, and this zone water may originate from free/leaking aquifers. The results of hydrophysical parameter measurements were TDS with a concentration value of < 1000 mg/L, conductivity parameter (σ) with a concentration value of σ < 2500 μS/cm, a pH parameter ranging from 7, and a salinity parameter with a concentration value < 1000 ppm which is allowed according to water quality standards which are found in dug wells (old wells, SGM-3), drilled wells (SBM) and pond (Em). While the hydrophysical parameters for measuring other groundwater samples are not in accordance with water quality standards. Modeling the distribution of water quality based on three hydrophysical parameters (TDS, s, and S) in the study area shows a shallow groundwater pattern and seawater intrusion has occurred in several wells (SGM-1, SGM-2, and SGM-4). The distribution of TDS, σ, and S concentration values at study sites varies with distance from the coastline and topography.

Introduction

Water is an absolute human need because almost all human activities require water. Realizing this, clean water and proper sanitation are the sixth targets of Indonesia's 17 sustainable development goals for 2030 [1].

In its use, some water quality meets quality standards, and some does not meet quality standards. Water that meets quality standards is used by many residents, in villages and cities. According to Soerjani [2], the human need for clean water is increasing along with the increasing population. The need for clean water is a basic need for meeting the needs of life and domestic activities locally [3]. Most of the water comes from groundwater. Not all water can be used by humans because it contains harmful substances or toxin bacteria and seawater intrusion. Likewise, the problem of water shortages is triggered by several things, such as water depletion caused by a long dry season or vegetation clearing, seawater intrusion, and garbage leaching.

This is what the people in Marsela Village experience, they fetch water from an old well every day. The water in this old well was taken by the people of two villages, namely Marsela Village and Ilbutung Village, and even in the previous decade, the people of Marsela Island came to fetch water from the old well. Apart from these old wells, some have dug wells in several places, but the local people do not consume it as drinking water, only use it for washing or bathing, and some do not use it. In addition to old wells, these wells are experiencing seawater intrusion. There are a few dug axes, but they all feel brackish. However, the Panci Mas company has drilled at a depth of about 15 meters and has obtained clean water with a moderate debit that is suitable for drinking. The distribution of water flow to people's homes consists of three lines. Water flow on the first line is carried out for one day, then the second line on the second day, and the third line on the third day, then rotates to the beginning. In addition, the people in the research area or related agencies have not taken any action to test groundwater quality.

Based on this, the authors conducted a hydrophysical study carried out in this study by analyzing the hydrophysical parameters of groundwater to identify groundwater genesis. In situ, measurement of water from dug wells drilled wells, and ponds. The parameters measured were air temperature (T_a), water temperature (T_w), electrical conductivity (σ), degree of acidity (pH), and Total Dissolved Solid (TDS). The benefits resulting from this research are to provide information to the community and the government about the quality of shallow groundwater based on hydrophysical parameters and efforts to manage clean water so that it can be used by the community in the research area.

Methodology

Field data collection locations were in Marsela Village, Masela Island District, Southwest Maluku Regency. Measurement of hydrophysical parameters was carried out on water samples from several dug wells, drilled wells, and ponds. The research location is shown in Figure 1.

Figure 1. Research area map.

In situ field data acquisition on four dug wells, one drilled well and one pond. Water samples were taken from each well, and the hydrophysical parameters were measured using a water quality tester. The results of field data acquisition are in the form of hydrophysical parameter values, plotted the relationship between air temperature (T_a) versus water temperature (T_w), TDS versus σ, TDS versus salinity, TDS versus temperature, and TDS versus pH using origin software. From the results of this hydrophysical parameter plot, it is possible to determine the hydrophysical characteristics of the study area. Modeling the distribution of water quality from hydrophysical parameter data in the study area uses surfer software.

Result and Discussion

The geohydrology of the research location includes the aquifer layer of sandy limestone units. The aquifer is formed from loose sand-sized material. The aquifer exists as a confined aquifer with a small number of dug wells. The productivity of the aquifer on Masela Island is in the form of a system of fractures, cracks and dissolution with a moderate level of productivity [4]. The pattern of groundwater flow in the study area is controlled by the topographical. Based on the topography, the northern part of the study area has a higher elevation than the southern part so the flow of groundwater in the study area generally moves from north to south and spreads in all directions through cracks or rock fissures.

Hydrophysical parameters

Measurements on water samples in dug wells drilled wells, and reservoirs are to obtain the parameter values of temperature (water and environment), Total Dissolved Solid (TDS), conductivity (σ), and salinity (S). The measurement results are used to analyze the quality of groundwater. To measure other than the six parameters in the study area, groundwater levels in each well were also measured. The results of hydrophysical measurements [5, 6] on six water samples are shown in Table 1. Only one old well is still used by the community for clean water consumption (Figure 2), and one drilled well is added. However, several other wells have experienced seawater intrusion so that it feels brackish, and is not used by the community.

Table 1. Measurement results of hydrophysical parameters.

Well type	Coordinate		Z (masl)	Depth MAT (m)	Temperature		TDS, (mg/L)	σ, (μS/cm)	Salinity, S (ppm)	pH
	x UTM	y UTM			T_w (°C)	T_a (°C)				
SGM-1	9098358	596038	9	1.5	26.5	26.7	1,970	3,200	3152.0	6.7
SGM-2	9098206	595856	12	0.7	26.7	27.0	1,514	2,436	2271.0	6.6
SGM-3	9098253	595871	13	0.4	26.7	27.8	413	723	454.3	7.2
SGM-4	9098215	595819	13	1.6	26.8	26.9	1,800	2,930	2700.0	6.4
SBM	9098212	595788	17	1.2	26.3	27.2	450	763	495.0	7.2
EM	9098401	595744	28	1.3	27.2	28.8	353	628	388.3	7.2

Remarks: MAT: Groundwater Surface, SGM: Marsela Dug Well, SBM: Marsela Bore Well, EM: Marsela Pond, T_w: Water temperature, T_a: Air temperature.

Water zoning based on T_w and T_a

Based on the results of direct measurements in the field (Table 1), a graph of the relationship between T_a and T_w is made (Figure 3). Most of the water samples in the study area are in the hypothermal zone. Water in the hyperthermal zone consists of river water and ponds. The mesothermal zone is dominated by groundwater and springs. The hypothermal zone is dominated by groundwater and seawater. Groundwater temperature in springs and dug wells is strongly influenced by air temperature. The mesothermal zone indicates the possibility of water originating from free/leaking aquifers. The difference between T_a and T_w indicates the possibility of groundwater originating from shallow streams. As for groundwater intruded by seawater, if there is a low difference in T_a and T_w. With increasing temperature, σ and TDS concentration values also tend to increase [7].

Figure 2. Location of air temperature and water temperature measurements in old wells (SGM-3).

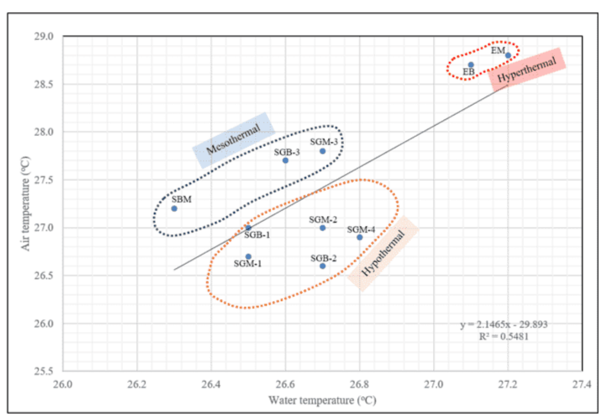


Figure 3. The water zone is based on water temperature and air temperature.

Relationship of TDS and σ concentration, pH and salinity to water samples

The TDS concentration indicates the saturation level of water or the number of dissolved solids in water, both ionized and not [8]. According to Prusty and Farooq [9], TDS is an indicator of seawater intrusion which shows the amount of dissolved salts. Figure 4 shows the water that is allowed according to the standard TDS concentration value of <1000 mg/L (ppm) [10,11], namely in dug wells (old wells, SGM-3), drilled wells (SBM), and ponds (Em). Meanwhile, the TDS concentration > 1000 mg/L is categorized as brackish water which is suspected of experiencing seawater intrusion [12]. The conductivity parameter (σ) is used to identify the type of water, which indicates the presence of dissolved salts based on the conductivity value [13]. Figure 5 shows the water that is allowed according to the standard σ concentration value <2500 mS/cm, namely in dug wells (old wells, SGM-3), drilled wells (SBM), and ponds (Em). σ values > 2500 mS/cm can be categorized as brackish water which is suspected of experiencing seawater intrusion (Kloosterman, 1983 in [14]).

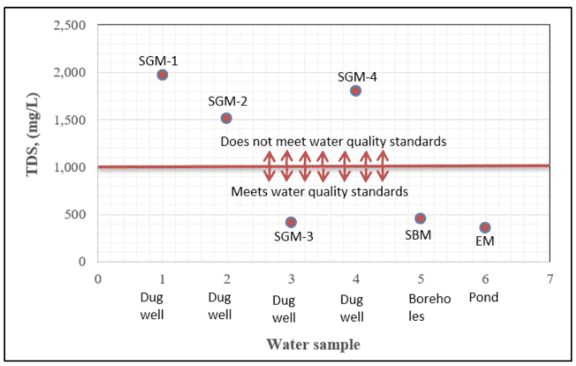


Figure 4. The relationship between TDS concentration values and water samples.

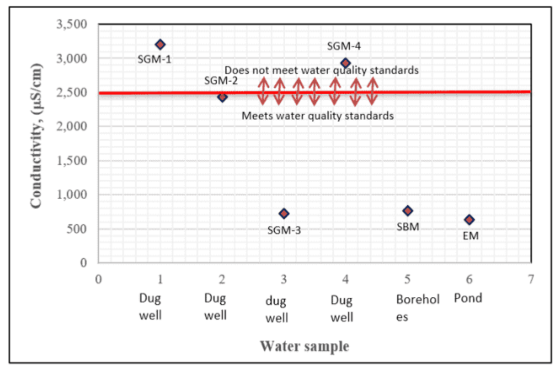


Figure 5. Relationship between conductivity concentration values and water samples.

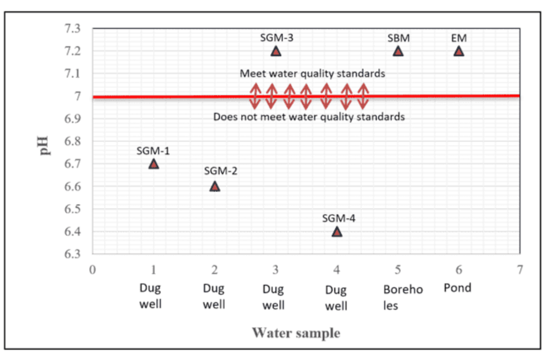


Figure 6. Relationship of pH concentration value to water samples.

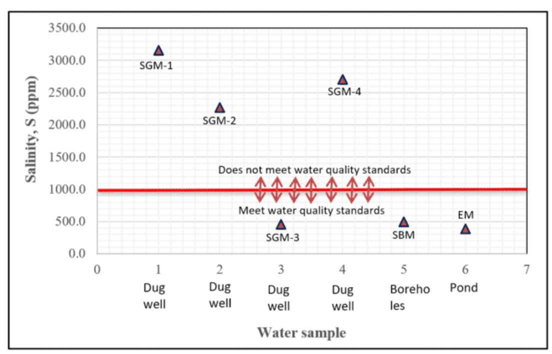


Figure 7. Relationship of the value of salinity concentration (S) to water samples.

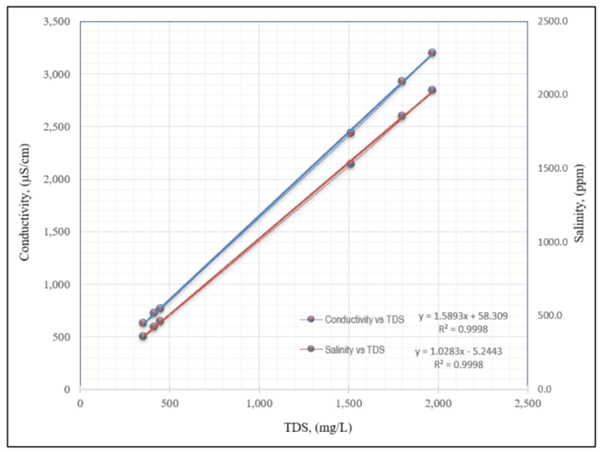
The pH parameter is used to express degree of acidity or alkalinity of a solution. Generaly, the pH value is divided into three categories: acidic pH < 7.0, neutral pH = 7.0, and alkaline pH > 7.0. According to Gasim et al., [15] for pH < 7.0 is during low tide, and pH > 7.0 is during high tide. Therefore, Figure 6 shows the water standards that are allowed to have a pH concentration value of around 7, namely in dug wells (old wells, SGM-3), drilled wells

(SBM) and ponds (Em). The next parameter is salinity which is used to identify the type of water. Salinity is strongly influenced by dissolved salts [16]. Therefore, Figure 7 shows the water standard that is allowed to have a concentration value of S < 1000 ppm, namely in dug wells (old wells, SGM-3), drilled wells (SBM) and ponds (Em).

The relationship between TDS concentration, σ and salinity

To study the relationship of the three parameters used simple linear regression analysis. The results of linear regression analysis of the relationship between DHL concentration and salinity to TDS are shown in Figure 8.

(a)



(b)

Figure 8. (a) One of the locations for measuring hydrophysical parameters in old wells (SGM-3), (b) Relationship between conductivity and salinity concentrations on TDS.

The concentration σ is a measure of the ability of a solution to conduct an electric current. Figure 8 shows that the σ value to TDS value has a positive relationship. The greater the TDS value, the greater the value of σ. The coefficient of determination (R^2) is 0.9998 which means that the TDS value greatly influences σ. This means, the σ value is very closely related to the value of TDS. The TDS value is usually smaller than the σ value.

Likewise, the infographic of the relationship between salinity concentration and TDS shows a correlation between the linear regression which is positive with a coefficient of determination (R2) of 0.9998, which means that the TDS value greatly influences the salinity valueSalinity value increases with increasing TDS value.

Relationship of σ, salinity, TDS and pH

Figure 9 shows a graph of the relationship between σ concentration and salinity with a coefficient of determination (R^2) of 1.0, which means that the σ value greatly influences salinity. The greater the σ, the greater the salinity, meaning that the level of salinity is higher. The infographic (Figure 10) shows the relationship between TDS concentration and pH with a coefficient of determination (R^2) of 0.874, which means that the TDS value has less effect on pH. So there is no relationship between pH and seawater intrusion.

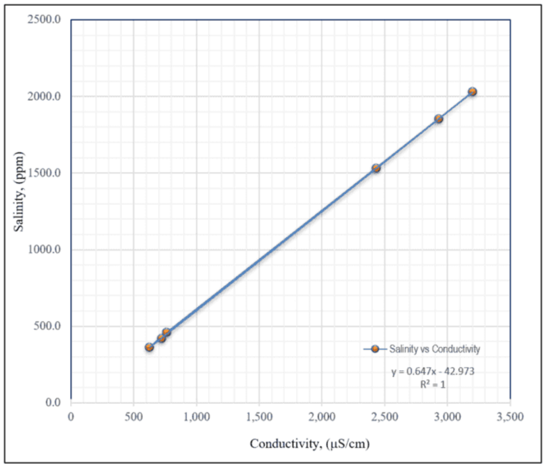


Figure 9. The relationship between the salinity concentration value and the conductivity concentration value.

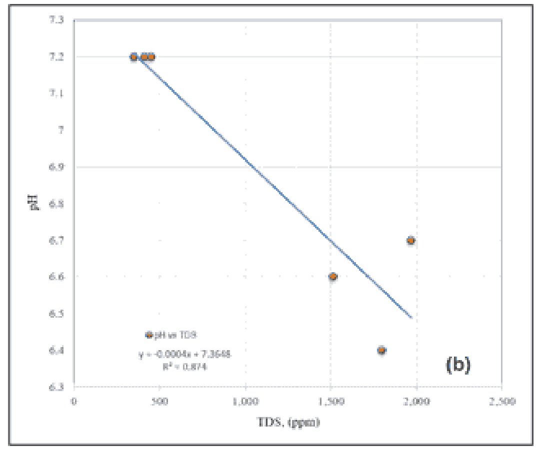


Figure 10. The relationship between the pH concentration value and the TDS concentration value.

Relationship of well depth to TDS and σ concentration

From the regression equation (Figures 11 and 12) it is obtained that the coefficient of determination (R^2) is 0.04, which means that the conductivity and TDS values do not affect the depth of the well. So, there is no relationship between well depth and seawater intrusion.

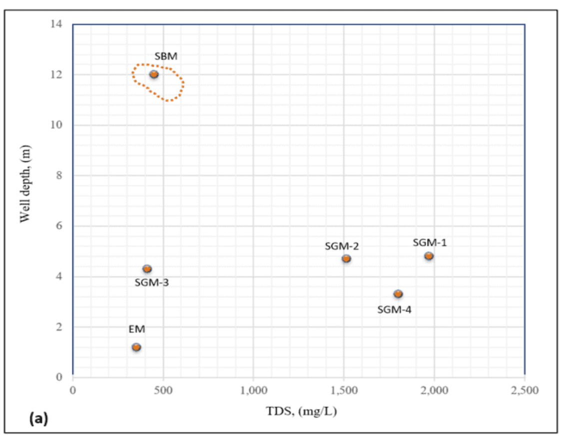


Figure 11. The relationship between the depth of the well and the value of TDS concentration.

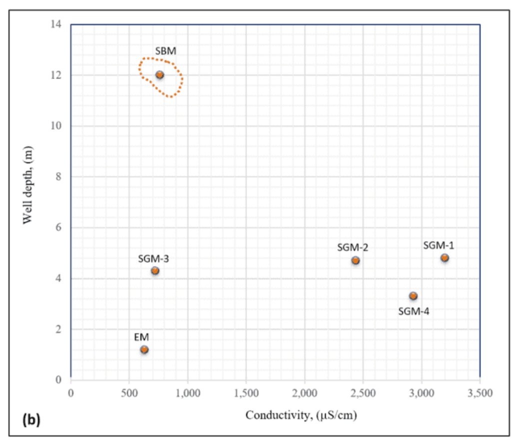


Figure 12. The relationship between the depth of the well and the conductivity concentration value.

Water quality distribution pattern

Before creating a distribution model for hydrophysical parameter values, a digitization process is first carried out by entering latitude and longitude coordinates as well as hydrophysical parameters into the Surfer software. After the digitization process was carried out, a contour map of the distribution of TDS, σ, and salinity was formed as shown in Figures 13, 14, and 15. The contour map of the distribution of TDS, and σ visually shows how the aquifer at the study area experienced an intrusion process.

The blue color in Figures 13 and 14 shows the TDS value and low conductivity, the green color shows the TDS value and medium conductivity, and the red color shows the TDS value and high conductivity. From the map it is explained that the elevation of the groundwater table does not affect the value of TDS concentration and conductivity. While the distance of the well from the shoreline also affects the value of TDS concentration and conductivity[17]. The contour map of the distribution of salinity concentration values (Figure 15) also has the same shape as the TDS distribution. Based on the distribution of TDS concentration, conductivity and salinity values at SGM-3 and SBM. It shows that the groundwater is classified as clean water and is not intruded by sea water, but its distribution is not too wide. The water samples from the other dug wells had TDS, conductivity, and salinity slightly salty or brackish, and were not suitable for consumption as clean water, but only for washing purposes. The results of the research on the distribution of TDS concentration, conductivity, and salinity show that the community well water (SGM-1, SGM-2, and SGM-4) has been intruded by seawater with moderate to medium intrusion classification.

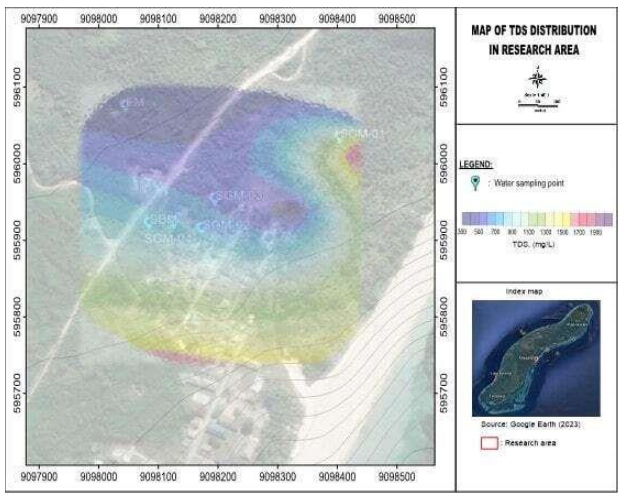


Figure 13. Map of the distribution of TDS concentrations at the study sites.

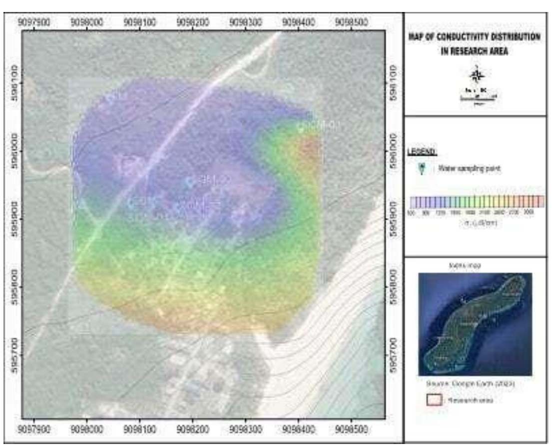


Figure 14. Map of the distribution of conductivity concentration values in the study area.

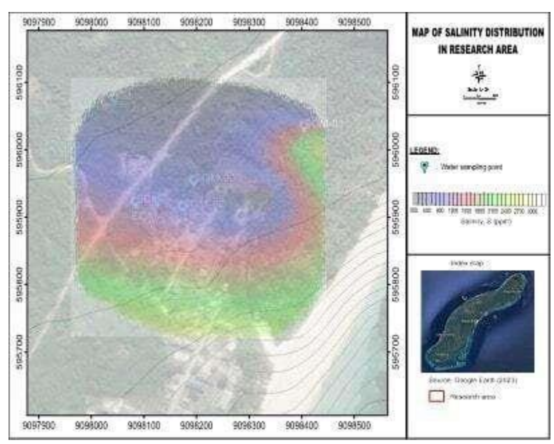


Figure 15. Map of the distribution of salinity concentration values in the study area.

The concentration of TDS, σ and *S* at the study site has a distribution that varies with distance from the coastline and topography. The difference in the concentration values of TDS, σ, and S is caused by the type of local rock formations. Rocks with the same formation do not necessarily have the same conductivity pattern, so that the concentration of TDS, σ and salinity varies from the distance of the coastline and the topography. Several other factors affect the uneven distribution of TDS, σ and S concentrations, including lithological composition and rock conditions, mineral composition, liquid content, and other external factors [18]. At the research location, a geo-forestry technology approach was used, namely by planting mangrove saplings along the coastline to the prevention of seawater intrusion. During tides, mangroves can support seawater seeping into the groundwater. This can happen because of the hydraulic relationship between seawater and fresh water. In this study did not examine the parameters of pressure and density. However, for information, seawater has a higher mineral content and greater water pressure than fresh water. Seawater also has a greater density (1025 kg/m^3) than fresh water (1000 kg/m^3). If at the depth of the water table (for example: 2 meters), the hydrostatic pressure of seawater (20,110.0 N/m^2) is greater than fresh water (19,620.0 N/m^2). Seawater will then enter through the aquifer gap to move inland, causing many shallow wells at the study site to be contaminated with saltwater because the seawater level is higher than the groundwater level. So, the rise and fall of sea level greatly affects the quality of well water. This shows that the tides and layers of porous rock are very influential on the concentration value of hydrophysical parameters at the study site.

Conclusion

The results of hydrophysical parameter measurements were TDS with a concentration value of < 1000 mg/L, conductivity parameter (σ) with a concentration value of σ < 2500 mS/cm, a pH parameter ranging from 7, and a salinity parameter with a concentration value < 1000 ppm which is allowed according to water quality standards which are found in dug wells (old wells, SGM-3), drilled wells (SBM) and pond (Em). While the hydrophysical parameters for measuring other groundwater samples are not in accordance with water quality standards.

Modeling the distribution of water quality based on three hydrophysical parameters (TDS, s, and S) in the study area shows a shallow groundwater pattern and seawater intrusion has occurred in several wells (SGM-1, SGM-2, and SGM-4). The distribution of TDS, σ, and S concentration values at study sites varies with distance from the coastline and topography.

Acknowledgment

Thanks are given to the Head of the Geosciences Expertise Group, the Department of Physics, who has provided financial assistance and facilities for data acquisition and analysis processes. The same thanks go to friends who have helped with data collection.

References

[1] BPS. *Potret Awal Tujuan Pembangunan Berkelanjutan (Sustainable Development Goals) di Indonesia*. Badan Pusat Statistik/Statistics Indonesia, Jakarta, pp. 95-109, 2016.

[2] M. Soerjani, "Lingkungan Hidup (*The Living Environment*)". Restu Agung, Jakarta, 2005.

[3] Harjito, "Metode Pumping Test Sebagai Kontrol Untuk Pengambilan Air tanah Secara Berlebihan". *Jurnal Sains dan Teknologi Lingkungan*, vol. 6, no. 2, pp. 138-149, 2014.

[4] M. Souisa, *Laporan Hasil Survei Akuifer Menggunakan Metode Geolistrik di Desa Bululora Kecamatan Pulau Masela Kabupaten Maluku Barat Daya*, Pemerintah Desa Bululora, Kecamatan Pulau Masela, MBD, Maluku, 2022.

[5] B. Agoubi, A. Kharroubi and H. Abida, "Geochemical Assessment of Environmental Impact on Groundwater Quality in Coastal Arid Area, South Eastern Tunisia". *Journal of Environmental Science and Engineering Technology*, vol. 2, no. 2, pp.35-46, 2014.

[6] M. Mukonazwothe, L.F. Munyai and M.I. Mutotii, "Groundwater quality evaluation for domestic and irrigation purposes for the Nwanedi Agricultural Community, Limpopo Province, South Africa. *Heliyon* vol.8, issue 4, e09203, pp.1-13, 2022.

[7] F. Irwan dan Afdal, "Analisa Hubungan Diantara Konduktivitas Listrik, Zat Padat terlarut (TDS) dan Temperatur pada Beberapa Jenis Air". *Jurnal Fisika Unand*, vol. 5, no. 1, pp. 85-93, 2016.

[8] R.A. Freeze and J.A, Cherry, "*Groundwater*". Prentice-Hall, Inc., Engle-wood Cliffs, New Jersey 07632, 1979.

[9] P. Prusty and S.H. Farooq, "Seawater Intrusion in The Coastal Aquifer of India – A Review". *HydroResearch* 3, pp. 61-74, July 2020.

[10] WHO, *Total dissolved solids in Drinking-water*. 2nd ed. Vol. 2, Health criteria and other supporting information. World Health Organization, Geneva, p. 1, 1996.

[11] A. Hilmi, A. Ulfa, A.M. A. Wijaya and L.I. Hadimi, *Study of seawater intrusion in coastal aquifer using total dissolved solid, conductivity and salinity measurement in Labuhan Kertasari Village, West Sumbawa*. Journal of Physics: Conference Series IO Publishing, 1816 (2021) 012064, 1-7, 2021.

[12] C.W. Fetter, *Applied Hydrogeology*, Fourth Edition. Merrill Publishing Company, London, pp. 388-389, 2000.

[13] H. Effendi, *Telaah Kualitas Air Bagi Pengelolaan Sumber Daya dan Lingkungan*. Kanisius, Yogyakarta, p.11, 2003.

[14] M. Souisa, "*Laporan Hasil Survei Air tanah Dalam Menggunakan Metode Geolistrik Schlumberger di Pulau Moa, Kabupaten Maluku Barat Daya, Provinsi Maluku*", Kerjasama dengan Universitas Pertahanan Republik Indonesia Jakarta, dan Fakultas MIPA Universitas Pattimura, Ambon, 2022.

[15] M.B. Gasim, N. A. Khalid and H. Muhamad, "The Influence of Tidal Activities On Water Quality Of Paka River Terengganu, Malaysia". *Malaysian Journal Of Analytical Sciences*, vol. 19, no. 5, pp. 979 – 990, 2015.

[16] T.A. Ardaneswari, T. Yulianto dan T. Triadi, "Analisis Intrusi Air Laut Menggunakan Data Resistivitas Dan Geokimia Airtanah Di Dataran Aluvial Kota Semarang". *Youngster Physics Journal*, vol. 5, no. 4, pp. 335-350, Oktober 2016.

[17] A. Nurrohim, B. Tjaturahono dan S. Wahyu, "Kajian Intrusi Air Laut di Kawasan Pesisir Kecamatan Rembangan Kabupaten Rembang". *Jurnal Unnes*, vol.1, no.1, pp.22-27, 2012.

[18] Y. Yanguo, Feng, Song, Liuting, W. Jinsheng dan L. Jian, *"Total petroleum hydrocarbon distribution in soils and groundwater in Songyuan oilfield, Northeast China"*. *Environmental Monitoring and Assessment*, ***185*** *(11)*, 2013.