Assessment of Borehole Water Quality in the Limestone Mountain Area of Lekobala Village

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Abstract. Lekobalo Sub-district, with a population of 3,543 people, relies primarily on borehole wells as its main source of domestic water. Although the water appears clear, interaction with surrounding limestone formations and possible anthropogenic inputs may compromise its quality and pose health risks. This study aimed to evaluate the quality of borehole water in Lekobalo Village based on physical (temperature, TDS), chemical (iron, manganese, hardness, pH), and microbiological (Escherichia coli and total coliform) parameters. Water samples were collected once from six borehole wells representing three locations (western edge, central area, and eastern edge of the settlement). Physical parameters were analyzed in situ, chemical parameters were examined at LPPT UGM, and microbiological parameters were analyzed at UPTD BLKD. Water suitability was assessed in accordance with Indonesian Ministry of Health Regulation No. 2 of 2023 on Environmental Health Quality Standards. The results showed that at Location 1, the mean TDS was 325 mg/L, with E. coli at 19 CFU/100 mL and total coliforms at 154 CFU/100 mL, all exceeding the permissible limits. At Location 2, mean TDS was 384 mg/L, with E. coli at 0.5 CFU/100 mL and total coliforms at 7 CFU/100 mL, both above drinking-water standards. At Location 3, the mean pH was 8.55, and E. coli and total coliform were 5.5 and 14 CFU/100 mL, respectively, exceeding the maximum allowable values. Overall, the borehole water in Lekobalo Village does not meet the required drinking water standards and therefore requires appropriate treatment before consumption.

1 Introduction

Water is one of the most important and abundant natural resources in Indonesia. Human water demand continues to increase in line with population growth and socio-economic development. In addition to quantity, ensuring safe water that meets health requirements remains a major development challenge, particularly in areas that depend on groundwater.

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In daily life, water is used for various purposes such as cooking, washing, bathing, drinking, industrial activities, and agriculture. In general, the two main sources of clean water that are widely utilised are surface water and groundwater. According to the Indonesian Ministry of Health Decree No. 416 of 1990, clean water is defined as water used for daily needs whose quality meets health requirements and can be consumed after boiling.

Previous studies have shown that water quality in several regions of Indonesia varies and does not always comply with quality standards. Mulis [11] examined the physical and chemical parameters of Limboto Lake and reported that although temperature, transparency, pH, and dissolved oxygen still supported aquatic life, phosphate concentrations had exceeded the normal requirements of organisms. Rompas et al. (2017) [17] found that the quality of raw river water and drinking water in the Tondano watershed did not meet the water quality standards set by the Indonesian Ministry of Health Regulation No. 492 of 2010 due to high levels of E. coli and total coliform. A study on groundwater quality in Griya Saka Housing, Natar Hajimena Sub-district, South Lampung, showed that several parameters did not comply with water quality standards, namely colour (67%), iron content (75%), chloride (65%), and total coliform (80%), so that borehole water was declared unfit for use as clean water [6]. Conversely, Izzati et al. (2019) [10] reported that groundwater quality in industrial (Bekasi) and residential (Depok) areas still met the quality standards set by the Indonesian Ministry of Health Regulation No. 32 of 2017. Yuniarti [22] also showed that several pollution parameters (DO, BOD, COD, faecal coliform, and total coliform) in the Jaing River had exceeded the class I river water quality standards, with a pollution index indicating a slightly polluted status.

These findings indicate that the quality of both surface water and groundwater is strongly influenced by environmental conditions, human activities, and local geological characteristics. Therefore, water quality assessments in areas with specific geological characteristics, such as limestone mountain regions, are important. Lekobalo Village, located in the Kota Barat Sub-district of Gorontalo City, lies within a limestone mountain area. The community in this region largely relies on borehole wells as its main source of clean water to meet daily needs, including cooking, washing, bathing, and other household uses. Geological conditions dominated by limestone may influence the concentration of dissolved minerals in groundwater, including hardness, pH, and other chemical constituents.

Borehole water that appears clear to the eye is not necessarily safe for consumption. Direct contact between groundwater and limestone layers, as well as the potential presence of other pollution sources around the settlement, can degrade water quality across both chemical and microbiological parameters. The proximity of Lekobalo Village to limestone mountains and the community's high reliance on borehole water raise concerns about the safety of the water consumed. Water that appears physically clean may not meet health requirements, particularly regarding chemical and microbiological parameters. The main problem addressed in this study is how the quality of borehole water in Lekobalo Village compares to the physical, chemical, and microbiological standards stipulated in relevant regulations. The results of this assessment are expected to provide a scientific basis for formulating appropriate clean water management policies to support the health and well-being of the local community.

2 Materials and Method

2.1 Study Area and Sampling Location

This study was conducted in Lekobalo Village, Kota Barat Sub-district, Gorontalo City, specifically along Usman Isa Street. Lekobalo is one of seven villages in Kota Barat Sub-district and is located approximately 7 km from the centre of Gorontalo City. Sampling

locations for borehole well water were selected at three points that represent the distribution of settlements in Lekobalo Village. Location 1 is in the western part, bordering Piloloda'a Village; Location 2 is in the central part of Lekobalo; and Location 3 is in the eastern part, bordering Dembe I Village. At each location, two borehole wells were selected, yielding a total of six as sampling points. Each well represents a hamlet or sub-area with similar water-use patterns.

2.2 Data Collection and Analysis

Water sampling was conducted once at each borehole, yielding 6 groundwater samples (2 per location). Samples were collected directly from the community's borehole wells used for daily needs. The measured water quality parameters included: (1) physical parameters, namely temperature and Total Dissolved Solids (TDS); (2) chemical parameters, namely iron (Fe), manganese (Mn), hardness, and pH; and (3) microbiological parameters, namely Escherichia coli and total coliform. Physical parameters were analysed in situ at the time of sampling. Chemical parameters were analysed at the Integrated Research and Testing Laboratory (LPPT), Universitas Gadjah Mada (UGM). In contrast, microbiological parameters were analysed at the Regional Health Laboratory (UPTD BLKD), Gorontalo District Health Office. The suitability of water quality was evaluated against the quality standards stipulated in the Indonesian Ministry of Health Regulation Number 2 of 2023 on Environmental Health Quality Standards [15]. The detailed analytical methods for each parameter are presented in Table 1.

Table 1. Sample Testing Methods

Parameter	Unit	Analysis Method	Instrument	Specification/Standard	Quality Standard
Physics					
Temperature	°C	Measurement	Thermometer	SNI 06-2413-1991	±3°C
TDS	mg/L	Gravimetric TDS	TDS meter	SNI 06-2413-1991	300
Chemistry					
pH	–	pH measurement	pH meter	SNI 06-2413-1991	6.50–8.50
Hardness	mg/L	Atomic Absorption Spectrophotometry (AAS)	AAS instrument	SNI 06-6989.12-2004	500.00
Iron (Fe)	mg/L	Atomic Absorption Spectrophotometry (AAS)	AAS instrument	SNI 06-6989.4.2004	0.3
Manganese (Mn)	mg/L	Atomic Absorption Spectrophotometry (AAS)	AAS instrument	SNI 6989.5.2009	0.1
Microbiology					
Coliform / *E. coli*	CFU/100 mL	Most Probable Number (MPN)	MC – Media Pad	ISO/IEC 17025.2005	0.00

3 Result and Discussion

3.1 Analysis of Physical Water Parameters

3.1.1 Temperature

Temperature is one of the key parameters influencing biological components and the balance of aquatic ecosystems. Temperature changes can alter the physicochemical properties of water, for example, through their effects on gas solubility and CO_2 dynamics in aquatic environments [13]. An increase in temperature beyond the tolerance range will affect the distribution patterns and survival of aquatic biota [5].

The measurement results show that water temperature at the three locations ranged from 30.5 to 31.35 °C. These values are still within the quality standard range required by the Indonesian Ministry of Health Regulation No. 2 of 2023 for clean water. Yolanda [21] reported a similar temperature range of 28.53–31.05 °C, with an average of 30.38 °C and a standard range of 29.8–32 °C. This indicates that groundwater temperature in Lekobalo Village remains suitable for domestic uses such as washing, bathing, and other household purposes. However, when the temperature exceeds the normal range, it may indicate contamination by certain chemicals such as phenols or sulfur compounds, and water with such characteristics is not suitable for consumption [7]. The temperature measurement results are presented in Figure 1.

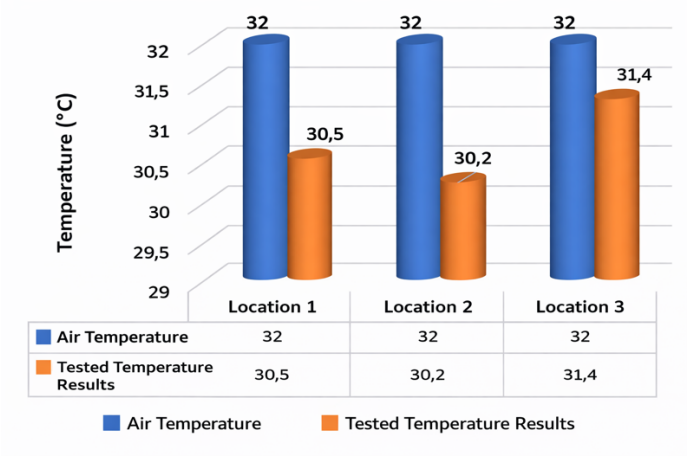

Figure 1. Water temperature measurement results

3.1.2 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) represent the amount of dissolved salts and other inorganic materials, including sodium, chloride, magnesium, sulfate, as well as products of rock and soil weathering [14]. High TDS concentrations can affect the taste and overall quality of water. In general, the higher the TDS value, the lower the suitability of water for drinking purposes [16]. Elevated TDS can also be negatively associated with certain aquatic environmental parameters and potentially increase toxicity to aquatic organisms [2].

The results show that two out of three locations did not comply with the TDS quality standard of 300 mg/L. The average TDS at Location 1 was 325 mg/L, at Location 2 was 384 mg/L, while Location 3 still met the standard with a value of 299 mg/L. The mean TDS across all locations was 336 mg/L, indicating that, in general, groundwater in Lekobalo Village does not meet the standard for drinking water with respect to TDS. Another study reported TDS

levels of around 385.09 mg/L influenced by seawater intrusion with high mineral content seeping into freshwater, demonstrating that geological and hydrogeological conditions significantly affect TDS values. The TDS measurement results are shown in Figure 2.

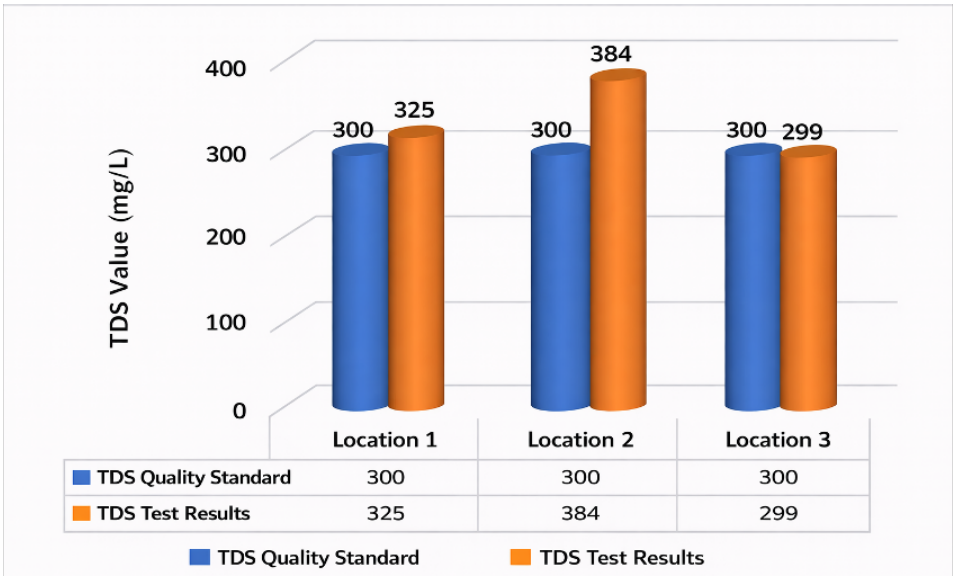

Figure 2. Results of water TDS measurements

3.2 Analysis of Chemical Water Parameters

3.2.1 Iron (Fe)

Iron concentrations greater than 1 mg/L can cause the water to appear reddish, impart an unpleasant taste, and form deposits in metal pipes and on laundry. However, in small amounts, iron is still required by the human body for the formation of red blood cells [7]. The measurement results indicate that iron concentrations at all three locations were below the quality standard of 0.2 mg/L set by Indonesian Ministry of Health Regulation No. 2 of 2023. The average iron concentration obtained was 0.02 mg/L. This value suggests that there are no significant industrial activities or pollution sources contributing Fe ions to the groundwater in the area. Another study reported an average iron concentration of 0.105 mg/L, still within the requirements of Government Regulation No. 32 of 2017. The values observed

in Lekobalo Village can be considered relatively safe with respect to excess iron exposure. The iron measurement results are presented in Figure 3.

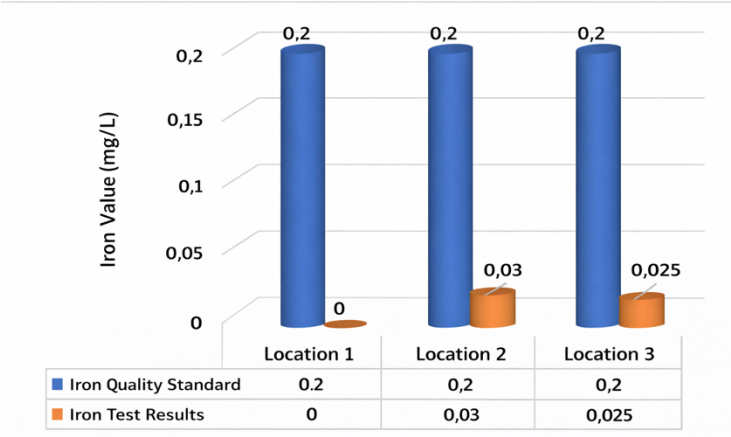

Figure 3. Results of the iron measurement

3.2.2 Manganese (Mn)

Manganese is one of the metals commonly found in the Earth's crust and is often present together with iron. Dissolved manganese is typically found in groundwater and surface water with low oxygen levels, allowing manganese concentrations in water to reach up to 0.5 mg/L and up to 0.4 mg/L in drinking water. Excessive manganese content in water can cause a metallic taste and odor in drinking water [4]. The measurement results showed that all three sampling locations in Lekobalo Village were not contaminated with manganese. The measured manganese concentration was 0 mg/L, indicating that the water quality in the area is safe for use. The results of the manganese measurements are presented in Figure 4.

Figure 4. Results of the manganese measurement

Research conducted by Hasanah [9] reported that manganese (Mn) concentrations ranged from 0.04 to 0.13 mg/L, while iron (Fe) concentrations ranged from 0.11 to 0.17 mg/L. These values complied with the Indonesian Ministry of Health Regulation No.

492/Menkes/PER/IV/2010, which sets the maximum allowable limits at 0.4 mg/L for manganese and 0.3 mg/L for iron. The treatment process achieved a reduction efficiency of 87.23% for manganese and 93.29% for iron. The reduction of manganese levels can be accomplished through coagulation–flocculation, sedimentation, filtration, and disinfection processes to meet the established quality standards.

3.2.3 Hardness

The presence of iron (Fe) and manganese (Mn) in water causes the water to change color to yellowish-brown after some time of contact with air. In addition to posing potential health risks, it can also produce an unpleasant odor, cause yellow staining on water storage tank walls, and leave yellow spots on clothing. According to clean water and drinking water quality standards, the maximum allowable hardness is 500 mg/L (as Ca), while the minimum allowable level is 75 mg/L [1]. The hardness measurement results at the three sampling locations are presented in Figure 5.

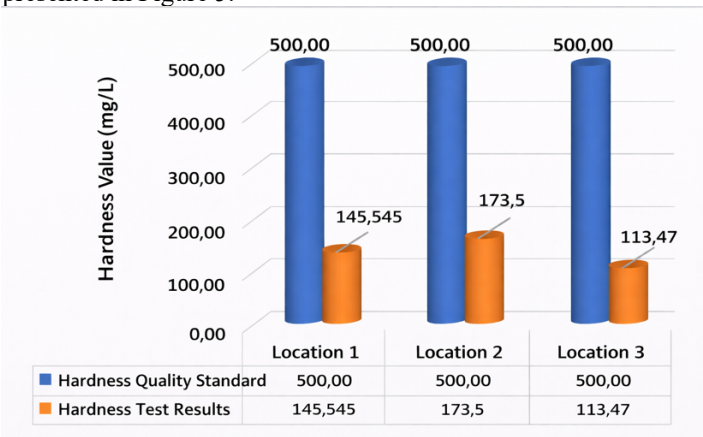

Figure 5. The hardness measurement results

Figure 5 shows that the hardness level meets the clean water quality standard with a maximum limit of 500.00 mg/L based on PMK RI No. 2 of 2023. The average hardness across the three locations was 144.17 mg/L. These results are lower compared to the study by Rosvita [18], which reported hardness levels ranging from 326.3 to 983.9 mg/L, exceeding the quality standard threshold and rendering the water unsuitable for direct consumption. Based on the hardness classification criteria (Table 2), Lekobalo Village falls into the moderately hard water category.

3.2.4 pH

pH is an important factor influencing the rate of pollution, directly affecting ecosystem conditions [19]. pH indicates the degree of acidity or alkalinity and represents the concentration of hydrogen ions. The recommended pH level for drinking water is approximately 7 (neutral pH). A pH level below 6.5 can increase the corrosiveness of metal

objects, potentially causing certain chemicals to become toxic [12]. The results of the pH testing are presented in Figure 6.

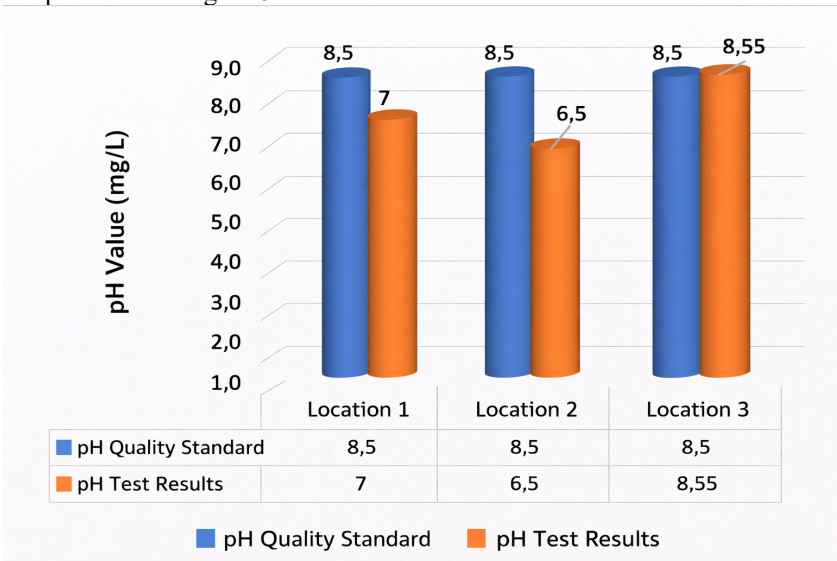

Figure 6. Results of the pH measurement

The pH measurement results indicate that 2 out of 3 sampling locations met the quality standard range of 6.50–8.50 based on PMK RI No. 2 of 2023. The average pH value at Location 1 was 7, and at Location 2 was 6.6, both of which comply with the standard. However, Location 3 did not meet the standard, with a pH value of 8.55. In Karangtengah Village, Bogor Regency, pH test results were 6.02 at Well 1 and 6.58 at Well 2. Since the quality standard range is 6.50–8.50, only Well 2 met the required standard [3]. Research conducted by Yoga [20] showed that pH values ranging from 7.4 to 8.5 are considered compliant with the established quality standard of 6.5–8.5.

3.3 Microbiological Parameter Analysis of Water

3.3.1 E. coli and Coliform

One cause of infectious disease is the bacterium Escherichia coli. E. coli is a normal intestinal flora originating from the human gut, where it plays a role in the decomposition of food residues in the large intestine and is excreted in feces. Although E. coli serves as beneficial normal flora in the human intestine, it can also have negative impacts by causing various infectious diseases [8].

According to the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, the quality requirements for clean water under physical parameters (odor, taste, and color) stipulate that water must be odorless, tasteless, and colorless. For microbiological parameters, the maximum allowable total coliform count is 50 colonies per 100 mL for non-piped water supplies, while E. coli must be 0 per 100 mL of water sample.

The analysis results showed that all three locations were contaminated with E. coli and coliform bacteria. The highest average measurement results were found at Location 1, with 154 CFU/100 mL for coliform and 19 CFU/100 mL for E. coli. At Location 2, the counts were 7 CFU/100 mL for coliform and 0.5 CFU/100 mL for E. coli. Meanwhile, at Location 3, the results were 14 CFU/100 mL for coliform and 5.5 CFU/100 mL for E. coli. These values exceed the quality standards for E. coli and coliforms, which are 0 CFU/100 mL. Therefore, the well water in Lekobalo Village must be treated before use. A study conducted

by Yustati [23] reported the presence of coliform bacteria in 31.5% of dug wells. The measurement results are presented in Figure 7.

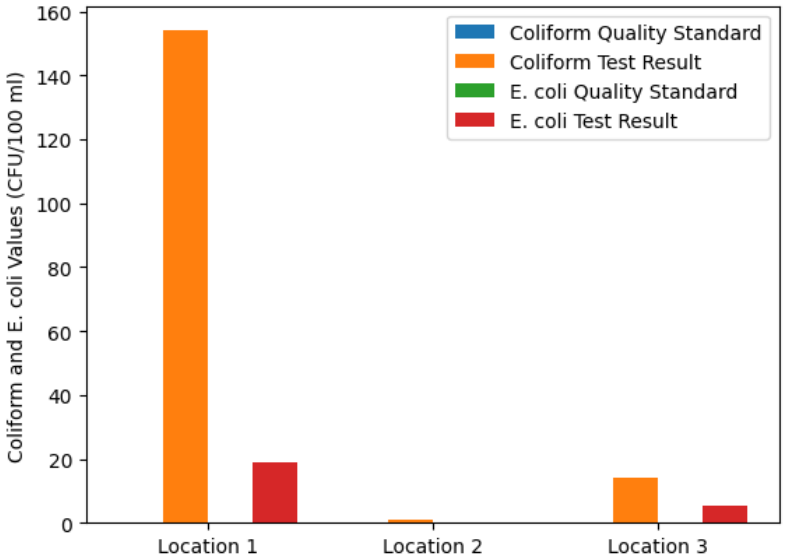

Figure 7. Microbiological Measurement Results

4. Conclusions

The results of the chemical and physical parameter analysis, particularly temperature, indicate that the water in Lekobalo Village meets the established quality standards. However, several parameters did not comply with the required standards. For the physical parameter, the Total Dissolved Solids (TDS) level was recorded at 336 mg/L. For the microbiological parameters, *E. coli* was detected at 8.17 CFU/100 mL and coliform bacteria at 56.33 CFU/100 mL. These findings indicate that the physical and bacteriological characteristics of the groundwater do not meet the quality standards and, therefore, the water is not suitable for direct consumption as drinking water. The factors contributing to the reduced water quality, based on the analysis results, include high mineral content and bacterial contamination

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