Journal Home Page:
https://e-journal.unair.ac.id/JKL

Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Vol. 17 No. 4
DOI: 10.20473/jkl.v17i4.2025.351-360
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X

ORIGINAL RESEARCH Open Access

ANALYSIS OF THE QUALITY CLEAN WATER SOURCES THROUGH GEOGRAPHIC INFORMATION SYSTEM MAPPING AND GEOELECTRIC METHODS IN FLOOD-PRONE AREAS

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Article Info

Submitted	: 22 January 2024
In reviewed	: 11 August 2025
Accepted	: 12 September 2025
Available Online	: 31 October 2025

Keywords : *Flood-prone Areas, Geoelectrical, Geographic Information System, Quality Clean Water Sources*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *Astambul Subdistrict in Banjar Regency is classified as a flood-prone area. Such regions tend to experience a decline in clean water quality. In Astambul, no mapping has been conducted regarding clean water quality based on water management and land conditions to improve clean water quality in flood-prone areas. This study aims to analyze the availability of clean water sources in flood-prone areas using geoelectrical methods and Geographic Information Systems (GIS).* ***Methods:*** *This study used a quantitative research design with a cross-sectional method to analyze clean water sources using geoelectric and Geographic Information System (GIS) methods. This study was conducted in five villages in Banjar Regency, South Kalimantan Province. Testing using the geoelectrical method was conducted at five locations in five villages, while the GIS method was used at 30 locations across the five villages.* ***Results and Discussion:*** *The geoelectric method showed that 4 villages had turbid water quality, and 1 village had very turbid water. The GIS (Geographic Information System) method indicated that the parameters for turbidity, iron (Fe), manganese (Mn), and coliforms did not meet the standards. The average values of Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and turbidity are 8.03 mg/L, 179.27 mg/L, 0.22 mg/L, and 17.23 NTU, respectively. The average values for pH, iron (Fe), and manganese (Mn) are 6.44, 0.68 mg/L, and 21.02 mg/L, respectively.* ***Conclusion:*** *Based on Geoelectric and Geographic Information System analysis, the Astambul District area has clean water sources that are still below quality standards.*

INTRODUCTION

The use of clean water that meets standards is essential for maintaining public health. The health impacts of using substandard water include diarrhea, cholera, typhoid, or dysentery. Communities that use clean water have a lower risk of experiencing diarrhea (1). Other potential health disorders include nervous system disturbances, developmental problems in children, and an increased risk of chronic diseases. These disorders arise due to the use of water contaminated with heavy metals, which are typically toxic and tend to accumulate in the kidneys (2-4).

Cite this as :
Marlinae L, Biyatmoko D, Husaini, Irawan C, Arifin S, Saidi AR, et al. Analysis of the Quality Clean Water Sources Through Geographic Information System Mapping and Geoelectric Methods in Flood-Prone Areas. *Jurnal Kesehatan Lingkungan*. 2025;17(4):351-360. https://doi.org/10.20473/jkl.v17i4.2025.351-360

Diarrhea is a health issue that has become a focus of the Ministry of Health of the Republic of Indonesia. According to the 2023 Indonesia Health Survey (SKI), there were 877,531 cases of diarrhea across all age groups (5). In South Kalimantan Province, there were 13,299 reported cases of diarrhea (5). Diarrhea cases are more common in flood-prone areas (6). Flood-prone areas are closely associated with an increase in diarrhea cases, mainly due to disruptions in access to clean water (7). Sources of clean water, such as wells or distribution pipes, are often contaminated by wastewater, feces, and garbage (8). This condition makes it difficult for the community to obtain water that is suitable for drinking, cooking, and maintaining personal hygiene. The limited access to clean water increases the risk of consuming food and beverages contaminated with bacteria that cause diarrhea. Monitoring the quality of drinking water is essential in flood-prone areas.

According to the health profile data from the Banjar District Health Office, in 2022, 22 out of 24 subdistricts (92%) were still below the clean water quality target, and 17 subdistricts (71%) were under drinking water quality monitoring (9). Astambul Sub-district is one of the areas still below the clean water quality target. Based on the 2023 household drinking water quality surveillance using the Sanitarian Kit at the Astambul Public Health Center, the results showed that Kaliukan Village had a color level of 170, iron (Fe) concentration of 1.26 mg/L, manganese (Mn) concentration of 1.24 mg/L, and coliform count of 101 CFU/100 ml. In Sungai Alat Village, the pH was 6.1, Fe was 0.15 mg/L, Mn was 0.25 mg/L, with E. coli and coliform counts both at 101 CFU/100 ml. Meanwhile, Kelampaian Ulu Village had a coliform count of 101 CFU/100 ml. This is in line with a 2020 study by the Environmental Agency, which found that eight parameters exceeded the permitted threshold values. These included MPN coliforms at 35,000/100 ml of water (standard: 100/100 ml), TSS at 846 mg/L (standard: 50 mg/L), BOD at 398 mg/L (standard: 3 mg/L), COD at 189.3 mg/L (standard: 25 mg/L), DO at 6 mg/L (standard: 4 mg/L), and pH ranging from 6 to 7 (standard: 6–9). Data from 2021 showed the following values: turbidity at 57.55 NTU, TDS at 343.3 mg/L, pH at 6.69, and dissolved oxygen at 15.13 mg/L (11).

This is in line with a 2020 study by the Department of Environmental, which found that eight parameters exceeded the permitted threshold values. These included MPN coliforms at 35,000/100 ml of water (standard: 100/100 ml), TSS at 846 mg/L (standard: 50 mg/L), BOD at 398 mg/L (standard: 3 mg/L), COD at 189.3 mg/L (standard: 25 mg/L), DO at 6 mg/L (standard: 4 mg/L), and pH ranging from 6 to 7 (standard: 6–9). Data from 2021 showed the following values: turbidity at 57.55 NTU, TDS at 343.3 mg/L, pH at 6.69, and dissolved oxygen at 15.13 mg/L (12).

In general, the soil in Astambul Subdistrict has a granular structure, with varying consistency ranging from sticky, slightly sticky, to non-sticky. The soil colors include reddish yellow, gray pinkish, and brown, with plasticity ranging from plastic, slightly plastic, to non-plastic. About 77.62% of the soil has a fine texture, including clay, loamy, sandy, and silty soils. Medium-textured soil accounts for 14.93%, consisting of loam, silty, and sandy clay soils, while the remaining 5.39% is coarse-textured soil, such as loamy sand and silty sand (13).

Based on data reviews from the Department of Health, the Department of Environmental, and the Department of Public Works and Spatial Planning (PUPRP), no mapping has been conducted regarding clean water quality in relation to water management and land conditions to improve clean water quality in flood-prone areas. The available data only provide separate information on water quality without integrating it with land conditions (14). Based on the urgency of this issue, the researcher conducted a study to analyze the availability of clean water sources in flood-prone areas using the geoelectric method and Geographic Information System (GIS) in Astambul Subdistrict, Banjar Regency.

METHODS

This study used a quantitative research design with a cross-sectional method to analyze clean water sources using the geoelectric method and Geographic Information System (GIS). The research was conducted in Astambul Subdistrict, specifically in Sei Alat Village, Kaliukan Village, Lok Gabang Village, Kelampaian Ulu Village, and Kelampaian Tengah Village, Banjar Regency, South Kalimantan Province. The research samples consisted of water and soil from Astambul District, homogenized using purposive sampling. Sampling was carried out based on the requirement that the samples were taken from areas that are frequently flooded and from water sources that do not meet the quality standards. Testing using the geoelectrical method was conducted at five locations in five villages, while the GIS method was used at 30 locations across the five villages. Samples were collected using the proportional random sampling method, namely.

$$\frac{\text{Number of Wells}}{\text{Population Size}} \times 30$$

The inclusion criteria for the study were areas with clean water shortages and annual cases of diarrhea. The independent variables included depth, discharge, and the potential of water sources. The dependent variable was the mapping of clean water sources using the geoelectric and GIS methods. Data were analyzed descriptively to obtain the frequency distribution of each variable separately.

The geoelectric measurements using the resistivity method were conducted with a Resistivitimeter, brand OYO McOHM 2119EL made in Japan, using the Schlumberger configuration at five (5) measurement points. SIG measurements were carried out using physical, chemical, and biological parameters. Water sample measurements for physical parameters were performed using a thermometer (temperature), turbidimeter (turbidity), oxygen meter (DO), TDS meter (TDS), and TSS meter (TSS). Turbidity measurement referred to SNI 06-6989.25-2005. pH testing was conducted using a pH meter and litmus paper, with the examination method referring to SNI 06-6989.11-2004. Fe and Mn examinations were conducted using a UV Spectrophotometer Vest 2008. Biological parameter measurements were performed using Brilliant Green Lactose Broth (BGLB)

The sample examinations in this study were conducted at the soil quality laboratory and the water quality laboratory, both of which are standardized and equipped with the necessary instruments and materials that comply with established standards. The feasibility of sample collection in the laboratory was carried out in accordance with the prescribed standards. The quality standard used in the laboratory refers to the Regulation of the Minister of Health of the Republic of Indonesia (Permenkes RI) Number 2 of 2023 concerning Environmental Health Quality Standards and Health Requirements for Water, Air, Soil, Food, Facilities and Buildings, Vectors, and Disease-Carrying Animals.

RESULTS

Availability of Clean Water Sources in Terms of Quality and Quantity Using Geoelectric Prediction

The geoelectric measurements using the resistivity method were conducted with a Resistivitimeter, brand OYO McOHM 2119EL made in Japan, using the Schlumberger configuration at five (5) measurement points. The coordinates of the measurement locations are presented in Table 1.

Table 1. Coordinates of the Sampling Location

Location	Coordinates
GL-1 (Sungai Alat Village)	- 03° 22' 34.66" and 114° 53' 38.63"
GL-2 (Kaliukan Village)	- 03° 21' 39.34" and 114° 49' 45.62"
GL-3 (Lok Gabang Village)	- 03° 21' 18.31" and 114° 53' 17.46"
GL-4 (Limamar Village)	- 03° 21' 04.91" and 114° 52' 30.14"
GL-5 (Kelampaian Village)	- 03° 21' 33.62" and 114° 52' 08.06"

Based on the interpretation results of the geoelectric survey assisted by computer analysis and correlated with local geological and hydrogeological data, the resistivity logs at each survey point were obtained as shown in Table 2.

Table 2. Results of Geoelectrical Measurements

Survey Point	Layer	Interpretation Result			Estimated Lithology	Rock Behavior Toward Groundwater	Water Quality
		Depth (m)	Thickness (m)	Resistivity (Ωm)			
GL1 Sei Alat	1	0.0 – 0.72	0.72	81.54	Topsoil	Wet	Turbid
	2	0.72 – 13.91	13.19	14.24	Sandy Clay	Poor Aquifer	
	3	13.91 – 25.53	11.62	54.12	Sand	Aquifer	
	4	25.53 – 68.75	43.22	3.00	Clay	Aquitard	
	5	68.75 –- ∞	∞	122.03	Sand	Aquifer	
GL2 Kaliukan	1	0.0 – 1.09	1.09	48.23	Topsoil	Wet	Turbid
	2	1.09 – 15.95	14.86	8.62	Sandy Clay	Aquitard	
	3	15.95 – 29.49	13.54	40.69	Sand	Aquifer	
	4	29.49 – 73.99	44.50	2.91	Clay	Aquitard	
	5	73.99 –- ∞	∞	133.53	Sand	Aquifer	
GL3 Lok Gabang	1	0.0 – 0.54	0.54	35.61	Topsoil	Wet	Highly turbid
	2	0.54 – 3.60	3.06	6.24	Sandy Clay	Aquitard	
	3	3.60 – 9.50	5.90	16.12	Sand	Poor Aquifer	
	4	9.50 – 77.73	68.23	6.81	Clay	Aquitard	
	5	77.73 –- ∞	∞	44.74	Sand	Aquifer	
GL4 Kelampain Ulu	1	0.0 – 0.33	0.33	51.26	Topsoil	Wet	Turbid
	2	0.33 – 4.56	42.3	7.70	Sandy Clay	Aquitard	
	3	4.56 – 15.49	10.93	21.78	Sand	Poor Aquifer	
	4	15.49 – 72.41	56.92	6.12	Clay	Aquitard	
	5	72.41 –- ∞	∞	89.58	Sand	Aquifer	

Survey Point	Layer	Interpretation Result			Estimated Lithology	Rock Behavior Toward Groundwater	Water Quality
		Depth (m)	Thickness (m)	Resistivity (Ωm)			
GL5 Kelampain Tengah	1	0.0 – 0,33	0.33	51.26	Topsoil	Wet	Turbid
	2	0.33 – 4,56	42.3	7.70	Sandy Clay	Aquitard	
	3	4.56 – 15,49	10.93	21.78	Sand	Poor Aquifer	
	4	15.49 – 72.41	56.92	6.12	Clay	Aquitard	
	5	72.41 –- ∞	∞	89.58	Sand	Aquifer	

The resistivity values at the investigation site can be classified into several groups. A resistivity of 0.33–1.21 Ωm in the upper layer at a depth of 0.0–2.0 meters is interpreted as wet topsoil and rock. A resistivity of <10 Ωm is interpreted as impermeable clay (aquitard). A resistivity of 10–30 Ωm is interpreted as sandy clay with poor water permeability (poor aquifer). A resistivity of 30–150 Ωm is interpreted as sand with moderate water permeability (moderate aquifer). A resistivity of 150–300 Ωm is interpreted as sand with good water permeability (good aquifer).

Clean Water Quality Map Based on Physical Parameters

The Dissolved Oxygen (DO) test on water samples in Astambul Subdistrict showed an average value of 8.03 mg/L, which meets the standard for water used in sanitation. However, there were 9 sampling points with DO levels below the standard of 4 mg/L, spread across 5 villages (Figure 1). The DO levels were consistent with the low levels of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in the waters of Astambul Subdistrict. When DO levels meet the standard, TDS and TSS levels are also within the standard range and remain low.

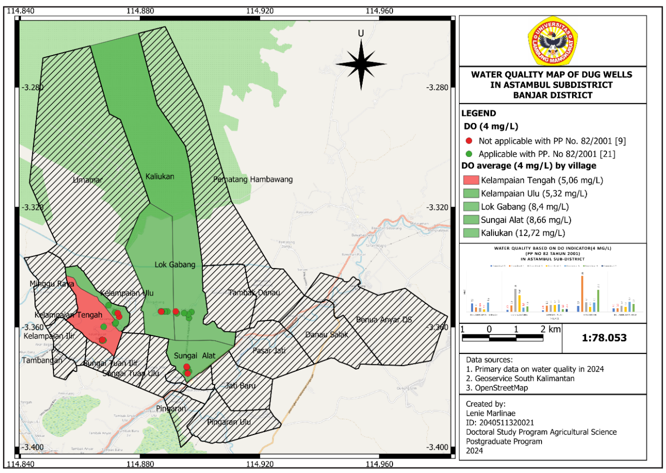

Figure 1. Water Quality Map Based on DO Indicator

The average value of Total Dissolved Solids (TDS) obtained was 179.27 mg/L. This average meets the water quality requirements for hygiene and sanitation purposes, as stated in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023, which sets the standard at <300 mg/L (Figure 2). However, there was one point in Kaliukan Village that exceeded the maximum limit, with a TDS value of 339 mg/L.

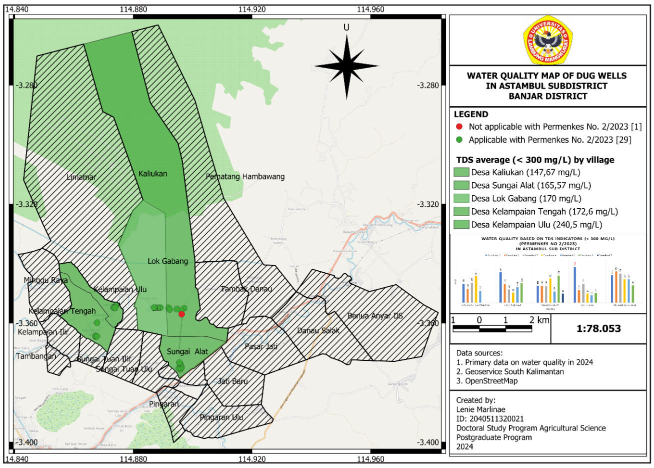

Figure 2. Water Quality Map Based on TDS Indicator

The average value of Total Suspended Solids (TSS) obtained was 0.22 mg/L. This value meets the environmental quality standards based on the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023, which sets the maximum limit for TSS at 50 mg/L. Based on the test results, no sampling points exceeded the maximum limit.

The turbidity test results showed an average value of 17.23 NTU (Figure 4). This value is above the maximum threshold for water used for hygiene and sanitation purposes, indicating that in terms of turbidity, it does not meet the required standard. A total of 29 points (97%) had high turbidity levels, exceeding 3 NTU, and therefore did not meet the eligibility criteria for hygiene and sanitation water as stated in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023.

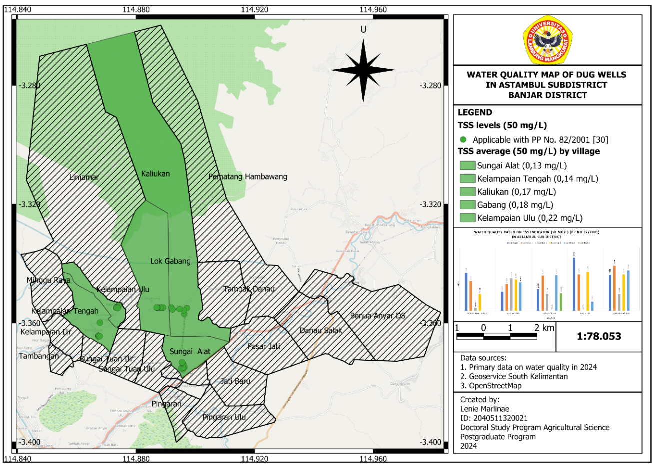

Figure 3. Water Quality Map Based on TSS Indicator

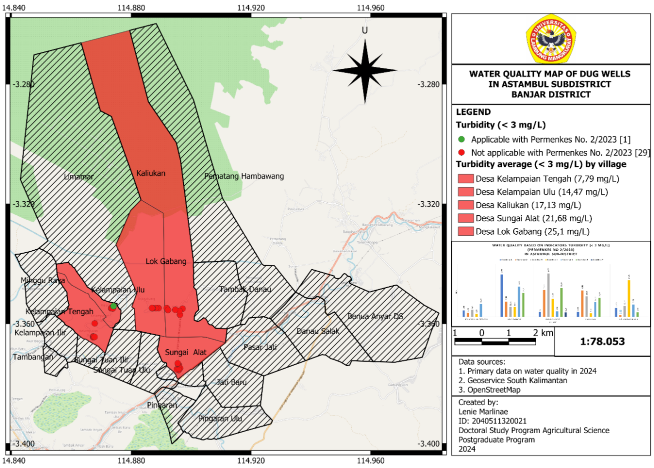

Figure 4. Water Quality Map Based on Turbidity Indicator

Clean Water Quality Map Based on Chemical Parameters

The acidity level or pH test results from 30 sampling points across Astambul Subdistrict showed an average of 6.44 mg/L, indicating that most water sources in the area are acidic (Figure 5). This value is below the standard for water used for hygiene and sanitation purposes. There were 8 points (27%) that met the standard, while 22 points (73%) did not.

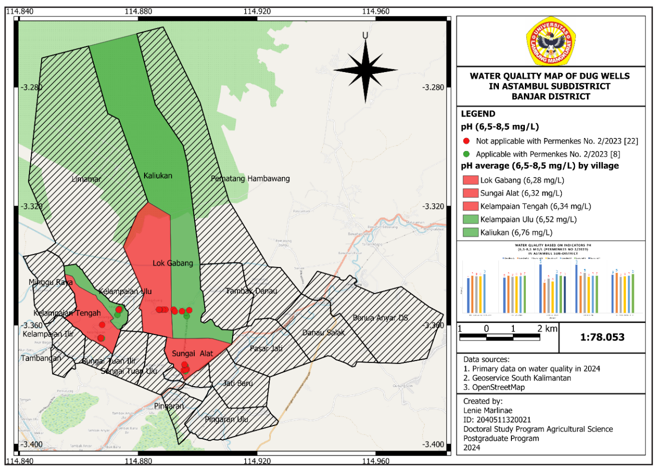

Figure 5. Water Quality Map Based on pH Indicator

The iron (Fe) content in water samples from 30 points in Astambul Subdistrict showed an average of 0.68 mg/L (Figure 6). This value exceeds the maximum allowable limit for water used for hygiene and sanitation, which is 0.2 mg/L. However, one point (3%) had an iron content that met the standard.

The test results for manganese (Mn) content in water samples showed an average of 21.02 mg/L (Figure 7). All 30 points had manganese levels exceeding the maximum allowable limit for hygiene and sanitation water use, which is 0.1 mg/L. No points met the standard for manganese content.

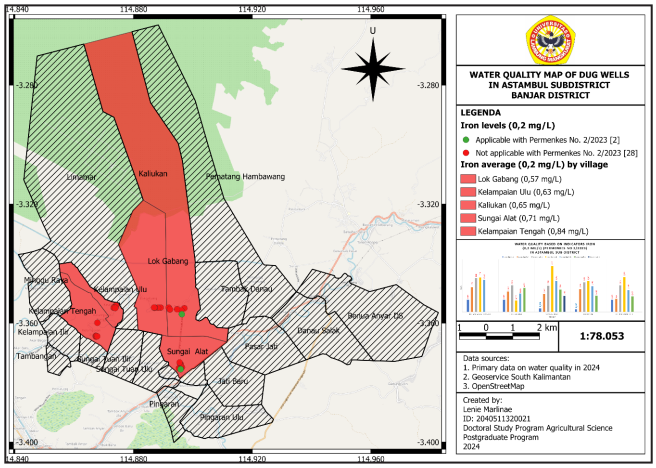

Figure 6. Water Quality Map Based on Iron (Fe) Indicator

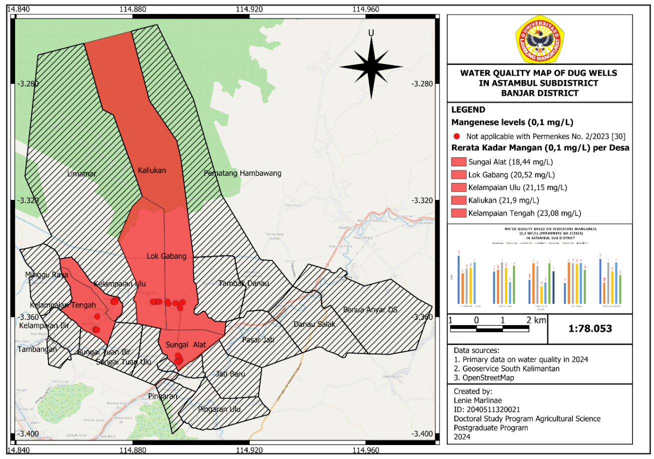

Figure 7. Water Quality Map Based on Manganese (Mn) Indicator

Clean Water Quality Map Based on Biological Parameters

The results of water sample testing for coliform levels per 100 ml from all sampling points showed an average of 1,494.4 CFU/100 ml (Figure 7). This exceeds the maximum allowable limit for water used for hygiene and sanitation purposes, which is 0 CFU/100 ml. If drinking water contains total coliforms above the maximum threshold, the water is considered unsafe and unsuitable for consumption.

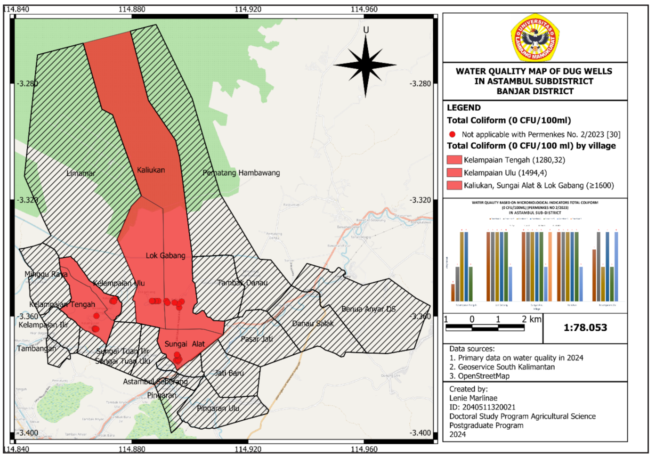

Figure 8. Water Quality Map Based on Coliform Indicator

DISCUSSION

Availability of Clean Water Sources Using Geoelectric Prediction

At the GL-1 measurement location, it is recommended to drill into the sand layer at a depth of >70 meters. The targeted lithological layer is sand with a resistivity of 122.03 Ωm, which indicates a good aquifer in terms of quantity and water permeability; however, the groundwater quality appears turbid. At the GL-2 location, drilling is recommended at a depth of >75 meters in a sand layer with a resistivity of 133.53 Ωm, which also represents a good aquifer in terms of quantity and permeability, though the groundwater quality appears turbid. At the GL-3 location, drilling is advised at a depth of >80 meters in a sand layer with a resistivity of 44.74 Ωm, which indicates a poor aquifer in terms of quantity and permeability; the groundwater quality appears very turbid.

At the GL-4 location, drilling is recommended at a depth of >75 meters in a sand layer with a resistivity of 86.60 Ωm, which suggests a good aquifer in terms of quantity and permeability, but the groundwater quality appears turbid. At the GL-5 location, it is also recommended to drill at a depth of >75 meters into a sand layer with a resistivity of 89.58 Ωm, indicating a good aquifer in terms of quantity and permeability; however, the groundwater quality remains turbid

Clean Water Quality Based on Physical Parameters

The concentration of dissolved oxygen (DO) in water can be influenced by several factors, such as TSS content, sanitation, photosynthesis rate, and atmospheric pressure. DO levels in water are inversely proportional to temperature and altitude, but directly proportional to atmospheric pressure and pH (15). As dissolved oxygen levels decrease, pressure also decreases; and as temperature and altitude increase, DO levels tend to decline (16). Dissolved oxygen (DO) is the amount of oxygen present in water, originating from photosynthesis and atmospheric or air movement.

The main source of TDS in water bodies is runoff from agriculture, domestic waste, and industry. The most common chemical elements are calcium, phosphate, nitrate, sodium, potassium, and chloride (17-18). These chemicals may appear as cations, anions, molecules, or agglomerations of thousands of molecules. Harmful TDS includes pesticides originating from surface runoff. Pesticides can cause various health disorders, such as cancer (19-20). Some natural total dissolved solids originate from the weathering and dissolution of rocks and soil (21). An increase in dissolved solids can directly kill fish, increase disease, reduce fish growth rates, cause behavioral changes, and reduce reproduction (22). In addition, the quantity of natural fish food will also decrease. For humans, this results in a reduced source of food from the sea.

Total Suspended Solids (TSS) are solids contained in water that are not dissolved. These are distinguished from dissolved solids through laboratory filtration tests. The unit is mg/l. TSS consists of settleable, floating, and non-soluble (colloidal suspension) components (23). TSS generally contains organic and inorganic compounds (24). TSS has a direct relationship with turbidity: the higher the TSS, the higher the turbidity, so the water appears more turbid (25). This relationship is well known and can be used to estimate TSS from turbidity measurements.

Water quality testing in Astambul Subdistrict shows that the water sources in the area are not experiencing significant pollution, either naturally or due to human activities. This is because the TDS levels found are far below the maximum threshold. This condition occurs because there are no visible industrial activities near the sampling locations that discharge waste into the waters. Several samples were also taken from residents' wells, which are more protected from waste contamination. Although many of the sampling locations are in agricultural areas, it is likely that the farmers still use natural materials to fertilize their crops without using chemical fertilizers.

Turbidity values indicate that river water is not suitable for consumption. The turbidity of river water is caused by the large amount of material suspended in the river water, such as soil, mud, and other organic materials. Suspended sediment from the land is carried by surface runoff during rainfall (26). Turbidity reflects the lack of clarity in the waters due to the presence of colloidal and suspended materials such as mud, organic and inorganic substances, and aquatic microorganisms.

Turbidity is directly proportional to rainfall (27). The maximum standard for turbidity in water used for hygiene and sanitation according to Permenkes RI No. 2 of 2023 is <3 NTU.

The average turbidity level is still below the maximum threshold. Water from sampling points is still quite clear, especially those taken from residents' wells. Since well water is not moving or flowing, the materials in it can settle. The bottoms of the waters are dominated by mud, which settles more easily. The low turbidity level in Astambul Subdistrict is related to the low TDS level as well. Water turbidity can be reduced by adsorption and by minimizing movement, allowing sedimentation to occur more easily.

Clean Water Quality Based on Chemical Parameters

The pH value is an important factor in water bodies, as it determines whether water is acidic or alkaline. pH affects biological life in water and its quality (28-29). pH is the degree of acidity or alkalinity of a solution. According to the Indonesian Ministry of Health Regulation No. 2 of 2023, the standard pH for water used for hygiene and sanitation is between 6.5 and 8.5.

The pH level is influenced by fluctuations in oxygen and carbon dioxide content (30). Not all living organisms can survive sudden pH changes, so nature has a unique mechanism to maintain balance or allow slow changes. A pH level below 4.8 or above 9.2 is considered polluted. High CO_2 concentrations in water also alter water quality parameters, particularly pH and the carbonate system (31). Water acidification disturbs aquatic life, especially organisms that depend on calcification during their life cycle.

The average pH of water sources in Astambul Subdistrict is low. Although the pH values are not yet categorized as polluted, they still need attention since the water is also used for drinking. This could affect public health, and the taste of the water becomes unpleasant. Fish would also struggle to survive, leading to a decrease in food supply.

Handling or adjusting the pH value will be more effective if alkalinity is managed first. A decrease in pH may be caused by acid rain, high CO_2 content, and acidic substances. Fungi thrive in low pH (acidic) environments. To lower pH, the hardness must be measured first. If it is too high (12 or more), it needs to be reduced, which usually will automatically lower the pH. However, if the pH is too high (above 8) while hardness is within a good range (6–12), it indicates a poor equilibrium process.

High levels of iron (Fe) affect the color of groundwater. Samples with the highest Fe content are brownish, while those with lower Fe appear yellowish. Generally, rainwater that infiltrates FeO-rich soil reacts with H_2O and CO_2 in the soil to form $Fe(HCO_3)_2$. The deeper the water infiltrates, the higher the Fe solubility.

Heavy metal Fe is toxic not only to plants but also to animals and humans. It is difficult to degrade, accumulates in aquatic environments, and is hard to eliminate naturally. It can accumulate in aquatic biota, including shellfish, fish, and sediments. It has a long half-life in marine organisms and a high bio-concentration factor (32-33). The presence of Fe can also reduce DO levels. This is likely because dissolved oxygen is used by bacteria to oxidize contaminants in the water.

The Fe content in Astambul's water sources is still considered normal. It has not exceeded the maximum threshold. The low Fe concentration is indicated by the high DO levels, showing that oxygen is not heavily consumed for Fe decomposition and oxidation. However, the pH remains low or acidic. Low pH can affect Fe solubility, causing corrosion of Fe and other metals in water. In acidic conditions, Fe appears as Fe^{2+} (ferrous) and Fe^{3+} (ferric); ferric forms precipitate and are not visible, making water colored, smelly, and unpleasant (31-32).

Water samples from Astambul Subdistrict show very high manganese (Mn) levels, exceeding the maximum permissible limit. This poses a serious health risk, especially since the water is used for drinking. Many local residents are toddlers or elementary school children, making the health impact even more severe for their future.

Water with high Mn content causes taste, odor, color (brown/purple/black), and turbidity issues (36). Mn toxicity is noticeable even at low concentrations. The maximum allowed Mn level for hygiene and sanitation water is 0.5 mg/L according to Permenkes RI No. 2 of 2023. Water from acid mine drainage may contain up to ±1 mg/L Mn. At higher pH and in aerobic conditions, insoluble forms like MnO_2, Mn_3O_4, or $MnCO_3$ may form, although Mn^{2+} oxidation occurs relatively slowly.

Clean Water Quality Based on Biological Parameters

Total coliform levels in Astambul are very high. This is because rivers there are still used as open defecation sites by locals. Such activity significantly increases the presence of bacteria in water bodies (37). Rivers are still used by residents for daily needs, from bathing to drinking. Bacteria are more likely transmitted via water than air (38).

The allowed coliform content in drinking water is very low (50 CFU/100 ml). If the total coliform content exceeds this threshold, the water is unsafe to consume.

Contaminated drinking water poses serious health risks, especially to vulnerable groups such as children, the immunocompromised, and the elderly. One major health impact is waterborne disease, with diarrhea being one of the most common illnesses related to unsafe drinking water (39).

Total coliform refers to a group of bacteria that includes aerobic and facultative anaerobic gram-negative bacteria. Most are heterotrophic and can grow in water and soil. They may also multiply in water distribution systems under favorable conditions. Total coliform may originate from human or animal feces, or occur naturally in water. Coliforms are indicators used to suggest the possible presence of other pathogenic microbes, such as Giardia, Cryptosporidium, E. coli, etc. (40). Based on Permenkes RI No. 32 of 2017, the maximum allowable total coliform for water used in hygiene and sanitation is 0 CFU/100 ml.

ACKNOWLEDGMENTS

The author would like to thank the research respondents who permitted water and soil samples to be taken in 5 villages in Astambul District, Banjar Regency.

CONCLUSION

Based on Geoelectric and Geographic Information System analysis, the Astambul District area has clean water sources that are still below quality standards. As a flood-prone area, more in-depth interventions are needed to maintain the availability of clean water sources.

AUTHORS' CONTRIBUTION

LN, DB, and H: Conceptualization, Methodology, Software. CI and SA: Data curation, Writing- Original draft preparation. ARS and AF: Visualization, Investigation. BBA and TZ: Software, Validation. MR and AUA: Writing- Reviewing and Editing.

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