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Research article

Phreatic Groundwater Quality Analysis Based on Physical and Chemical Parameters in Kuta Raja Sub-District

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Abstract

Phreatic groundwater, discovered easily around communities in the Kuta Raja Sub-district, is sourced from the subsurface and stored in saturated areas, where it flows naturally through seepage or jets. Therefore, this study aimed to analyse the quality of phreatic groundwater using physical and chemical parameters. Color, taste, smell, and temperature were the physical parameters analysed, while chemical parameters tested included electrical conductivity value, acidity (pH), and hardness level. A total of 50 samples were obtained using a random sampling method for the experiment. Physical parameters were evaluated using the observational method. Test for groundwater hardness level was conducted at the Aceh Health Office's Health & Medical Equipment Testing Laboratory. The pH was measured using a pH meter, while electrical conductivity value and phreatic groundwater temperature were tested using a water quality checker. The results showed that the physical quality of groundwater was in good condition. Approximately 64% of the samples had characteristics of yellow, tasteless, and odourless. The temperature value was in the medium category (30°C-35°C). Additionally, the electrical conductivity value of 84% was in the medium class (1,200–2,500) brackish groundwater category. It was important to acknowledge that a groundwater pH value of 6.5–8.5 based on field measurements was in the normal class. The hardness level ($CaCO_3$) of phreatic groundwater was evaluated using the Titrimetric method based on SNI Number 06-6989.12-2004. The test was conducted on six groundwater samples in terms of water flow and variations in electrical conductivity values. Based on observations, four samples were categorised as "hard" samples, while 2 were classified as "very hard".

Keywords: Phreatic groundwater; Physical parameters; Chemical parameters; Hardness; Kuta Raja Sub-district.

1. Introduction

Climate change is a phenomenon that has increasingly impacted various aspects of life. Furthermore, it has a detrimental effect on the quality of water (Kurwadkar, S *et al.*, 2020). According to explanations from numerous studies, environmental changes and human activities have significant impacts on natural resources. Water resources play a crucial role in life but are easily overlooked due to the complex components and long evolution time of water quality (Sruthy Sajeev *et al.*, 2023).

Approximately 97% of the water on earth is saltwater, with only 3% being freshwater. Among the 3%, a mere 0.01% is accessible for human consumption. A total of 99% of freshwater available and suitable for use are sourced from underground aquifers, making groundwater a primary reservoir (Qureshi *et al.*, 2021). Phreatic groundwater is a term used to refer to the amount of water below the earth's surface that can be collected through wells, tunnels, or drainage systems. It can also be referred to as streams that naturally flow to the ground surface through emission or seepage. Natural and anthropogenic factors influence the quality. The natural factors include geology, topography, and climate.

Meanwhile, the anthropogenic factors are agricultural chemical runoff and household waste disposal (Ghimire *et al.*, 2023). Several categories of groundwater contamination vulnerability include permeability, thickness of the unsaturated zone through which water passes, soil conditions, human activities, distance between potential pollutant sources, and environmental vulnerability (Agyemang, 2022). The characteristics and quality are based on topography, climate, and vegetation. Topography and geology reflect landforms and the ability of groundwater to infiltrate, percolate, and absorb water, thereby affecting the characteristics.

Several conditions determine the suitability of groundwater for consumption. The quality criteria should meet physical, chemical, and biological standards outlined in the PERMENKES Number 492/MENKES/PER/IV/2010. Physical parameters include odour, colour, turbidity, taste, temperature, and total dissolved solids (TDS). Meanwhile, chemical parameters are hardness, acidity (pH), and freedom from toxic substances. Biological quality implies freedom from disease-causing microorganisms (Herdini *et al.*, 2023). It is important to acknowledge that human activities such as agriculture, household actions, and industrial processes can lead to pollution and deterioration of the physical, chemical, and biological attributes of groundwater (Kiran *et al.*, 2023).

Groundwater conditions reflect a combination of physical, biological, and chemical attributes influenced by natural sources and human activities. Physical properties comprise flow patterns, volume, velocity, and direction of groundwater flow at a given location. Biological contaminants include bacteria, viruses, protozoa, and other pathogens. Groundwater contains chemicals from human activities or due to natural occurrence. Water can appear good, but should not be immediately considered usable. This is because water is an excellent solvent and can contain many dissolved. The movement of groundwater through rocks and soils below the surface leads to the dissolution of physical substances in the surroundings. Therefore, groundwater often has more solutes than surface water. Despite soil being an excellent medium for filtering particulate matter, such as leaves, soil, and insects, dissolved chemicals and gases can still be dissolved in appreciable concentrations, which can cause problems. Some sources of chemical contaminants include industry, domestic, and agricultural waste products. Pollution occurs when contaminants enter the groundwater system, making it unsafe for human use and potentially endangering the environment (Ringle Raja *et al.*, 2023).

Based on historical records, Gampong Pande in Kuta Raja Sub-district, Banda Aceh City, was a centre for craftsmen of metal objects and tombstones with typical Acehnese carvings for sultanate and trade purposes (Balai Pelestarian Cagar Budaya Aceh, 2023). Furthermore, Gampong Jawa is a landfill area and a place for the final stage of waste management. The landfill activities are suspected of causing environmental pollution impacts such as polluting water and soil (Astry Axmalia & Surahma Asti Mulasari, 2021). This occurs due to the leakage of leachate originating from waste (Chai *et al.*, 2024). The conditions can lead to changes in pH and an increase in soil temperature. It is important to acknowledge that leachate infiltrates into soil, contaminating and affecting groundwater quality.

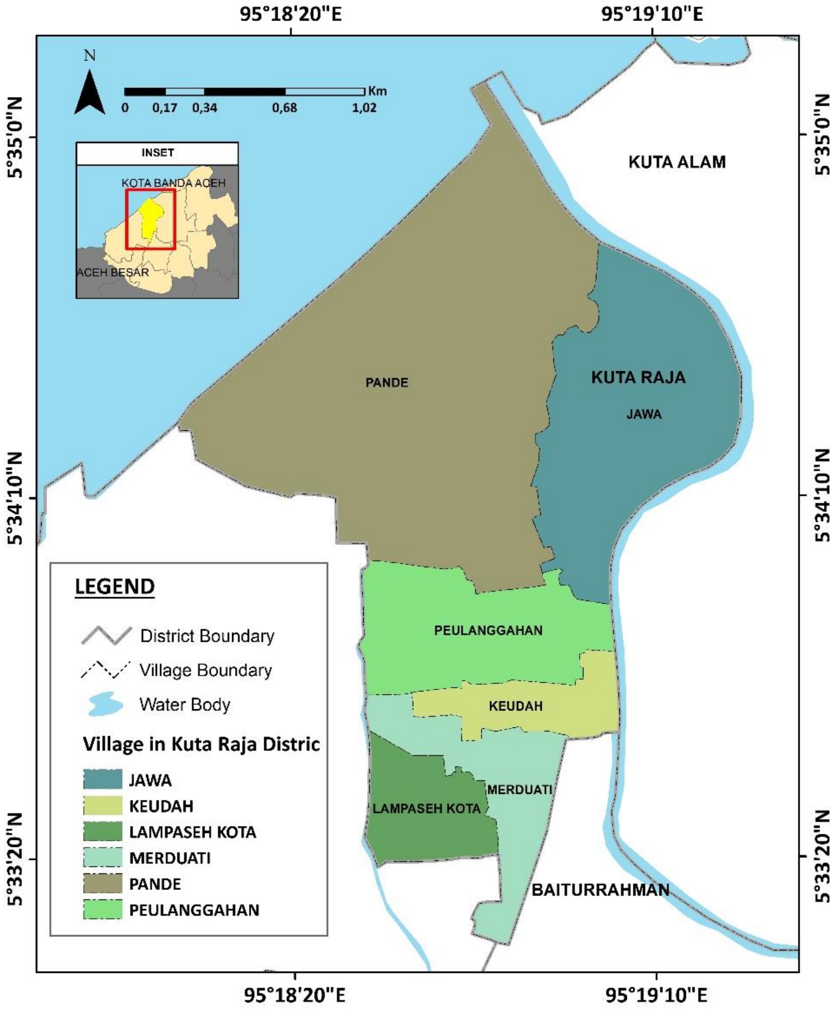

Figure 1. Administrative Map of Kuta Raja Sub-district.

This study was conducted to evaluate the quality of shallow groundwater by measuring the level of physical and chemical parameters. Water hardness is mandatory in analysing the quality of clean water. It is a chemical property of groundwater that is attributed to the presence of alkaline elements. The main cause of groundwater hardness is the interaction between water and rocks to form calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium sulfate ($CaSO_4$), and magnesium sulfate ($MgSO_4$) compounds, leading to precipitation. These compounds tend to separate from the solution in the form of sediment, eventually becoming scale (Madalena Da Costa & Maria Angelina Tuas, 2022). According to PERMENKES Number 492/MENKES /PER/IV/2010, the permissible upper limit for hardness in clean and drinking water is 500 mg/L. Hard water contributes to the intake of calcium and magnesium to living things, specifically humans (Nurullita *et al.*, 2020). Meanwhile, it impacts environmental hygiene and causes corrosion in households (Jiang *et al.*, 2024). Hard water also has an impact on health problems, including blockage of heart vessels, cancer, damage to the central nervous system, Alzheimer's disease, diabetes, kidney stones, reproductive health, and bone loss (Thirumoorthy *et al.*, 2024).

Numerous communities, including the Kuta Raja Sub-district, use groundwater for bathing, washing, and toilet purposes. The area consists of 6 Gampongs, namely Gampong Keudah, Gampong Lampaseh Kota, Gampong Merduati, Gampong Jawa, Gampong Pande, and Gampong Peulanggahan. According to BPS 2023 data, the population in Kuta Raja Sub-district is located at 2.2 meters above sea level. It has a population of 13,900 people and an area of 5.12 km^2 (521.1 Ha). Kuta Raja Sub-district borders the Strait of Malacca, Baiturrahman Sub-district, Kuta Alam Sub-district, and Meuraxa Sub-district to the north, south, east, and west, respectively. The administrative map of the area is shown in Figure 1. Therefore, the quality of phreatic groundwater in this area needs to be studied based on physical parameters such as odour, taste, colour, and temperature, as well as chemical parameters, namely pH, electrical conductivity, and water hardness.

2. Research Methods

This study was conducted in Kuta Raja Sub-district, Banda Aceh City. A total of 50 samples were selected using a random sampling method to represent the physical and chemical quality of groundwater for the experiment. The level of groundwater hardness was assessed in 6 of the samples. Among the 6, 4 were obtained from wells in the Gampong Jawa area, while the remaining two were obtained from Gampong Pande and Gampong Keudah, respectively.

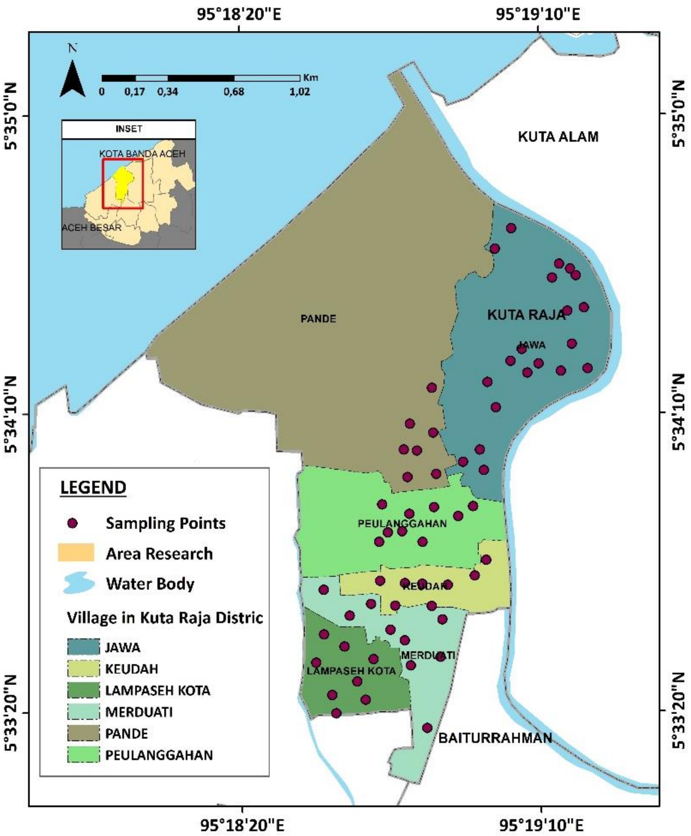

Figure 2. Map of sampling points for testing physical properties, pH, and electrical conductivity of groundwater.

According to (Afriyani *et al.*, 2020), groundwater sampling locations were determined by considering variations in the value of Electrical Conductivity (EC) and flow patterns in an area. The determination was conducted after the grid map processing stage and the electrical conductivity zoning map. This sampling method was used to test the hardness level because the flow needed to be observed in one segment or flow corridor. The observation wells for groundwater collection in hardness assessment were selected based on the flow network (flow net) and electrical conductivity values obtained from field data.

Physical quality checks in the form of odour, taste, colour, and temperature of phreatic groundwater were conducted using observational methods. The pH test was measured using a pH meter, while electrical conductivity value and temperature were tested using a water quality checker. The hardness level of groundwater samples was evaluated at the UPTD Health Laboratory & Medical Device Testing Center of the Health Office. $CaCO_3$ test was performed based on the Indonesian National Standard Number (SNI) 06-6989.12-2004 and using the Titrimetric method.

Sampling locations were determined using the grid sampling method. Groundwater mapping survey was also conducted using the same method. It includes dividing the study area into several grids of the same size at 50 m x 50 m with an area of 5.12 km^2. As a result, 50 sampling well points were obtained through random selection (random sampling). Groundwater sampling points for physical and chemical parameters testing are shown in Figure 2. At 50 well points, level measurements were taken, to create a local groundwater flow map in the study area, as presented in Figure 3.

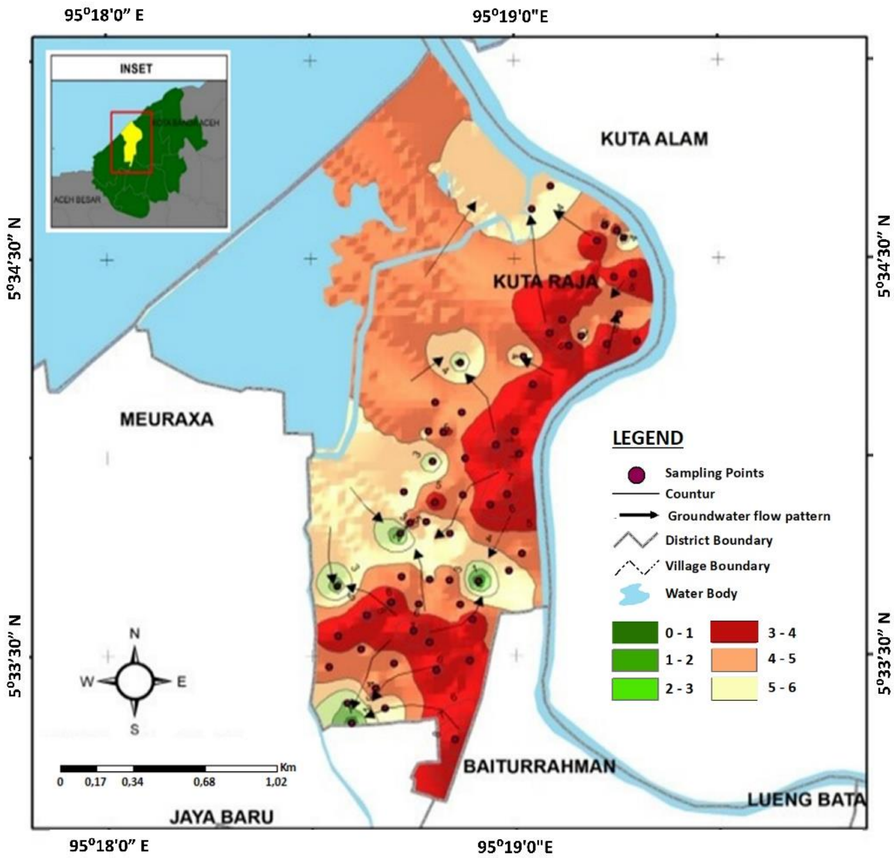

Figure 3. Groundwater Flow Map Based on Electrical Conductivity in Kuta Raja Sub-district.

The sampling location for testing water hardness levels in the Kuta Raja Sub-district is shown in the overlaid electrical conductivity map and flow net. A flow net map is a description of groundwater flow patterns from higher to lower areas. It was important to acknowledge that the pattern in Kuta Raja Sub-district flows was from south to north. Groundwater flow patterns and electrical conductivity values were evaluated to determine sampling points. As a result, 6 samples were selected from a total of 50 wells. The sampling point for testing the level of hardness is shown in Figure 4. The flow pattern was from the highest to the lowest groundwater level. It was important to acknowledge the accumulation of ions which is centered on a flow. The closer water flows to the upstream, the higher the ion concentration. The well was selected based on an electrical conductivity value of 1,200 – 15,000. Furthermore, groundwater levels in the study area had various variations, ranging from 0.29 to 8.75, with an average of 4.18 meters above sea level. At lowland areas, the value tended to be relatively flat, with a shallow depth ranging from approximately 1-14 m below the surface (Andreas Adriel *et al.*, 2023). The flow pattern was according to the topography of the earth's surface and from areas of high to low groundwater levels (Mice Putri Afriyani, 2019).

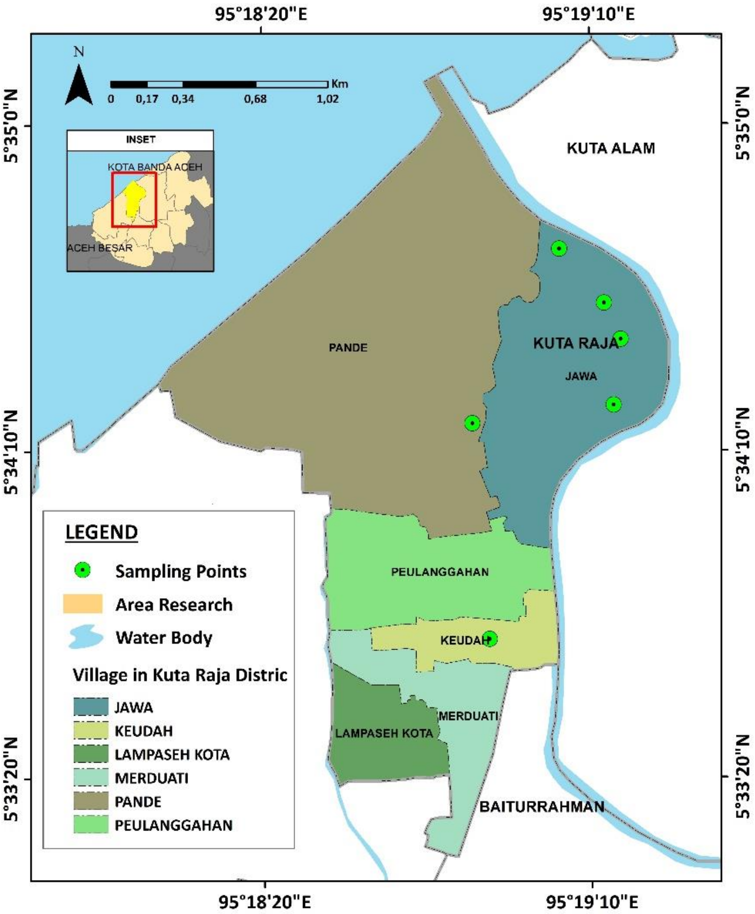

Figure 4. Map of Sampling Points for Groundwater Hardness Assessment in Kuta Raja Sub-district.

3. Results and Discussion

3.1. Physical Properties of Phreatic Groundwater in Kuta Raja Sub-District

Clean water was characterised by being physically clear, colourless, odourless, and tasteless. Clear signified that phreatic groundwater had very small mixture of mud. Meanwhile, being colourless suggested the absence of organic matter and harmful chemicals. Odorless implies that there is no microbial weathering in the water. Any occasional scent detected in water was an indication of the decomposition of organic substances by microorganisms during the process of weathering (Amik *et al.*, 2023).

Based on the criteria commonly adopted to assess the physical characteristics of unpredictable groundwater, the parameter of odour relies on the sense of smell (nose) for measurement. Water exhibiting an undesirable smell is not only an aesthetic concern but is generally unpleasant to the community. The taste of water is a parameter that is very easy to measure by the sense of taste (tongue). An unpleasant taste signifies the presence of various substances, such as metallic/fishy taste, bitterness, and saltiness. Water temperature should be cool to prevent the dissolution of chemicals in the channel/pipe, which can endanger health by causing rapid multiplication of pathogenic microorganisms through biochemical reactions. The sense of sight (eye) was adopted to determine the colour. Ideally, water should be colourless for aesthetic reasons and to prevent poisoning from various chemicals and microorganisms which may be coloured (Sugeng Nuradji & Sercyana Sampo, 2021). The parameters were examined based on the clean water quality and standards outlined in Regulation of Ministry of Health No. 492 of 2010. Information about the physical properties of phreatic groundwater is presented in Table 1 and the corresponding diagram.

Table 1. Categorisation of physical characteristics of phreatic groundwater in Kuta Raja Sub-district.

No	Categories of physical properties of groundwater	Number of Wells	Percentage
1	Clear, tasteless, odorless	1	2 %
2	Yellow, tasteless, odorless	32	64%
3	Turbid, tasteless, odorless	10	20%
4	Slightly cloudy, salty, no odour	6	12 %
5	Slightly cloudy and oily, salty, no odour	1	2%

Source: Primary data, 2023

In Kuta Raja Sub-district, 2% of groundwater had distinctive physical properties, namely tasteless and odourless. It was important to acknowledge that another 2% had a slightly cloudy colour. Additionally, 12% of phreatic groundwater wells in the area had physical properties characterised by a slightly cloudy colour, salinity, and no discernible odour. Approximately 64% had yellow watercolour, no flavour, and an odourless scent. The yellow colour that occurs in phreatic groundwater was attributed to one of Gampong being used as a final waste disposal site. The disposal of household waste products is a form of human-induced pollution. Waste deposited in landfills typically contains organic, inorganic, and metallic (Alsalme *et al.*, 2021). Furthermore, it can be in the form of solid, liquid, or gas. Landfills in both developed and developing regions lack adequate facilities such as waste collection and sorting systems, methane gas management, environmental monitoring, as well as hazardous and toxic waste storage systems (Li *et al.*, 2024). Based on observation, seven wells had a salty taste due to the level of salinity in groundwater. Salinity is the amount of dissolved salt caused by the seepage of seawater (Mice Putri Afriyani *et al.*, 2024). The quality of groundwater in terms of physical or chemical is strongly influenced by the depth structure and the presence of surrounding waste, causing surface water to mix with contaminants. This can lead to a poor infiltration process and a subsequent decline in quality (Angrianto *et al.*, 2021). Figure 5 shows the temperature measurements of phreatic groundwater based on field data.

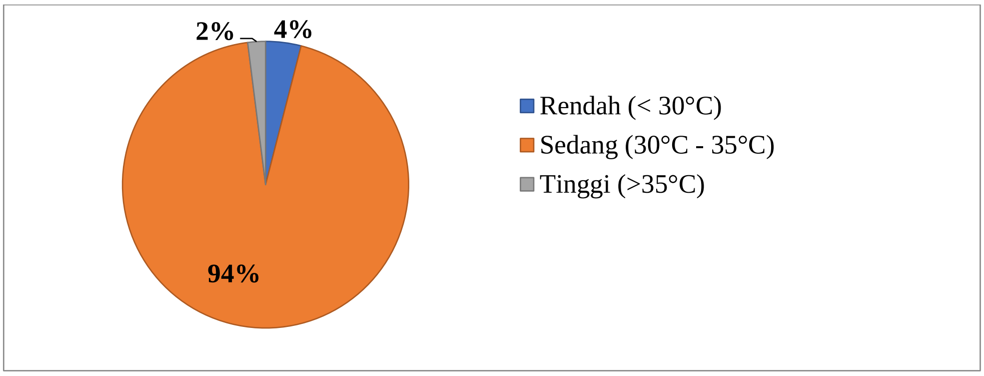

Figure 5. Pie Chart of phreatic groundwater temperature values in Kuta Raja Sub-district.

Based on field study, temperature values in the low, moderate, and high categories accounted for 4, 94, and 2%, respectively. The temperatures of phreatic groundwater were highly influenced by the surrounding air and the location of the wells (Micky Kololu & Zapheline Matakupan, 2023), with the majority falling into the high category. This was because the wells were located outdoors in open spaces. The study area was previously affected by a *tsunami* disaster. Furthermore, the government provided houses and phreatic wells to assist the victims. The characteristic feature of these phreatic wells is the location, which is either beside or in front. The location contributes to high groundwater temperatures due to direct exposure to sunlight, as presented in Figure 6.

Figure 6. The location of the Phreatic Well is Outside the Residents' Houses.

3.2. Chemical Properties of Phreatic Groundwater in Kuta Raja Sub-District

Chemical parameters are among the most essential in assessing the quality of groundwater. The chemical properties of groundwater include the content of ions or compounds. When water moved through the subsurface soil, the chemical contents in the surrounding area of the flow direction were contaminated, thereby affecting the chemical properties (Walter *et al.*, 2023). It was important to acknowledge that phreatic groundwater sources were vulnerable to contamination due to pollution on the land surface. Among Gampong in Kuta, Raja Sub-district is a landfill area, prompting the need for a review of quality using chemical parameters. Pollution of groundwater sources occurs due to waste disposed through dumping and open landfills. The waste is subjected to a decomposition process, which, alongside rainwater, produces leachate (Meiliyadi, 2023). In this study, the chemical properties to be evaluated include Electrical Conductivity (EC), pH, and water hardness ($CaCO_3$). The original quality of groundwater is difficult to restore when contaminated by chemicals. However, technological advancements and the discovery of chemicals facilitated the reduction of the contaminant without complete elimination (Chaudhari *et al.*, 2024).

3.2.1. Electrical Conductivity (EC)

EC serves as a chemical parameter to assess groundwater quality. Furthermore, it represents the capacity of water to conduct electricity. The conductivity depends on the concentration of dissolved salt in direct proportionality (Wahyuningsih *et al.*, 2023). The established units for the measurement of electrical conductivity are millimhos per centimetre (mmhos/cm) and millisiemens per centimetre (mS/cm) or microsiemens per centimetre (Wongkar *et al.*, 2023). According to Afriyani (2019) groundwater can be categorised into several classes based on electrical conductivity values, as presented in Table 2.

Table 2. Groundwater classification based on electrical conductivity values.

No	Class	Electrical Conductivity ($\mu S/cm$)	Groundwater Classification
1	Low	< 1.200	Fresh Groundwater
2	Medium	1.200 – 2.500	Brackish Groundwater
3	High	2.500 – 4.500	Saline Groundwater
4	Very High	4.500	Very Saline Groundwater

Source: Mice Putri Afriyani 2019.

Table 3. Electrical conductivity values of phreatic groundwater in Kuta Raja Sub-district.

No	Categories of electrical conductivity values	Number of Wells	Percentage
1	Fresh Groundwater	0	0 %
2	Brackish Groundwater	42	84 %
3	Saline Groundwater	2	4 %
4	Very Saline Groundwater	6	12%

Source: Primary data, 2023.

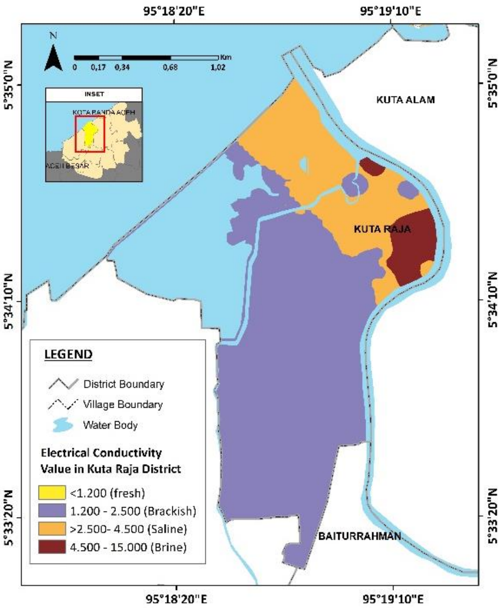

Figure 7. Map of The value of electrical conductivity.

Analysis of the distribution of electrical conductivity was conducted using a spatial method. This method was selected due to its ability to explain the influence of flow patterns on electrical conductivity. It was important to acknowledge that high conductivity values are obtained at gathering points. The values are directly proportional to the Cl-content in groundwater (Afriyani *et al.*, 2023). The results of a study showed that 84% of phreatic groundwater was included in the brackish category. Generally, a brackish to salty taste is produced by the process of evaporation in the past when the area was a fairly large river (Sulis Tiani & Yuli Priyana, 2022). Approximately 4% and 12% of groundwater were classified as salty and very salty, respectively. Furthermore, 84% of phreatic groundwater was categorised as brackish. The slightly salty or brackish flavor was observed associated with the historical evaporation of water when the region served as a substantial river (Sulistiani & Priyana, 2022). The value of electrical conductivity is shown in Figure 7.

3.2.2. Potential Hydrogen (pH)

The determination of pH or alkalinity in a substance, solution, or object is expressed through pH level, representing the potential of Hydrogen. Standard, alkaline, and acidic pH, are assigned values of 7, >7, and <7, respectively. Furthermore, values of 0 and 14 denote a high level of pH and utmost degree of basicity, (Kuhunuz *et al.*, 2024).

Table 4. pH value in Kuta Raja Sub-district.

No	Groundwater pH category	Number of Wells	Percentage
1	Low (pH < 6,5)	0	0 %
2	Normal (pH 6,5 – 8,5)	50	100 %
3	High (pH > 8,5	0	0 %

Source: Primary data, 2023.

The results of 50 phreatic groundwater sample wells showed pH values in the normal category, in the range of 6-8,5. According to drinking water regulations specified in permeate numbers. 492/Menkes/Per/IV/2017, the permissible pH level ranged between 6.5 to 8.5. A value lower than 6.5 is identified as acidic, featuring low solid content and exhibiting corrosive properties. The conditions show the presence of iron, potentially causing harm to transmission pipes. This also leads to unpleasant taste, stains on clothing and toilets, and adverse health effects. Water with a pH >8.5, is considered alkaline and might not present substantial health hazards. However, it can lead to problems such as the impartation of alkaline taste to the water (Zuraida *et al.*, 2022).

3.2.2. Water Hardness (CaCO3)

Water hardness refers to the presence of $CaCO_3$ or $MgCO_3$ in groundwater. It is characterised by the existence of abundant dissolved polyvalent metal cations, primarily dominated by Ca_2+ and Mg_2 + ions. Additionally, the total water hardness is affected by the presence of extra cations such as Ba_2 +, Sr_2 +, Fe_3 +, and Zn_2 +. It is important to acknowledge that calcium and magnesium are the 5th and 8th elements in the order of the primary components of water in nature (Mosoud Shariati-Rad & Saeideh Heidari, 2020). Hard water can be categorised into two types, namely permanent and temporary. The distinction between these categories lies in the hardness reduction methods adopted. Temporary hardness is alleviated through heating, while permanent hardness is mitigated by treating the water with a solution of Na_2CO_3 or K_2CO_3 (Ishak *et al.*, 2022). Hardness can be assessed by measuring the quantity of $CaCO_3$ in the sample. In the study area, groundwater shows diverse levels of this parameter, categorised into distinct classes, as presented in Table 5.

Table 5. Categorisation of hardness level of water.

Hardness (mg/litre)	Classification of Waters
<50	Low
50 - 150	Medium
150 - 300	Hard
>300	Very Hard

Approximately 67% of groundwater samples in the hard category, are sourced from Gampong Keudah (sample code 01), Gampong Pande (sample code 02), and Gampong Jawa (sample codes 03, and 05). Furthermore, 35% of samples with very high levels of hardness (35%) are sourced from Gampong Jawa, featuring codes 04 and 06. According to Regulation Number 492 of 2010 issued by the Ministry of Health, the maximum standard for hardness in water is 500 mg/L. Therefore, 4 samples in the "Hard" category and sample code 04 in the “Very hard” category are suitable for drinking, while 1 in the "Very hard" category (sample code 06) is not suitable. Water hardness impacts humans in terms of economy, ecology, and health. The economic impact includes increased detergent usage, buildup of scale on water pipes, and corrosion. Meanwhile, the ecological impact is comprised of the effect on the success of fisheries cultivation. World Health Organization action (WHO) states that consumption of hard water causes cardiovascular disease (Dan Wu & Yinglu Hu, 2023), cancer, damage to the central nervous system such as Alzheimer's, diabetes, kidney stones, reproductive health problems, and bone loss (Kanyagui *et al.*, 2023).

Based on the results of laboratory tests using the Titrimetric method (SNI 06-6989.12-2004) Figure 8 shows the hardness classification of phreatic groundwater.

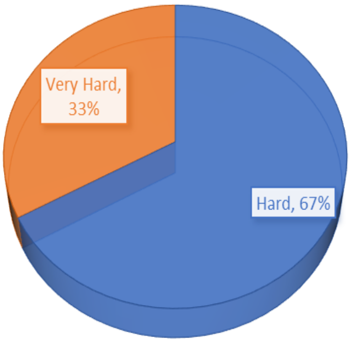

Figure 8. Pie chart showing the levels of groundwater hardness.

Groundwater in the study area appears clear and colourless, possibly due to the filtration process from soil and rock layers. This resulted in good water quality suitable for use to meet daily needs (Katharina B. V. Ngere *et al.*, 2023). The high and low concentration of hardness levels is influenced by the development of soil types in each landform. For example, young soil types have a higher level of temporary hardness than permanent hardness due to an underdeveloped soil profile. It is important to acknowledge that regions characterised by mature soil types and developing soil profiles tend to possess a higher permanent hardness value. The study site features alluvial soil types derived from weathering of alluvial parent material. This soil is considered to be relatively young with incomplete profile development, as evidenced by laboratory tests that detect the presence of temporary hardness in the Kuta Raja Sub-district. Positioned near Malacca Strait to the north, the increased degree of hardness of groundwater is associated with the interaction between seawater, carbonic acid, and specific calcium-containing rocks. This interaction leads to the creation of soluble $CaCO_3$, contributing to the overall water hardness (Herdini *et al.*, 2023b). The overall water quality was not assessed, and considering the position of the wells outside the house, some are uncovered and susceptible to contamination. It is important to acknowledge that phreatic wells in the study area are only used for daily needs, except for drinking, addressed through water refills.

In the study novelty, the landfill site in one of the kampongs was discovered to contribute to the yellow colour of the water and the level of groundwater hardness. Temporary and permanent hardness was differentiated, and reduction methods were provided. A more specific overview of phreatic water quality, including colour, taste, odour, temperature, electrical conductivity, pH, and hardness level, was presented. Additionally, primary data obtained from the field was used, making the results more accurate and relevant to the actual conditions in Kuta Raja Sub-district.

4. Conclusion

In conclusion, the measurement of physical properties (colour, taste, and odour) showed that 64% of groundwater at the study location was yellow in colour, tasteless (fresh), and odourless, thereby categorised as safe according to Ministry of Health regulations. The quality influencing factors included contact between seawater with carbonate acid content and some rocks containing calcium, as well as household waste disposed of in landfill sites. In terms of temperature, 94% of groundwater temperature fell into the moderate category, which ranged from 30°C to 35°C. Results showed that 42 wells (84%) were categorised under the brackish groundwater class, with electrical conductivity values ranging from 1,200 to 2,500. Meanwhile, 4 and 12% were categorised as saline and very saline. In terms of pH, 50 wells were in the normal range of 6.5 – 8.5, signifying safe limits. Among six observed samples, four fell under the "hardness" category, and two were "very hard". Based on the maximum hardness value standard for water, according to the Ministry of Health of Indonesia, drinking and clean water needs to possess a maximum value of <500 mg/L. Using these guidelines, four samples under the "hardness" category and one under the "very hard" category were considered acceptable. However, 1 sample categorised as very hard was not suitable due to the hardness level exceeding 500 mg/L. Laboratory testing using $CaCO_3$ compounds showed that the hardness of water in the Kuta Raja Sub-district was classified as temporary and permanent. Temporary hardness was reduced by heating, while permanent hardness was reduced through reaction with Na_2CO_3 or K_2CO_3 solutions. It was important to acknowledge that the class of hardness in the Kuta Raja Sub-district was temporary hardness.

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Author Contributions

Conceptualisation: Afriyani, M. P., Muttakin, M., Desfandi, M., Azis, D., Afriza, R.. & Ruliani, R.; **methodology**: Afriyani, M. P.; **investigation**: Afriyani, M. P., & Afriza, R.; **writing—original draft preparation**: Afriyani, M. P., & Afriza, R.; **writing—review and editing**: Afriyani, M. P., Muttakin, M., Desfandi, M., Azis, D., Afriza, R.. & Ruliani, R.; **visualisation**: Afriyani, M. P., Muttakin, M., Desfandi, M., Azis, D., Afriza, R.. & Ruliani, R. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability

Data is available upon Request.

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