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COMPARATIVE ANALYSIS AND RISK ASSESSMENT OF RAINWATER AND BORED WELL WATER AS POTABLE WATER SOURCES IN COASTAL REGIONS

Analisis Komparatif dan Risiko Kualitas Air Hujan dan Sumur Bor Sebagai Sumber Air Minum di Wilayah Pesisir

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ABSTRACT

Water is a vital resource for coastal communities, which often have limited access to clean water. This study aimed to analyze and compare the quality of rainwater and borehole water as drinking water sources in Sayolo 3, Tanjung Village, South Sorong Regency. This study employed a quantitative descriptive approach. Water samples were collected directly from the sources and analyzed in a laboratory for 12 physical and inorganic chemical parameters. The results were compared with the quality standards stipulated in the Indonesian Minister of Health Regulation Number 2 of 2023. The findings indicate that rainwater meets all tested parameters, including pH, total dissolved solids (TDS), turbidity, iron (Fe), lead (Pb), manganese (Mn), nitrate, and hardness. In contrast, the borehole water contains iron (Fe) at a concentration of 0.309 mg/L, exceeding the maximum permissible limit of 0.2 mg/L, although its other parameters remain within the safe limits. It was concluded that rainwater is more suitable for direct use as a drinking water source in the study area, whereas borehole water requires additional treatment, specifically to reduce iron content, to ensure its safety for consumption.

Keywords: Borehole Water, Coastal Area, Drinking Water Source, Rainwater, Water Quality

ABSTRAK

Air merupakan sumber daya vital bagi masyarakat pesisir yang sering menghadapi keterbatasan akses air bersih. Penelitian ini bertujuan untuk menganalisis dan membandingkan kualitas air hujan dan air sumur bor sebagai sumber air minum di Sayolo 3 Kampung Tanjung, Kabupaten Sorong Selatan. Metode penelitian menggunakan pendekatan deskriptif kuantitatif. Sampel air diambil secara langsung dari sumbernya dan dianalisis di laboratorium terhadap 12 parameter fisika dan kimia anorganik, kemudian dibandingkan dengan standar baku mutu Peraturan Menteri Kesehatan Nomor 2 Tahun 2023. Hasil penelitian menunjukkan bahwa air hujan memenuhi seluruh parameter yang diuji, termasuk pH, TDS, kekeruhan, besi (Fe), timbal (Pb), mangan (Mn), nitrat, dan kesadahan. Sebaliknya, air sumur bor mengandung besi (Fe) sebesar 0,309 mg/L, melebihi ambang batas maksimum 0,2 mg/L, meskipun parameter lainnya masih dalam batas aman. Kesimpulan dari penelitian ini adalah air hujan lebih layak digunakan sebagai sumber air minum langsung di wilayah studi, sedangkan air sumur bor memerlukan pengolahan tambahan, khususnya untuk menurunkan kadar besi, agar aman untuk dikonsumsi.

Kata Kunci: Air Hujan, Air Sumur Bor, Kualitas Air, Pesisir, Sumber Air Minum

INTRODUCTION

Water is a source of life and a vital factor for living things, especially humans, who desperately need water to sustain life. Water use is crucial in daily life, particularly for drinking and cooking (Rambe et al., 2022; Tombeng et al., 2013). As a renewable natural resource, water contributes to various sectors such as fisheries, agriculture, industry, and household needs. However, in reality, water crises continue to occur, resulting in the need to conserve groundwater use, including well water (Wiyono et al., 2022). According to data from the Statistics Indonesia (BPS) for the People's Welfare of South Sorong Regency in 2022, 60.81% of households still use rivers or rainwater as their primary water source for bathing, washing, and other purposes. This indicates that the issue of clean water availability remains a serious concern, especially in rural and remote areas.

Polluted clean water quality, especially in hilly or limestone mountain areas, can have negative health impacts. Excessive and continuous use of well water mixed with lime can impact health, including causing kidney disease (Widyastuti et al., 2022). South Sorong Regency, known as the "Regency of 1001 Rivers," has significant water potential, but on-the-ground conditions indicate that clean water availability remains limited. The PDAM network system is also unable to optimally serve community needs. As an alternative, residents often utilize rainwater through a rainwater harvesting system, which collects rainwater from building roofs into reservoirs (Riyanto & Agung, 2020). This system has been implemented in Sayolo 3, Tanjung Village, Teminabuan District, South Sorong Regency.

Rainwater is essentially free of contamination, but when it comes into contact with reservoir surfaces, streams, or reservoirs, it can become physically, chemically, and microbiologically contaminated. The residents of Sayolo 3, Tanjung Village, utilize two water sources: borehole water for bathing and washing, and rainwater for drinking and cooking. This is based on concerns about the high lime content in drilled well water, given that the Teminabuan area is known to have significant limestone potential (Rusdi & Dwi, 2018). Water with a high lime content (>500 mg/L) is classified as hard water and, if consumed long-term, can trigger health problems such as kidney stones. Furthermore, previous research by Lestari & Putri (2024) showed that local residents prefer rainwater because it is considered safer than drilled well water, which is suspected to contain lime.

Based on these conditions, an in-depth study is needed to examine the quality of rainwater and drilled well water used by the Sayolo 3 community in Tanjung Village. This study aims to analyze the physical and inorganic chemical composition of both water sources and assess their suitability as drinking water sources based on the quality standards stipulated in Minister of Health Regulation No. 2 of 2023. The research results are expected to form the basis for formulating recommendations for healthy and sustainable water management in the area.

RESEARCH METHODS

Tools and Materials

Tools

1. Dipper: Used to collect rainwater samples from the collection gutter.

2. Sterile Bottle (500 mL): Container for storing borehole water and rainwater samples. Three bottles were used.
3. Plastic Jerry Can (5 Liter): The main container for collecting larger volumes of water samples from boreholes.
4. Gloves: To maintain cleanliness and prevent sample contamination.
5. Stationery and Labels: To record and label each sample.

Materials
1. Soap and Clean Water: To clean hands before sampling.
2. Ice (in a Cool Box)

Time and Place

This study was conducted to analyze the quality of rainwater and borehole water used by coastal communities in Sayolo 3, Tanjung Village, South Sorong Regency. Testing was conducted from March to April 2024, referring to the water quality standards stipulated in Regulation of the Minister of Health of the Republic of Indonesia Number 492/Menkes/Per/IV/2010 concerning Water Quality Supervision and Requirements. For comparison, Regulation of the Minister of Health Number 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene and Sanitation was also used (Ministry of Health of the Republic of Indonesia, 2010; Ministry of Health of the Republic of Indonesia, 2017). The purpose of this quality testing was to evaluate the suitability of the two water sources as drinking water sources based on physical and inorganic chemical parameters.

Rainwater samples were taken from gutters in residential areas, while well water samples were obtained from taps connected to a pump system. Both samples were then analyzed at the Water Productivity and Quality Laboratory, Faculty of Marine Sciences and Fisheries, Hasanuddin University. The analytical methods used included organoleptic, spectrophotometric, gravimetric, turbidimetric, and atomization testing, according to the parameters measured. The test results were compared with drinking water quality standards based on Minister of Health Regulation Number 2 of 2023 to determine suitability for consumption (Ministry of Health of the Republic of Indonesia, 2023). This research is expected to provide an objective picture of the quality of water consumed by the community and necessary management recommendations.

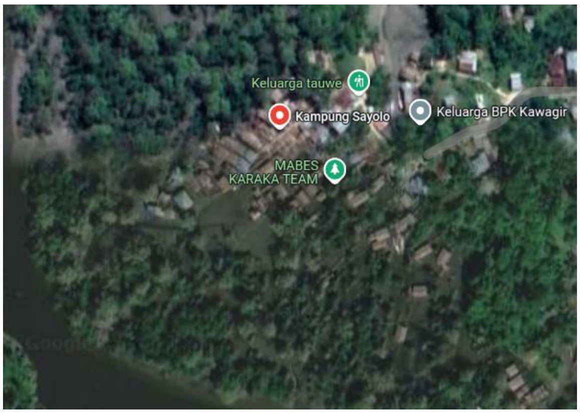

Figure 1. Research Location

Sampling

Rainwater sampling was conducted using gutters placed under residential roof tiles during the study period, March to April 2024. Sampling was conducted once during the study to represent the rainy season conditions that year. The sampling procedure included ensuring the gutter was clean and filled with rainwater, washing hands or wearing gloves before sampling, preparing sterile bottles, and collecting samples with a dipper to prevent contamination by foreign objects. Sediment at the bottom of the gutter was not sampled, and the bottles were then tightly capped to prevent contamination from air or other foreign materials. This sampling approach aims to obtain representative rainwater samples for analysis of their physical and inorganic chemical composition, such as temperature, odor, taste, TDS, pH, and concentrations of heavy metals such as iron (Fe), lead (Pb), and manganese (Mn). The analysis results are then compared with drinking water quality standards based on Minister of Health Regulation Number 2 of 2023. This procedure ensures that the samples taken remain sterile and represent the quality of rainwater consumed by the community at the research site, thus providing an accurate picture of rainwater's suitability as an alternative drinking water source. The sampling procedures are as follows:

Rainwater Sampling

a. Ensure the collection gutter is clean and full of rainwater
b. Clean hands with soap and clean water before sampling/wear gloves
c. Prepare a clean, sterile bottle
d. Collect the rainwater sample using a dipper to avoid contamination with other surrounding objects
e. If there is sediment at the bottom of the gutter, do not collect the sample
f. Cap the bottle tightly to avoid contamination with air or other materials

Well Water Sampling

Several studies have used standardized methods to ensure a true representation of the water source (Nurjanah et al., 2025; Saputra et al., 2026; Effendi et al., 2026; Susanti et al., 2025; Lestari & Sri, 2024). Generally, samples are obtained by pumping groundwater using a pump, flowing it through a connected piping system, and then collecting the water coming out of the tap or outlet directly into a sterile container, such as a sample bottle. This process is carried out with adherence to antisepsis procedures, such as cleaning or sterilizing the tap beforehand and allowing the water to run for a while before sampling to avoid contamination from the pipeline (Nurjanah et al., 2025; Effendi et al., 2026). More specifically, several researchers have emphasized the importance of maintaining sterile conditions during sample transportation and storage to the laboratory to prevent changes in physical, chemical, and microbiological parameters (Susanti et al., 2025). Sampling using this method ensures that the water tested is actually consumed by the community, allowing the analysis results to reflect the actual risks and suitability of borehole water as a clean water source (Saputra et al., 2026; Lestari & Sri, 2024).

Sampling

In the analysis of rainwater and borehole water quality conducted in Sayolo 3, Kampung Tanjung, the research method used was quantitative descriptive analysis to visualize inorganic physical and chemical parameters, followed by laboratory testing. Data obtained from the field and laboratory test results were then compared with drinking water quality standards based on Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 (PerMenKes No. 2 of 2023) to assess the suitability of collected rainwater as a clean water source. The number of samples used in this study was two water samples, consisting of one rainwater sample (taken from a gutter in a residential area) and one well water sample (taken from a tap connected to a pump system), each containing 500 ml.
The parameters and methods applied in this study are as follows:

Table 1. Parameters and Testing Methods for Rainwater and Well Water Samples

No	Parameter	Testing Method
	I. Physic	
1	Temperature	Expansion
2	Odor	Organoleptic
3	Taste	Organoleptic
4	Color	Spectrophotometry
5	Total Dissolved Solids (TDS)	Gravimetry
6	Turbidity	Turbiditymeter
	II. Inorganic Chemical	
7	pH	pH Meter
8	Iron (Fe)	Atomization
9	Lead (Pb)	Atomization
10	Manganese (Mn)	Atomization
11	Nitrate-NO_3	Spectrophotometry
12	Hardness	Titrimetry

RESULT

In a study analyzing the quality of rainwater and borehole water as drinking water sources for coastal communities, the following results were obtained:

Table 2. Laboratory Test Results for Rainwater and Borehole Water Samples

No	Parameter	Unit	Maximum Permissible Level	Sample Code		Method
				Rainwater	Tap Water	
	I. Physic					
1	Temperature	^{0}C	Air temperature ± 3°C	27.2	27.1	Expansion
2	Odor	-	Odorless	Odorless	Odorless	Organoleptic
3	Taste	-	No taste	No taste	No taste	Organoleptic
4	Color	Units PtCo/Color	10	1.644	2.612	Spectrophotometry
5	Total Dissolved Solids (TDS)	mg/L	<300	5.0	211.0	Gravimetry
6	Turbidity	NTU	<3	0.41	0.36	Turbiditymeter
	II. Inorganic Chemical					
7	pH	-	6.5-8.5	6.39	7.36	pH Meter
8	Iron (Fe)	mg/L	0.2	0.000	0.309	Atomization
9	Lead (Pb)	mg/L	0.01	0.000	0.000	Atomization
10	Manganese (Mn)	mg/L	0.1	0.003	0.000	Atomization
11	Nitrate-NO_3	mg/L	20	0.0079	0.0449	Spectrophotometry
12	Hardness	mg/L	500	0.601	27.427	Titrimetry

DISCUSSION

Temperature

Temperature parameters indicate that the temperature of the rainwater samples was 27.2°C, while the temperature of the well water was 27.1°C. The analysis of physical parameters was based on temperature parameters according to the standard quality of ±3°C, where ±3°C is the minimum difference between the air temperature and the water sample temperature. It can be seen that all samples, both from rainwater and from wells, met the water quality standards for hygiene and sanitation purposes. Contaminated water has a temperature above or below air temperature (Nurasia, 2018). Temperature differences can be caused by factors such as sunlight intensity, heat exchange with the surrounding air, and geographical altitude (Aryasa & Rizky, 2019).

Odor

The analysis results for odor parameters showed that the rainwater and well water samples were odorless. This is in accordance with the provisions for odor and taste parameters in the quality standards stipulated in Minister of Health Regulation No. 2 of 2023 for hygiene and sanitation purposes, as well as mandatory drinking water parameters, rainwater and well water can be used as raw materials for processing into drinking water. Gafur et al. (2017) explained that odor in water is produced by aquatic organisms such as algae, gases such as H2S formed under anaerobic conditions, and certain organic compounds.

Taste

Laboratory tests showed that water normally used by the public is generally odorless, colorless, and tasteless. If water has a taste (except seawater), it indicates the dissolution of salts. Tasteful water typically originates from dissolved salts. This also indicates the dissolution of metal ions, which alters the concentration of hydrogen ions in the water. The taste and color parameters of rainwater and well water measured in this study were relatively similar to those of clean/hygienic water in general. This situation demonstrates that the taste of rainwater and borehole water still meets the clean/hygienic water quality standards set out in Minister of Health Regulation No. 2 of 2023. Rainwater quality, when evaluated based on taste and color parameters, remains within the clean/hygienic water quality standards for its intended use.

TDS (Total Dissolved Solids)

This is the number of dissolved solids, including organic ions, compounds, and colloids, present in water. As the total dissolved solids increase, water hardness also increases. Rainwater has a low TDS content due to its relatively low mineral content. This is due to the interaction of falling water with air before reaching the ground. Laboratory tests showed that the TDS value for rainwater was 5.0 mg/L, while the TDS value for borehole water was 211.0 mg/L. Although the TDS value from the processed water did not exceed the drinking water quality standards set out in Minister of Health Regulation No. 2 of 2023, it was still considered low, soft, and not rich in minerals. According to the WHO, drinking water should have a TDS of at least 300 mg/L and a maximum of 500 mg/L. Water with a TDS of 100 mg/L or below is classified as clean and soft water. Conversely, water with a TDS of 100-500 mg/L is classified as clean water, containing minerals. Solids can cause a foul odor and reduce dissolved oxygen levels. Solids can block sunlight from penetrating the water. The higher the TDS, the worse the water quality. High TDS is also detrimental for aquaculture, as it can impair oxygen circulation (Hanum, 2002).

Turbidity

The turbidity readings showed 0.41 NTU in rainwater and 0.36 NTU in well water. These figures are still far below the standard for clean water turbidity, which is a maximum of 25 Nephelometric Turbidity Units (NTU). Furthermore, the standard for drinking water turbidity is <3 NTU. Turbidity can be caused by dirt and dust in gutters or roof tiles. Turbidity reflects the optical properties of water, based on the amount of light absorbed or emitted by the materials in the water. High turbidity values can hinder filtration efforts and reduce the effectiveness of disinfection through water purification processes (Effendi, 2003). Turbidity can be caused by the presence of organic and inorganic materials in the water. From an aesthetic perspective, consumers are generally reluctant to drink colored water due to the potential health risks.

pH

The pH analysis results for refilled drinking water meet the standards set out in Minister of Health Regulation No. 2 of 2023 concerning drinking water quality requirements. Laboratory tests revealed a pH of 6.39 for rainwater, while well water was 7.36. The permissible pH range, according to Minister of Health Regulation No. 2 of 2023 concerning drinking water quality requirements, is 6.5-8.5. pH is a vital parameter in water quality analysis due to its influence on the biological and chemical processes within the water. It is used to describe the acidity and alkalinity of a solution. pH is determined using a pH meter; the pH measurement ranges from 0-14. A solution with a pH of 7 is considered neutral, a pH <7 is considered acidic, and a pH >7 is considered basic.

Water with a pH lower than 6.5, or an acidic pH, can increase corrosivity on metal objects, cause an unpleasant taste, and potentially cause health problems. In addition to affecting the taste of water, pH also indicates the presence of certain chemical compounds and microbes. A pH value above 7 indicates low corrosion resistance. This is because the lower the pH, the higher the corrosion resistance. Water quality, for pH parameters, should be neutral, neither acidic nor basic, to prevent heavy metal dissolution and water corrosion. The pH value of a solution represents the balance between acid and base in water, a measure of the concentration of hydrogen ions in a solution. A pH value greater than 7 tends to form scale and is less effective at killing bacteria. Therefore, neutral or weakly acidic conditions are more effective (Ningsih et al., 2018).

Iron (Fe)

Rainwater tests showed an Fe level of 0.000 mg/L, while borehole water showed 0.309 mg/L. This exceeds the standard for potable water. This is because the water exits through the borehole machine, flows through pipes, and exits through the water shell, which is made of iron. The hygienic water quality standard is 0.2 mg/L, as stipulated in Minister of Health Regulation No. 2 of 2023. Therefore, this rainwater is safe for use or drinking.

Water containing iron tends to cause nausea when consumed. Furthermore, in large doses, it can damage the intestinal wall and can even cause death. Meanwhile, Fe levels exceeding the threshold level can cause eye and skin irritation. Precipitation of $Fe(OH)_3$ can have detrimental effects, including contaminating zinc tubs, sinks, and toilets, corroding pipes, and depositing in pipelines, leading to blockages. Physical problems caused by dissolved iron in water include discoloration, odor, and taste (Joko, 2010).

For drinking water, the iron concentration is limited to a maximum of 0.2 mg/L. This limit is not solely for health reasons but is also established based on concerns about color, taste, the formation of scale on piping systems, and other aesthetic concerns. Humans and other living organisms require iron in certain amounts as a nutrient, but excessive levels should be avoided. For example, ferrous salts, such as ferrous sulfate ($FeSO_4$), with a concentration of 0.1-0.2 mg/L, can cause an unpleasant taste in drinking water. Large amounts of iron in drinking water can cause the water to turn an undesirable reddish-brown color (Said, 2005). The body needs iron as a vital mineral for water metabolism. The body requires 7-35 mg of this element daily, and it cannot be obtained solely from water. The presence of Fe in water causes the water to turn yellow-brown after (a short time) contact with air. Furthermore, it can be detrimental to health. Iron in water also causes an unpleasant odor, yellowing of the tub walls, and yellow spots on clothing (Iyabu et al., 2020).

Lead (Pb)

The analysis results for the lead (Pb) parameters in rainwater and well water samples were 0.000 mg/L, below the measurement limit of the measuring instrument. Lead (Pb) is a heavy metal that cannot be destroyed and is toxic when absorbed into the body. However, depending on where the heavy metal binds in the body, it can have negative effects on human health. Its toxicity can inhibit enzymes and halt metabolism. Heavy metals can also cause allergies, poisoning, and even death in high doses (Mairizki & Cahyaningsih, 2016). According to Minister of Health Regulation No. 2 of 2023, the maximum dissolved lead (Pb) water quality standard is 0.01. Therefore, the results indicate that rainwater and well water with lead (Pb) parameters in Sayolo 3, Kampung Tanjung can be used as raw materials for processing drinking water. This research is related to the studies by Heny et al. (2022) and Handriyani et al. (2020), which produced different findings. The results showed that lead (Pb) levels in all well water samples around the Kalipancur Landfill in Purbalingga Regency were below the detection limit, at less than 0.01 mg/L. Meanwhile, research by Handriyani et al. (2020) at the Banjar Suwung Batan Landfill in Kendal showed lead (Pb) levels in the range of 0.0060 to 1.023 mg/L. The discrepancy between the two studies is due to differences in sampling locations and significant differences in the results. Therefore, it is crucial for both the public and authorities to monitor lead levels in water and take the necessary steps to maintain safe and healthy water quality for consumption.

Manganese (Mn)

Manganese in raw water showed a reading of 0.003 mg in rainwater and 0.000 mg in well water. These values are still below the manganese (Mn) quality standard for drinking water, as stipulated in Minister of Health Regulation No. 2 of 2023, which is 0.1 mg/L. Therefore, both types of water can be used as clean water or drinking water.

Mn is an essential nutrient for the body, with a requirement of 10 mg, which can be obtained from food. This element is toxic to the respiratory system. In the human body, large amounts of manganese can accumulate in the liver and kidneys. Chronic manganese poisoning can cause nervous system disorders and symptoms similar to Parkinson's disease. Symptoms include nervous system symptoms such as insomnia, weakness in the legs and facial muscles, and frozen facial expressions, resulting in a mask-like appearance. Mn deposits will stain white objects. The presence of this element contributes to the odor and taste of beverages. Mn concentrations exceeding 0.1 mg/L can cause an unpleasant taste in beverages, leave a brown stain on laundry, and even cause liver damage (Said, 2005). Laboratory test results indicate that the water is still safe for consumption. This is also in line with research (Awliahasanah et al., 2021), which explains that univariate analysis showed a manganese content of 1.36 mg/L in well water from residents in Depok City. The calculated risk quotient (RQ) was less than 1, indicating that the manganese content in well water does not pose a risk for exposure over the next 30 years.

Nitrate-NO_3

The nitrate content in rainwater was 0.0079 mg/L, while the concentration in borehole water was 0.0449 mg/L. These levels are still far from the threshold for hygienic water and the limit required for drinking water.

Nitrate is a type of nitrogen oxide (NOx) that is largely produced through the combustion of fossil fuels. NOx is primarily produced through transportation; the presence of nitrate (NO_3^-) in rainwater is closely correlated with the natural nitrogen cycle. The nitrogen cycle demonstrates that nitrate can form from atmospheric N_2, fertilizers, and the oxidation of NO_2^- by bacteria of the Nitrobacter group (Ambarsari, 2004). Some natural water sources can naturally have high nitrate content due to geochemical processes or the presence of rocks containing nitrogen compounds (Joann et al., 2022).

Hardness

Lime is a substance that can damage the environment, including water pollution. Water containing high levels of lime is generally referred to as hard water. Water is considered hard if it has a lime content of 500 mg/L. Water with excessive lime content is not suitable for consumption. The effects of high lime ($CaCO_3$) content in water are very detrimental in daily life. Consuming large amounts of hard water can lead to kidney stones. Furthermore, hard water can disadvantage industries due to lime deposits on faucets. Furthermore, hard water prevents soap from foaming (Utami, 2017).

Rainwater hardness is 0.601 mg/L and 27.427 mg/L, both of which are still below the standard for hygienic and drinking water quality, which is 500 mg/L. Therefore, rainwater is considered safe for consumption.

CONCLUSION

The conclusion is a response to the stated objectives and is not intended to be a summary of the results. In the conclusion, the author must and only address the research problem and objectives formulated in the Introduction chapter. The conclusion is a generalization of the research findings and the author's arguments, or a brief statement that embodies the essence of the Results and Discussion chapter or the results of testing various related hypotheses.

Based on the analysis of rainwater and borehole water quality in Sayolo 3, Tanjung Village, South Sorong Regency, it can be concluded that, in general, rainwater meets all physical and inorganic chemical parameters as stipulated in Minister of Health Regulation No. 2 of 2023 concerning drinking water quality requirements. Meanwhile, the borehole water showed an iron (Fe) content of 0.309 mg/L, exceeding the maximum threshold of 0.2 mg/L, although other parameters remained within safe limits. Therefore, rainwater is more suitable as a direct drinking water source, while borehole water requires further treatment to reduce iron levels to ensure safe consumption.

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