

Article history

Submitted: 19 September 2024

Revised: 15 October 2024

Accepted: 3 November 2024

Published: 8 December 2024

***Corresponding author:**

arlin.ms@unimal.ac.id

COMPREHENSIVE ANALYSIS OF GROUNDWATER QUALITY IN BANTAYAN VILLAGE TOURISM AREA, NORTH ACEH: PHYSICAL, CHEMICAL, AND MICROBIOLOGICAL PERSPECTIVES**Syafrizal^a, Arlin Maya Sari^{a*}, Ucia Mahya Dewi^b, Nurul Azmi Nasution^a, Putri Fadillah^a**^aPhysics Education Department, Malikussaleh University, Aceh Utara, Indonesia.^bChemistry Education Department, Malikussaleh University, Aceh Utara, Indonesia.**Abstract**

The water quality of drilled wells in the tourist area of Bantayan village, North Aceh, has been carried out. This study aims to find out how suitable the water from the drilled well is for use by the community in the area. Samples were taken from five water sources of drilled wells with a depth of 3.5 m located in Bantayan village. The feasibility of water consumption can be assessed by testing the quality based on microbiological, physical, and chemical parameters. The parameters measured were color, turbidity, odor (physics), heavy metal content pH (chemical), and bacterial content (microbiology). The measurement results showed that although almost all water samples had water quality that met the standards based on physical and chemical parameters, the water sourced from the five borewells did not meet the standards of biological tests. Testing revealed the presence of total coliform and *Escherichia coli* (*E. coli*) ranging from 8-370 CFU/100 mL and 0-150 CFU/100mL, respectively. According to the requirements of the Regulation of the Minister of Health of the Republic of Indonesia No. 2/MENKES/2023 concerning drinking water quality, the acceptable levels for total coliform and *E. coli* in drinking water are 0 CFU/100mL. Therefore, the presence of these contaminants in the drilled well water renders it unsuitable for consumption, posing potential health risks to the community.

Keywords: Groundwater; Water quality; Bantayan; Quality parameters 10.24815/jcd.v12i2.41336Attribution-NonCommercial-ShareAlike 4.0 International
(CC BY-NC-SA 4.0)**INTRODUCTION**

Water is essential to human life quality as it underpins health, economic development, and environmental stability. Clean water access reduces the prevalence of waterborne diseases, directly impacting public health and life expectancy. Safe drinking water and improved sanitation practices are foundational for disease prevention, contributing to overall physical well-being, particularly in vulnerable groups such as children and the elderly. Furthermore, water availability influences economic stability, particularly through agriculture and industry. Reliable water sources enable agricultural productivity and food security, as irrigation supports consistent crop yields, stabilizing food prices and securing livelihoods. Industries, which rely on water for production, cooling, and waste management, drive job creation and economic growth, thereby elevating living standards. Moreover, energy production, particularly in hydroelectric and thermal plants, depends on accessible water resources, crucial for infrastructure development and economic resilience. When communities have a stable water supply, they experience growth in services, modernization, and improved quality of life.

Environmental health and social stability are also intricately linked to water availability and quality. Freshwater ecosystems support diverse species,

contributing to biodiversity, climate regulation, and natural water purification—essential services that benefit human communities by maintaining balanced ecosystems. Ecosystems like wetlands and forests, which naturally store water, enhance climate resilience by helping communities withstand floods and droughts, which are becoming more frequent with climate change. Social equity also improves with fair water distribution, as it reduces the burdens placed on women and children who often spend significant time collecting water in low-income regions, thereby opening up opportunities for education and economic participation. Furthermore, collaborative water management practices can help prevent conflicts over shared water resources, promoting peace and regional stability. Access to clean, nearby water also fosters mental well-being, as it reduces the daily stress of water scarcity and provides recreational and aesthetic benefits that enhance overall life quality. Thus, sustainable water management is integral to building resilient, equitable, and thriving communities worldwide, highlighting water's role as an indispensable resource for human advancement and environmental sustainability. Access to clean water is crucial for communities' drinking and activities such as agriculture, power generation, and industrial use. In many regions, groundwater has become one of the most reliable sources of clean water to meet these

demands, particularly when surface water is unavailable or contaminated. Groundwater, which is stored in and passes through underground rock formations known as aquifers [1], [2], serves as a vital supply for residential, agricultural, and industrial purposes [3], [4]. Its quality, however, depends on several factors, including the environment it flows through and the length of time it remains within geological layers. [5], [6], [7], [8], [9].

Seawater intrusion seriously threatens groundwater quality in coastal regions, such as Bantayan Village, or *Ulee Rubek*, a popular beach tourist destination. This phenomenon, common in areas near the coast, leads to saline contamination of groundwater, making it taste salty and unsuitable for consumption. To counter this, locals often dig shallow wells, which typically provide fresh water, as the density of fresh water is lower than that of saltwater, causing it to float on top of saltwater in the upper layers of the rock [9]. However, these shallow wells have limitations: they dry quickly and may not offer a sustainable water supply for daily needs. [10], [11].

As the tourism industry in Bantayan Village has grown, so has its population and infrastructure, leading to increased household waste. If this waste is not correctly managed, it can pollute the shallow groundwater, further compromising water quality [12]. Given this rapid development, it is essential to assess the groundwater quality in Bantayan, especially from drilled wells that residents rely on for drinking water and other household purposes. This study is particularly relevant in light of the growing population, which increases the demand for clean water and heightens the risk of contamination. [13], [14].

This research is guided by the Regulation of the Minister of Health No. 2 of 2023, which outlines the quality standards for drinking water [15]. These standards require that water be free from microbiological contaminants (such as harmful bacteria), physical pollutants (including turbidity and color), and chemical substances (such as heavy metals and hazardous waste) [16], [17], [18]. It also emphasizes the importance of hygiene and sanitation in managing and delivering water to ensure public health [19].

The findings are expected to provide critical information for the local community, enabling them to decide whether water from drilled wells is suitable for consumption or should be restricted to other uses, such as washing and bathing. Moreover, the results will help stakeholders determine optimal locations for future borewells to meet the increasing demand for clean water, particularly for public facilities such as worship spaces. [20]. With tourism continuing to develop in Bantayan Village, ensuring access to safe and reliable water is essential for the well-being of both residents and visitors.

METHOD

The water quality research of this drilled well consists of several stages: field orientation based on the

description of geological maps and Google Earth images, an initial survey of the research location to determine the location of water sampling points, sampling of drilled well water, pH data measurement, water quality tests in the Aceh Institute of Standardization Industrial Service, including data processing and data interpretation.

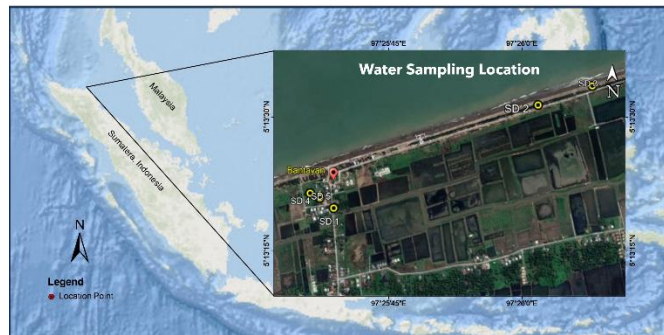


Figure 1. Water sampling location

This research is located in Bantayan Village, *Seunuddon* District, North Aceh Regency, Aceh Province. It was conducted across five points of drilled wells used by the community. The parameters measured in groundwater quality data are microbiological (bacteria), physics (pH, color, temperature, turbidity, and odor), and chemistry (heavy metal content, etc.).

Water sampling was carried out at 5 points. Groundwater quality data is collected by sampling water from drilled wells. Then, the water samples were analyzed at the Testing Laboratory of the Industrial Services Standardization and Service Center in Banda Aceh. The pH is measured using a portable pH meter, and the temperature is measured directly in the field using a thermometer. The heavy metal measurement in water was conducted using EDTA Titration. Water samples (500 mL) are collected from five locations and filtered to remove large particles. The sample's pH is adjusted to 10 using an ammonia buffer solution. Eriochrome Black T (EBT) indicator (2-3 drops) is added to detect the presence of heavy metal ions (Ca^{2+} , Mg^{2+}). The sample is titrated with 0.01 M EDTA solution and added dropwise while stirring continuously until the color changes from red to blue, indicating all metal ions have complexed with EDTA. The volume of EDTA used is recorded, and heavy metal concentration is calculated based on stoichiometry.

The Multiple-Tube Fermentation (MTF) method is employed for total coliform testing. Samples are inoculated into Lauryl Tryptose Broth (LTB) and incubated at 35°C for 24-48 hours. Positive tubes showing gas formation are transferred to Brilliant Green Lactose Bile Broth (BGLB) for confirmation. For *E. coli*, samples are inoculated into EC Broth and incubated at 44.5°C. Membrane filtration passes water through m-Endo agar and m-FC agar for coli form and *E. coli* identification, respectively. Results are compared with

SNI 3554:2015 standards. Meanwhile, collecting coordinate data for water sampling locations uses the GPS coordinate application on mobile phones.

Table 1. Coordinate Point of Borewell Water Sampling Location

Point	Latitude	Longitude	Depth (m)
SD 1	05°13'19,40" N	97°25'38,59" E	3.5
SD 2	05°13'31,02" N	97°26'3,11" E	3.5
SD 3	05°13'33,52" N	97°26'08,21" E	3.5
SD 4	05°13'20,57" N	97°25'36,97" E	3.5
SD 5	05°13'21,07" N	97°25'35,87" E	3.5

The water quality of drilled wells is interpreted based on microbiological, physical, and chemical parameter data obtained from the results of lab tests linked to the Minister of Health Regulation No. 2 of 2023.

RESULTS AND DISCUSSION

The research on groundwater quality analysis in the Bantayan Village tourist area, North Aceh aims to determine the quality of drilled well water in the coastal tourist area of Bantayan Village based on physical and chemical parameter data. The location of this research is geologically based on the geological map of the Lhokseumawe [21] is included in the unnamed surface deposit formation consisting of coastal and fluvial deposits. An initial research team has carried out an initial survey to determine 5 (five) points of location for sampling water from drilled wells in Bantayan Village, Seunuddon District, North Aceh Regency. The coordinates of the selected points are given in the following picture. The SD 1 sample is a sample taken from a drilled well in a residential area in Bantayan village. Samples of SD 2 and SD 3 were sourced from a drilled well in the tourist center of Bantayan village. The SD 4 sample was sourced from a drilled well in Meunasah of Bantayan village. while the SD 5 sample was sourced from a drilled well of the Islamic boarding school located in Bantayan village. Water samples at each location point are taken 2 bottles of water samples with a size of 5 liters/each container.

Clean water is the standard for environmental health quality for air media for sanitation hygiene purposes, including physical, biological and chemical parameters which can be mandatory parameters and additional parameters [22]. Interpretation of groundwater quality (well water) at this research location refers to the Regulation of the Minister of Health of the Republic of Indonesia No. 2/MENKES/2023 concerning environmental health quality standards and health requirements for water media for drinking water and for hygiene and sanitation purposes. Mandatory parameters for drinking water consists of types of microbiological parameters (escherichia coli and total coliform), physical (odor, dissolved solids, color and turbidity) [23], and chemical (pH, dissolved nitrate (as NO₃), dissolved nitrite (as

NO₂), 6-valent chromium (Cr⁶⁺) (dissolved), iron (Fe) (dissolved), manganese (Mn) (dissolved), residual chlorine (dissolved), arsenic (As) (dissolved), cadmium (Cd) (dissolved), lead (Pb) (dissolved), fluoride (F) (dissolved), and aluminum (Al) (dissolved)). Good water quality includes physical, chemical and biological quality tests, so that when consumed it does not cause side effects for health [22].

Meanwhile, the mandatory parameters for hygiene and sanitation purposes are fewer than for drinking water, where the chemical parameters only consist of pH, dissolved nitrate (as NO₃), dissolved nitrite (as NO₂), 6-valent chromium (Cr⁶⁺) (dissolved), iron (Fe) (dissolved), and manganese (Mn) (dissolved). The results of data from water samples from drilled wells in Bantayan Village obtained after being tested at the Testing Laboratory Industrial Services Standardization and Service Center as follows.

Table 2. Water quality analysis results from SD1 sample

Parameters	Standard	Results
<i>Physical</i>		
Odor	Odorless	Odorless
Color (TCU)	Normal	1
Muddiness (NTU)	Max.<3	0.05
<i>Chemical</i>		
Fluoride (mg/L)	Max. 1.5	0.8265
Nitrate (mg/L)	Max. 20	8.5543
Nitrite (mg/L)	Max. 3	14.4925
Dissolved iron (mg/L)	Max. 0.2	<0.0008 [#]
TDS (mg/L)	<300	290
pH		7.7
<i>Microbiology</i>		
Total Coliform (CFU/100ml)	0	370
<i>E. coli</i> (CFU/100ml)	0	150

SD 1 point is a drilled well located in a community house, where the water from the drilled well is used for household activities. The drilled well has a depth of 3.5 m. Approximately 10 meters south of the SD 1 location, there is a small river. The soil composition, predominantly made up of silt and sand, facilitates the infiltration of river water into the borewell. The results of the drilled well water quality test at this point location showed that the drilled well water was not suitable for consumption because the results of the chemical test type, namely the Nitrite test (As NO₂ (dissolved) obtained were 14.4925 mg/L exceeding the maximum threshold of 3 mg/L. High levels of nitrite in drinking water can have harmful effects on health, one of which is causing methemoglobinemia [24]. The microbiological test results showed a total coliform count of 370 CFU/100 mL and an *E. coli* count of 150 CFU/100 mL. Where the requirements based on Permenkes No.2/2023 should be that both microbiological tests have a value of 0. So it can be stated that the quality of the water of the drilled well at this point is not suitable for consumption. The total dissolved solids (TDS) based on the data from the test results in the laboratory obtained a result of 290 mg/L.

This proves that the sample point contains organic compounds and inorganic compounds. Organic compounds provide nutrients for aquatic microbes. The high levels of nitrite and *E. coli* at this point may be caused by organic waste pollution in the small river located 10 meters from the borewell. The decomposition of waste in the river promotes the growth of microorganisms and pathogenic microbes [25]. The decaying organic matter in small rivers can lead to the development of microorganisms and pathogenic microbes, which eventually seep into the ground through the soil's pores and contaminate borehole water. This phenomenon, often linked to the decomposition of animal or plant matter, can release harmful bacteria, such as *e-coli* and other coliform bacteria, into the groundwater. As these bacteria proliferate, they pose a significant risk to water quality, especially if the water is used for drinking or household purposes [26].

Table 3. Water quality analysis results from SD2 sample

Parameters	Standard	Results
<i>Physical</i>		
Odor	Odorless	Odorless
Color (TCU)	Normal	1
Muddiness (NTU)	Max.<3	0.05
<i>Chemical</i>		
Fluoride (mg/L)	Max. 1.5	0.3541
Nitrate (mg/L)	Max. 20	9.2357
Nitrite (mg/L)	Max. 3	1.8937
Dissolved iron (mg/L)	Max. 0.2	<0.0008 [#]
TDS (mg/L)	<300	206
pH		7.47
<i>Microbiology</i>		
Total Coliform (CFU/100ml)	0	53
<i>E. coli</i> (CFU/100ml)	0	5

SD point 2 is a point on the beach with a distance of approximately 30 m from the sea. SD 2 drilled well water is not used for consumption but only for bathing and washing. The results of the borewell water quality test at the location of SD point 2 obtained the result that the borewell water was not suitable for consumption due to the results of the type of microbiological testing, namely total coliform 53 CFU/100 ml and also *E. coli* 5 CFU/100 ml. The high levels of total coliform and *E. coli* contamination in groundwater near waste discharge areas (about 10 meters), especially in sandy soils, can be linked to the proximity of the borehole to potential contamination sources like bathroom drains or washing areas. Sandy soils, with their high permeability, allow contaminants from organic waste, such as those found in domestic wastewater, to easily infiltrate through soil layers into groundwater sources.

Studies have shown that factors like the hydrogeology of an area, particularly in sandy or porous soils, exacerbate the ease with which pathogenic microorganisms like *E. coli* and total coliforms travel through the subsurface into water wells, especially when these wells are less than 52 meters

deep. In arid and semi-arid regions, this contamination is further aggravated due to the scarcity of surface water, leading to a reliance on shallow boreholes for water consumption, heightening the risk of microbial contamination [27], [28].

The presence of waste discharge, organic materials, and nitrates in the groundwater system can lead to long-term contamination, posing a threat to human health through waterborne diseases.

Table 4. Water quality analysis results from SD3 sample

Parameters	Standard	Results
<i>Physical</i>		
Odor	Odorless	Odorless
Color (TCU)	Normal	1
Muddiness (NTU)	Max.<3	0.05
<i>Chemical</i>		
Fluoride (mg/L)	Max. 1.5	0.3276
Nitrate (mg/L)	Max. 20	0.0992
Nitrite (mg/L)	Max. 3	<0.0043 [#]
Dissolved iron (mg/L)	Max. 0.2	<0.0008 [#]
TDS (mg/L)	<300	222
pH		7.99
<i>Microbiology</i>		
Total Coliform (CFU/100ml)	0	58
<i>E. coli</i> (CFU/100ml)	0	1

SD Point 3 is also a point located on the beach with a distance of approximately 30 m from the sea. Like the water from the SD 2 drilled well, the water from the SD 3 well is also not used for consumption, but only for bathing and washing. Based on direct observation, the water sample at this point is the clearest and has the highest pH value among other samples, which is 7.99 (table 4.1). The results of the borewell water quality test at the location of SD point 3 (table 4.4) obtained the result that the borewell water was not suitable for consumption due to the results of the type of microbiological testing, namely total coliform 58 CFU/100 ml and also *E. coli* 1 CFU/100 ml.

E. coli in drinking water poses serious health risks because it indicates fecal contamination, signaling that harmful pathogens may have entered the water supply. *E. coli* itself is a diverse group of bacteria; At the same time, most strains are harmless and even part of the healthy human gut flora, some pathogenic strains, like *E. coli* O157:H7, can cause severe gastrointestinal illnesses. These illnesses often manifest as intense stomach cramps, diarrhea (sometimes bloody), vomiting, and fever. In vulnerable groups, including children, the elderly, and those with weakened immune systems, infections can progress to more serious conditions, such as hemolytic uremic syndrome (HUS), which can lead to kidney failure and even death. In addition, *E. coli* is used as a key indicator organism in water quality testing, meaning its presence often reflects broader microbial contamination, as it can coexist with other harmful pathogens, including viruses (e.g., norovirus, hepatitis A), bacteria (e.g., *Salmonella*, *Shigella*), and protozoa (e.g., *Giardia*,

Cryptosporidium). When total coliform counts are also elevated, as in the reported borewell water with 58 CFU/100 mL, it confirms a high likelihood of environmental contamination due to compromised sanitary conditions. While total coliforms alone are generally not harmful, their presence alongside *E. coli* strengthens concerns that the water may carry a range of pathogens. To ensure water safety, effective disinfection methods, such as chlorination or ultraviolet (UV) treatment, are necessary to eliminate potential threats. Thus, the borewell water in question is unsuitable for consumption without proper treatment, as it poses health risks through both direct infection from *E. coli* and potential exposure to a broader spectrum of pathogens.

Table 5. Water quality analysis results from SD4 sample

Parameters	Standard	Results
<i>Physical</i>		
Odor	Odorless	Odorless
Color (TCU)	Normal	1
Muddiness (NTU)	Max.<3	1
<i>Chemical</i>		
Fluoride (mg/L)	Max. 1.5	0.1130
Nitrate (mg/L)	Max. 20	2.2712
Nitrite (mg/L)	Max. 3	0.0487
Dissolved iron (mg/L)	Max. 0.2	<0.0008 [#]
TDS (mg/L)	<300	126
pH		7.62
<i>Microbiology</i>		
Total Coliform (CFU/100ml)	0	16
<i>E. coli</i> (CFU/100ml)	0	0

SD point 4 is a point located in Bantayan. SD 4 drilled well water is used for ablution water. The results of the borewell water quality test at the location of SD point 4 obtained the result that the borewell water was not suitable for consumption due to the results of the type of microbiological testing, namely a total coliform of 16 CFU/100 ml. total coliforms are indicators of potential contamination, often associated with fecal matter, even if the source of contamination is not immediately apparent. Even though the borehole is located far from waste disposal and sanitation facilities, the presence of total coliform could stem from various factors. Research suggests that coliform bacteria can originate from environmental sources, such as soil, sediments, or wildlife, which may introduce bacteria into the groundwater system [29]. The cloudy condition of the water is attributed to the upper soil layer at the site, which consists of a clay layer. This composition allows the water to mix with the borewell water due to the shallow depth of the borewell.

Table 6. Water quality analysis results from SD5 sample

Parameters	Standard	Results
<i>Physical</i>		
Odor	Odorless	Odorless
Color (TCU)	Normal	1
Muddiness (NTU)	Max.<3	0.05
<i>Chemical</i>		

Fluoride (mg/L)	Max. 1.5	0.6351
Nitrate (mg/L)	Max. 20	4.0440
Nitrite (mg/L)	Max. 3	0.0158
Dissolved iron (mg/L)	Max. 0.2	<0.0008
TDS (mg/L)	<300	22
pH		7.67
<i>Microbiology</i>		
Total Coliform (CFU/100ml)	0	8
<i>E. coli</i> (CFU/100ml)	0	8

SD Point 5 is a point where the borehole water is used for bathing, washing and ablution water activities by students at an Islamic Boarding in Bantayan Village. The results of the borewell water quality test at the location of SD 5 (table 4.6) obtained the result that the borewell water was not suitable for consumption due to the results of the type of microbiological testing, namely total coliform 8 CFU/100 ml and also *E. coli* 8 CFU/100 ml. While the water source is located far from waste disposal sites, its proximity to livestock enclosures raises significant concerns regarding potential contamination.

Research indicates that animal waste can be a major source of coliform bacteria in water supplies. Livestock excretions may contain pathogens and nutrient-rich waste, which can easily leach into nearby water sources, especially in areas where surface runoff occurs or where groundwater is recharged through permeable soil. Studies have shown that even in well-maintained environments, the presence of animals near water sources can lead to bacterial contamination, affecting water quality and posing health risks to consumers.

In general, the water quality results obtained at all points of drilled wells have met the standard of physical parameters, but all points do not meet the standard of microbiological parameters. As for the standard chemical parameters, only SD point 1 does not meet.

CONCLUSION

The results of testing drilled well water samples to determine water quality based on physical, chemical and microbiological parameters at 5 drilling locations (SD 1, SD 2, SD 3, SD 4, and SD 5) in Bantayan Village, Seunuddon District, showed that the quality of drilled well water at these points was not suitable for consumption according to the requirements of the Regulation of the Minister of Health of the Republic of Indonesia No. 2/MENKES/2023 concerning drinking water quality. Generally, all five sampling points have met the requirements for physical parameters testing (odor, total dissolved solids, color, and turbidity) and chemical parameters (SD 2, SD 3, SD 4, and SD 5). However, none of the borewell sites met the microbiological testing standards.

Several concrete steps can be taken to improve water quality in Bantayan Village, including establishing proper wastewater management systems to prevent contamination, conducting community education programs on sanitation, and implementing regular

water quality monitoring. Upgrading borewell infrastructure and collaborating with local authorities will also enhance water safety. Future research directions should focus on identifying specific contamination sources, exploring effective treatment technologies, conducting hydrological studies to understand water flow, and assessing the health impacts of contaminated water. These initiatives will improve drinking water quality and promote community health and sustainability in the area.

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