Study of Distribution of Groundwater Salinity in Pacitan Sub-District, Pacitan District Based on GIS

Muchlis[1*], Sri Sunarsih[1], Muhid Bariruddin[1]

[1]*Jurusan Teknik lingkungan, Institut Sains & Teknologi AKPRIND Yogyakarta, Indonesia*
Corresponding author's email: muchlis@akprind.ac.id

ABSTRACT
The Pacitan District's coastal area is a tourist destination and a settlement and pond land. Excessive groundwater extraction and land use might decrease groundwater levels, allowing seawater to seep (salinity). Salinity harms many elements of life, including health issues, reduced soil fertility, and structural damage, among others. The purpose of the study was to figure out how much groundwater salinity there is in Pacitan District and what causes it. Quantitative descriptive analysis based on primary and secondary data collecting was employed in this study. In the Pacitan District, 75 points of groundwater were collected from 25 communities. A Hand Refractometer was used to determine the salinity of groundwater. The Ministry of Energy and Mineral Resources (ESDM) regulation No. 31 of 2018 regulates the classification of groundwater conservation zones. According to the data, the salinity of well water in the research area ranges from 0 mg/L to 12,000 mg/L. In the safe, vulnerable, and critical categories, groundwater salinity levels in the Pacitan sub-district are 96 percent, 2.67 percent, and 1.33 percent, respectively. The distance from the shoreline and the use of pond land are the two most important aspects. Because pond land is made mainly of saltwater, it is pretty easy to seep into the earth.

Keywords: *Groundwater Salinity; GIS; Salinity Level*

1. INTRODUCTION

Rapid population increase has numerous detrimental consequences for groundwater supplies, both quantity, and quality. The amount of clean water required is proportional to population growth [1]. The decline in groundwater quality in coastal areas can be caused by seawater seepage. Seepage of seawater has an impact on increasing the salt (salinity) level in groundwater because seawater mixes with groundwater [2]. The decline in groundwater quality in coastal areas can be caused by seawater seepage. Seepage of seawater impacts increasing salt (salinity) levels in groundwater because seawater mixes with groundwater [2-3]. Seawater seepage can be through land use such as ponds. Pond land in coastal areas is very influential on seawater intrusion, which causes groundwater salinity to be high because the speed of seawater to land is effortless either through above or below the ground surface [4].

Pacitan District is located on the southern coast of Java Island, consists of 25 Kalurahan, and is a City District of Pacitan Regency with 7,710.87 Ha. The total population in Pacitan District is 78,086 people, consisting of 20,054 households, with an average population per village of 2,923 people [5]. Pacitan District has the highest population growth rate among other sub-districts in Pacitan Regency [6].

The large population and economic growth in Pacitan District and Pacitan Regency make the need for clean water continue to increase, both for daily and industrial markets. Excessive water withdrawal can decrease groundwater levels, which eventually becomes the cause of seawater intrusion into the aquifer.

The utilization of well water in the coastal area of Pacitan District is mainly used for daily living needs, namely bathing, washing, and others. Wihertanti [7] stated that the most widely used water source by resident respondents in Pacitan District is shallow wells, amounting to 78.8%. In this study, users of water sources in Pacitan District are presented in Table 1.

Pacitan sub-district in the downstream area or a distance of about 1 – 6000 m from the coastline is at an altitude between 1 – 36 meters above sea level [8]. This condition makes the Pacitan sub-district, located on the coast, have the potential for seawater intrusion to occur.

Z. B. Pambuko et al. (Eds.): BIS-HSS 2021, ASSEHR 667, pp. 1065–1069, 2023.
https://doi.org/10.2991/978-2-494069-49-7_177

According to Chen et al. [9], the extraction and utilization of groundwater through wells will result in a depression cone. The greater the rate of groundwater withdrawal, the steeper the curvature of the groundwater table that occurs around the well until a new equilibrium is reached if there is filling from the catchment area. This new groundwater balance can be achieved when the rate of groundwater uptake is less than the rate of rainwater erosion in the catchment region. Suppose the rate of groundwater withdrawal from many wells is much greater than its filling. In that case, the curvature of groundwater subsidence between one well and another will cause a permanent decrease in the groundwater level.

In coastal areas, the decrease in groundwater can result in seawater intrusion. The salinity value of groundwater is not only caused by seawater intrusion but is also caused by several factors, namely geomorphology, flow direction, tides, coastal characteristics, and land use [10-11]. Seawater intrusion (salinity) can also cause extensive negative impacts on various aspects of life, such as health problems, decreased soil fertility, damage to buildings, and so on [12]. Goetz [13] classified salinity levels and water types as shown in Table 2. The state has classified salinity levels related to conservation zones, namely the 2018 Minister of Energy and Mineral Resources Regulation, as shown in Table 3.

Table 1 Users of water sources in Pacitan District (reprinted with permission from [7])

Water Source	Number of Households	Percentage
Well and Tap water	37	14.8
Tap water	4	1.6
River	6	2.4
Springs water	6	2.4
Shallow well	197	78.8

Table 2 Classification of salinity levels and types of water (reprinted with permission from [13])

Salinity (%)	Classification
< 0.05	Freshwater
0.05–3.00	Brackish water
3.00 –5.00	Saline water
> 5	Brine

Table 3 Classification of Groundwater Conservation Zones Based on Considerations of Deteriorating Groundwater Quality (reprinted with permission from [14])

Zone	Description
Safe	The increase in salinity is less than 1000 mg/l, or the electrical conductivity is less than 1000μS/cm.
Vulnerable	The increase in salinity between 1000-10.000 mg/l or electrical conductivity between 1000-1500 µ S/cm.
Critical	The increase in salinity between >10.000-15.000 mg/l or electrical conductivity between >1500-5000 µ S/cm
Damaged	The increase in salinity is more than 100.000 mg/l, or the electrical conductivity is more than 5000 μS/cm or contaminated by heavy metals and/or hazardous and toxic materials.

2. METHOD

This study uses a survey method with a quantitative descriptive approach. The data collected in the field was interpreted and analyzed to create a map of salinity distribution in the study area. The independent variable in this study is the distance of the well from the sea, while the dependent variable is the salinity level.

There are 75 groundwater sample points taken from community wells with a distribution of three sample points in each village (Figure 1). Samples were taken in the dry season of 2021. The well is ordered from nearest to farthest away from the shoreline. The distance of each sample from one another is adjusted to the land use conditions at the study site. Groundwater from the sample point was measured for salinity instantaneously using a hand refractometer. The classification of salinity levels was analyzed based on Goetz [13]. The classification of groundwater conservation zones follows the regulation of the Ministry of Energy and Mineral Resources (ESDM) No. 31 of 2018 [14]. The sample wells are calculated from the coast to determine the effect of distance from the sea on groundwater salinity.

3. RESULT AND DISCUSSIONS

Pacitan District is located in the southern part of Pacitan Regency, directly adjacent to the Indian Ocean. Pacitan sub-district is located between 8° 07' 35" – 8° 14' 30" South Latitude and 111° 04' 16" – 111° 9' 37" East Longitude. The location of the Pacitan District with the

UTM coordinate system is between 9096918 - 9088960 mU and 506865 -517680 mT.

3.1. Groundwater Salinity Level

Salinity is one of the chemical parameters that can affect water quality. It can be seen that the highest salinity value in the study area is 12,000 mg/L which is located in sample no.7 with a distance of 200 m from the beach, precisely in the southern part of Kembang village. Meanwhile, the lowest salinity with a value of <1000 mg/L is located at a distance of more than 2000 m from the shoreline, namely at all the well points in the villages of Sidoharjo, Sukoharjo, Kayen, Sirnoboyo, Arjowinangun, Baleharjo, Bangunsari, Sedeng, Sumberharjo, Pucangsewu, Pacitan, Tanjungsari, Menadi, Mentoro, Purworejo, Nanggungan, Widoro, Semanten, Banjarsari, Bolosingo, Sambong, Ponggok, and Tambakrejo. These villages are located far from the coastline, except for Sidoharjo Village. Sidoharjo Village is located in the southern part of the Pacitan District and adjacent to the coastline. Sidoharjo village in the southern part (sample point 1 in Figure 2) has a salinity level of 700 mg/L, and in the center (sample point 2) has a salinity level of 400 mg/L. In comparison, the northern part (sample point 3) has a salinity level of 0 mg/L (<1000 mg/L).

From Figure 1, it can be seen that the distance from the well to the beach affects groundwater salinity. The farther the well is from the beach, the lower the salinity value, and the closer the well is to the beach, the salinity value will increase (Figure 2).

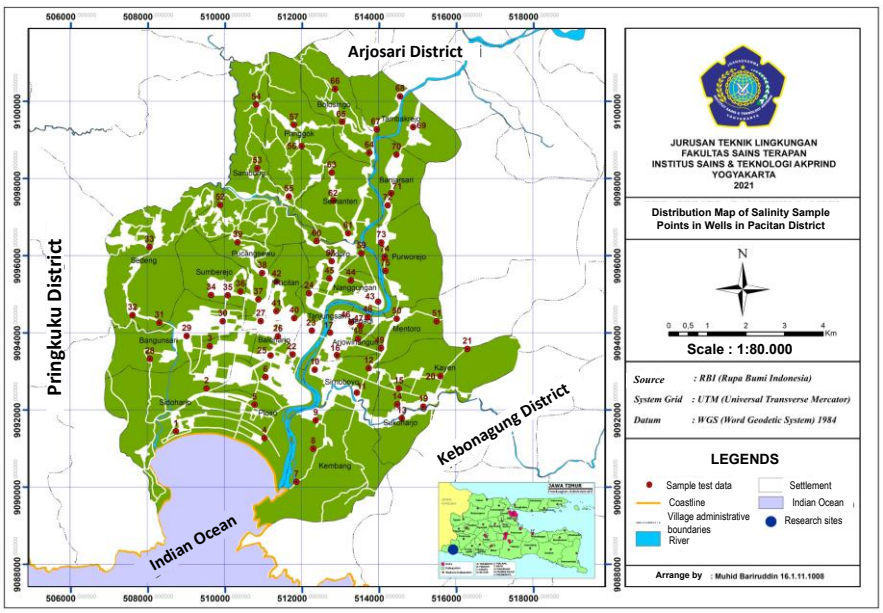

Figure 1 Sample point distribution (reprinted with permission)

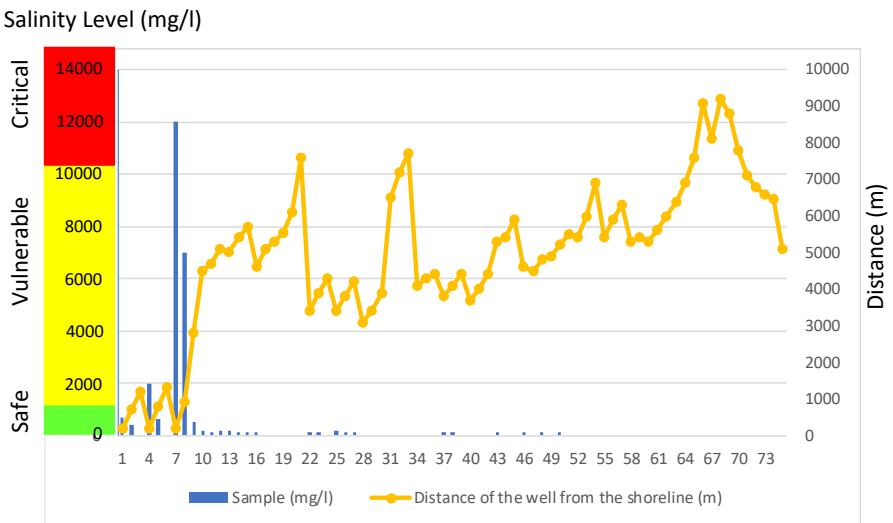

Figure 2 Relationship of salinity level and distance from the shoreline

Land use in coastal areas includes settlements, fish ponds, and rice fields. The population in the coastal area of Pacitan District is more than in the upstream or higher plains. This condition causes the population's activities in the area to increase, thus affecting groundwater quality. Most of the mangrove forest in the coastal area of Pacitan District has been lost due to human activities and changes in land use into shrimp ponds. The decreasing of the mangrove forest causes seawater to quickly go to the mainland because nothing is blocking the speed of seawater, either tides or sea waves. The presence of ponds that bring sea water well inland exacerbates this. Differences in the distribution of seawater intrusion can occur due to the presence of ponds. Pond land is the most dominant factor that causes differences in the extent of seawater intrusion. Pond land uses salt water to seep into the ground and pollute the surrounding groundwater [16-18]. The pond land makes groundwater salinity in the coastal area of Pacitan District high.

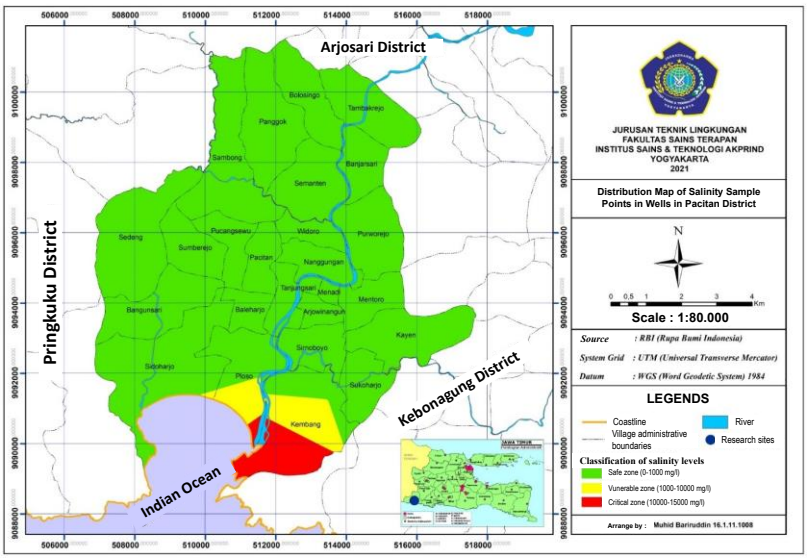

Figure 3 The distribution of salinity in Pacitan District

3.2. Distribution of Groundwater Salinity

Figure 3 shows a mathematical description of the salinity distribution in the Pacitan District. Sample points categorized as safe are depicted in green, vulnerable categories are displayed in yellow, and critical categories are represented in red.

The safe zone area with salinity values <1,000 mg/L of groundwater is found in 23 villages, namely Sidoharjo, Sukoharjo, Kayen, Sirnoboyo, Arjowinangun, Baleharjo, Bangunsari, Sedeng, Sumberharjo, Pucangsewu, Pacitan, Tanjungsari, Menadi, Mentoro, Purworejo, Nanggungan, Widoro, Semanten, Banjarsari, Bolosingo, Sambong, Ponggok, and Tambakrejo. The vulnerable zones (salinity >1,000-10,000 mg/L) are located in the southern part of Ploso Village with a salinity level of 2,000 mg/L and the central part of Kembang Village with a salinity level of 7,000 mg/L. The critical zone area (salinity >10,000-15,000 mg/L) is located in the southern part of Kembang village with 12,000 mg/L. Muchlis [19] stated that salinity levels are affected by the distance from the beach and the presence of ponds.

4. CONCLUSION

The salinity of well water in the research area ranges from 0 mg/L to 12,000 mg/L. In the safe, vulnerable, and critical categories, groundwater salinity levels in the Pacitan sub-district are 96 percent, 2.67 percent, and 1.33 percent, respectively. The distance from the shoreline and the use of pond land are the two most important aspects. Because pond land is made mainly of saltwater, it is pretty easy to seep into the earth.

REFERENCES

[1] N. Astriani, B. Rubiati, Y. Adharani, S.S. Afifah, R. Salsabila, and R. Diffa. "The Responsibility of the Indonesian Government to Fulfill the Rights to Water During the Covid-19 Pandemic: Some Legal Issues". *Environmental Policy and Law*. 51 (2021). 327-341. IOS Press. DOI: 10.3233/EPL-201044.

[2] A. Purwoarminta, N. Moosdorf, and R.M. Delinom. "Investigation of groundwater-seawater interactions: a review". Global Coloquium on GeoSciences and Engineering 2017. *IOP Conf. Series: Earth and Environmental Science*. 118 (2018) 012017. 1-4. DOI: 10.1088/1755-1315/118/1/012017.

[3] A.R. Costall, B.D. Harris, B. Teo, R. Schaa, F.M. Wagner and J.P. Pigois. "Groundwater throughflow and seawater intrusion in high quality coastal aquifers". *Scientific Reports*. (2020) 10:9866. 01-33. DOI: 10.1038/s41598-020-66516-6.

[4] A.W. Pramita, S. Syafrudin and D.N. Sugianto. "Effect of seawater intrusion on groundwater in the Demak coastal area Indonesia: a review". INCRID 2021. *IOP Conf. Series: Earth and Environmental Science.* 898 (2021) 012070. 1-9. DOI: 10.1088/1755-1315/896/1/012070.

[5] BPS Pacitan. "Kabupaten Pacitan Dalam Angka 2011". *Katalog BPS*: 1102001.35. (2012). Available at https://pacitankab.bps.go.id/publication/2012/10/12/0d0d58c28aced3ed110833ef/kabupaten-pacitan-dalam-angka-2011.html

[6] BPS Pacitan. "Kecamatan Pacitan Dalam Angka 2017". *Katalog BPS*: 1102001.3501040. (2017). Available at https://pacitankab.bps.go.id/publication/2017/09/21/ae14b74e3a91617a3e4ffa2a/kecamatan-pacitan-dalam-angka-2017.html

[7] Y. Wihertanti. "Analisis Penggunaan Air Untuk Kebutuhan Domestik di Kecamatan Pacitan". *Script*. Jurusan Pendidikan Ilmu Pengetahuan Sosial. UNS Surakarta. (2012). Available at https://digilib.uns.ac.id/dokumen/download/26994/NTcxNjU=/Analisis-Penggunaan-Air-Untuk-Kebutuhan-Domestik-Di-Kecamatan-Pacitan-Tahun-2012-abstrak.pdf.

[8] BPS Pacitan. "Kecamatan Pacitan Dalam Angka 2018". *Katalog BPS*: 1102001.3501040. (2018). Available at https://pacitankab.bps.go.id/publication/2018/09/26/b26b5842cc3ace727f59a04e/kecamatan-pacitan-dalam-angka-2018.

[9] J. Chen, H. Wu, H. Qian, and Q. Liu. "Analysis of evolvement for confined water cone of depression and its influence on groundwater resource sustainability in Yinchuan Area". *Advanced Materials Research*. 1073-1076 (201. 1656-1659. DOI: 10.4028/www.scientific.net/AMR.1073-1076.1659.

[10] H. Arslan and Y. Demir. "Impacts of seawater intrusion on soil salinity and alkalinity in Bafra Plain, Turkey". *Environ Monit Assess*. 185 (2013). 1027-1040. DOI: 10.1007/s10661-012-2611-3.

[11] M. Gises and R. Barthel. "Review: Saltwater intrusion on fractured crystalline bedrock". *Hysfrogeology Journal*. 29 (2021). 2313-232. DOI: 10.1007/s10040-021-02396-y.

[12] M. Shammi, Md. M. Rahman, S.E. Bondad and Md. Bodrud-Doza. "Impacts of salinity intrusion in community health: a review of experiences on drinking water sodium from coastal areas of Bangladesh". *Healthcare (Basel)*. 7 (1): 50 (2019). 01-19. DOI: 10.3390/healthcare7010050.

[13] P.W. Goetz. *The New Encyclopaedia Britannica*. 15th ed. 3. 937. Encyclopaedia Britannica Inc. Chicago.

[14] Ministry of ESDM. "Pedoman Penetapan Zona Konservasi Air Tanah". Permen ESDM Nomor 31 Tahun 2018. Jakarta. (2018) Available at https://jdih.esdm.go.id/peraturan/Permen%20ESDM%20Nomor%2031%20Tahun%202018.pdf

[15] BPS Pacitan. "Kecamatan Pacitan Dalam Angka 2021". *Katalog BPS*: 1102001.3501040. (2021). Available at https://pacitankab.bps.go.id/publication/2021/09/24/bf64df8930c524591a0d4f96/kecamatan-pacitan-dalam-angka-2021.html

[16] P. Prusty and S.H. Farooq. "Seawater intrusion in the coastal aquifers of India – a review". HydroResearch. 3 (2020). 61-74. DOI: 10.1016/j.hydres.2020.06.001.

[17] E. Hilmi, C. Kusmana, E. Suhendang and Iskandar. "Correlation analysis between seawater intrusion and mangrove greenbelt". Indonesian Journal of Forestry Research. 4 (2) (2017). 151-168. DOI: 10.20886/ijfr.2017.4.2.151-168.

[18] N. Alfarrah and K. Walraevens. "Groundwater overexploitation and seawater intrusion in coastal areas of arid and semi-arid regions". Water. 10 (143) (2018). 01-24. DOI: 10.3390/w10020143.

[19] Muchlis, P.D. Sukmawati, A.N. Rakhman and T.B. Antoni. "Persebaran salinitas air tanah di kecamatan dukuhseti kabupaten Pati". Jurnal Teknologi. 14 (1) 2021. 83-90. DOI: 10.3415/jurtek.v14i1.1384.