JOURNAL OF INTERDISCIPLINARY PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 3 No. 6, pp. 128-134, June 2025

Assessment of Groundwater Quality in Barangay Poblacion, Ayungon: Water Safety Education in WinS Program

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Date received: March 9, 2025
Date revised: April 19, 2025
Date accepted: May 15, 2025

Originality: 99%
Grammarly Score: 99%
Similarity: 1%

Recommended citation:
Malones, K., & Despojo, A. G. (2025). Assessment of groundwater quality in Barangay Poblacion, Ayungon: Water Safety Education in WinS Program. *Journal of Interdisciplinary Perspectives*, 3(6), 128–134.
https://doi.org/10.69569/jip.2025.202

Abstract. Clean and safe access to water is vital in human health and wellness, and thus regular water quality assessment is very important in avoiding waterborne disease and promoting public safety. Thus, the study aimed to assess the groundwater quality in Barangay Poblacion, Ayungon, Negros Oriental focusing on both microbiological and physicochemical parameters during dry and rainy seasons. The researcher utilized descriptive designs and employed simple random sampling. The water sampling was done during both rainy and dry periods at three groundwater sources for drinking. Microbiological and physicochemical analyses of the water samples were performed by third-party laboratories. The findings revealed that while the groundwater met the 2017 Philippine National Standards for Drinking Water (PNSDW) for total dissolved solids (TDS), color, nitrate, turbidity, arsenic, cadmium, lead, hardness, and heterotrophic plate count (HPC), it failed in terms of pH levels and coliform bacteria, indicating potential contamination risks. These findings emphasize the need for continued drinking water quality monitoring, enhanced sanitation practices, and sustained public education to ensure safe water consumption and prevent waterborne diseases.

Keywords: Microbiological; Physicochemical; Water quality; Assessment of groundwater quality.

1.0 Introduction

Access to clean and safe drinking water is a global concern, especially in schools where children rely on water daily. Fayaji et al. (2019) found that groundwater quality assessments over three years indicated total dissolved solids (TDS) levels exceeding the standard limit. Meanwhile, Hassan et al. (2022) reported that 50% of sampled wells in Ad-Dawadmi, Saudi Arabia, were contaminated with total coliform bacteria. Similarly, Mahami and Odonkor (2020) stressed the importance of microbiological testing, as contaminated drinking water can lead to diarrhea and other illnesses. These findings underscore the urgent need for continuous monitoring and improvement of drinking water sources to protect public health, aligning with Sustainable Development Goal (SDG) 3, which aims to ensure good health and well-being for all.

In the Philippines, groundwater serves as a primary source of drinking water, accounting for over 50% of the nation's supply and 85% of piped water (British Geological Survey, 2021). However, during the dry season, many communities experience water shortages and must depend on potentially unsafe sources. Studies have indicated that groundwater in certain areas becomes turbid and contaminated with coliform bacteria during this period (Yazawa et al., 2024). For instance, Yazawa et al. (2024) found coliforms in household drinking water samples in

Barbaza, Antique, posing health risks to residents. These challenges emphasize the need for improved access to clean water and sanitation, which directly supports SDG 6, centered on ensuring the availability and sustainable management of water and sanitation for all.

This study focuses on assessing groundwater quality in Barangay Poblacion, Ayungon, Negros Oriental, where groundwater serves as a vital resource for the community, including Ayungon Central School. While previous studies evaluated groundwater in different parts of the Philippines (Sudaria et al., 2020; Faulmino et al., 2023), limited research has been conducted in Negros Oriental, making this study a pioneering effort in Barangay Poblacion. The study evaluated the water quality in terms of microbiological and physicochemical parameters of Barangay Poblacion in accordance with the PNSDW (2017).

2.0 Methodology

2.1 Research Design

One liter of water was collected from each well for physicochemical analysis, while a sterile bottle provided by the testing laboratory was used to collect samples for microbiological analysis. Water samples for microbiological testing were collected during the hot period and during the rainy period. Meanwhile, samples for physicochemical analysis were also collected for the hot and rainy periods. As expected, only one sample was obtained for the rainy season due to heavy rains and the site location where the wells are near the river banks. Microbiological samples were submitted to Metro Dumaguete Water Laboratory, located at Metro Dumaguete Water Office, Diego dela Viña Road, Barangay Daro, Dumaguete City, Negros Oriental. Samples for physicochemical characterization were sent to Alpha Laboratory Calamba, Philippines Corporation, located at LTO Road, Real, Calamba, Laguna, for analysis of pH, total dissolved solids (TDS), color, nitrate, turbidity, arsenic, cadmium, lead, and total hardness. During sample collection, the presence or absence of bio-indicators was also observed at the sampling sites. The selected water parameters were based on the 2017 Philippine National Standards for Drinking Water (PNSDW) under mandatory parameter requirements. The water samples were tested to assess potability and determine whether their numerical values met or deviated from the standards.

2.2 Research Environment

The study was conducted in Barangay Poblacion, Ayungon, Negros Oriental, Philippines, a municipality located in the northern part of Negros Oriental, along the Tanon Strait, approximately 82 kilometers from Dumaguete City. Water samples were collected twice at appropriate periods from three groundwater sources. These sites were selected based on their significance as local drinking water sources, particularly for residents in Purok 4 and Purok 5. The vicinity includes residential areas, small businesses, and public institutions, making it essential to assess the water quality for community health and safety.

2.3 Research Instrument

Laboratory tests were utilized in the study to analyze the physicochemical properties of groundwater and the presence of microorganisms. The instruments used during laboratory testing were spectrophotometer, multi-tester, and classical titration set-up. This testing was done in DOH accredited laboratories.

2.4 Ethical Consideration

Research ethics was strictly observed and maintained throughout the duration of the study. First, ethical approval was obtained from the Ethics Committee of Foundation University Research Office prior to conducting this investigation. Moreover, all respondents were asked to sign the informed consent form attached to the questionnaire. The right to self-determination, confidentiality, and anonymity, as well as the benefits and risks of the study, were also emphasized and upheld. Additionally, the researcher declared that Open AI's GPT-3 and Quillbot were utilized as tools to enhance the readability of this manuscript. After using these tools, the author carefully reviewed and edited the manuscript and took full responsibility for its content.

3.0 Results and Discussion

3.1 Microbiological and Physicochemical Assessment of the Groundwater Quality in Poblacion Ayungon

Tables 1 and 2 present the microbiological analysis of groundwater in Barangay Poblacion, focusing on total coliforms, thermotolerant coliforms, and heterotrophic plate counts (HPC). The results show consistent contamination of coliforms across all tested wells (Wells 1, 2, and 3) during both rainy and dry seasons.

Table 1. *Quality of the Groundwater as Drinking Water Resource in Barangay Poblacion Microbiological Analysis Result (Hot/Dry Period)*

Parameter	Method	Limits*	Results			Mean
			Sample No. 1 *Well 1*	**Sample No. 2** *Well 2*	**Sample No. 3** *Well 3*	
Total Coliform (MPN/100mL)	Multiple Tube Fermentation Technique (MTFT)	<1.1	>8.0	>8.0	>8.0	>8.0
Thermotolerant Coliform (MPN/100mL)	Multiple Tube Fermentation Technique (MTFT)	<1.1	>8.0	>8.0	>8.0	>8.0
Heterotrophic Plate Count (CFU/mL)	Pour plate	<500	7	42	42	30

*Based on PNSDW2017

Table 2. *Quality of the Groundwater as Drinking Water Resource in Barangay Poblacion Microbiological Analysis Result (Rainy Days)*

Parameter	Method	Limits*	Results			Mean
			Sample No. 1 *Well 1*	**Sample** No. 2 *Well 2*	**Sample** No. 3 *Well 3*	
Total Coliform (MPN/100mL)	Multiple Tube Fermentation Technique (MTFT)	<1.1	>8.0	-	-	>8.0
Thermotolerant Coliform (MPN/100mL)	Multiple Tube Fermentation Technique (MTFT)	<1.1	>8.0	-	-	>8.0
Heterotrophic Plate Count (CFU/mL)	Pour plate	<500	18	-	-	18

*Based on PNSDW2017; -sampling is not possible

Total coliform levels in all samples exceeded 8.0 MPN/100 mL, which is far above the Philippine National Standards for Drinking Water (PNSDW, 2017) limit of <1.1 MPN/100 mL. This suggests possible fecal contamination, making the groundwater unsafe for drinking without proper treatment. Similarly, thermotolerant coliform levels also surpassed the allowable limits, further confirming significant microbial pollution. Moreover, heterotrophic plate count (HPC) values in Barangay Poblacion ranged from 7 to 42 CFU/mL, with an average of 30 CFU/mL in the dry season. While these values are within the PNSDW's acceptable limit of 500 CFU/mL, their presence, along with high total and thermotolerant coliform counts, suggests potential contamination risks.

A similar study in Pampanga by Cortez et al. (2023) also found high thermotolerant coliform levels in water sources near agricultural and residential areas, emphasizing the widespread problem of fecal contamination in the country. Research on the Matutinao River in Cebu also exposed elevated HPC levels, reaching as high as 4.57×10^5 CFU/mL, pointing to significant microbial activity (Bureros et al., 2022). Although HPC alone does not indicate fecal contamination, its increase alongside coliforms raises concerns about water quality. The combined results from total coliforms, thermotolerant coliforms, and HPC demonstrate microbial contamination in Barangay Poblacion's groundwater. This indicates on-going pollution, likely due to factors like agricultural runoff, septic system leaks, or improper waste disposal. Research has shown that the presence of thermotolerant coliforms and high HPC levels often correlates with a greater risk of harmful microorganisms in drinking water (Amatobi & Agunwamba, 2022).

Tables 3 and 4 show the physicochemical analysis of groundwater in Barangay Poblacion for both rainy and dry periods. The pH levels were consistently below the recommended range of 6.5–8.5, with values between 4.9 and 5.8 during rainy and dry seasons, indicating that water samples are acidic. According to Chegbeleh et al. (2020),

the acidity of groundwater can be due to carbonic acid precipitation, oxidation of sulfur and nitrogen compounds, dissociation of humic acid, the hydrolysis and oxidation of ferrous iron, and cation exchange.

Table 3. *Quality of the Groundwater as Drinking Water Resource in Barangay Poblacion Physicochemical Analysis Result (Hot/Dry Period)*

Parameter	Unit	Method	Limits*	Results			Mean
				Sample No. 1 *Well 1*	Sample No. 2 *Well 2*	Sample No. 3 *Well 3)*	
Potential hydrogen(pH)		Electrometric(SMEWW Part 4500-H+)	6.5-8.5	5.2	4.9	5.4	5.2
Total dissolved Solids(TDS)	mg/L	Conductometric Method	600	116	115	156	129
Color (Apparent)	CU	Visual Comparison (SMEWW2120B)	10	<1	<1	<1	<1
Nitrate	mg NO_3-N /L	Nitrate Electrode Method(SMEWW 4500-NO3- D)	50	<1	<1	<1	<1
Turbidity	NTU	Photometric (Nephelometric Method, SMEWW 2130B)	5.0	<1	<1	<1	<1
Arsenic	mg/L	ICP Method(SMEWW 3120B)	0.01	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/L	ICP Method(SMEWW 3120B)	0.003	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	ICP Method(SMEWW 3120B)	0.01	<0.003	<0.003	<0.003	<0.003
Total hardness	mg $CaCO_3$/L	EDTA Titration (SMEWW Part 2340C)	300	62	57	86	68

*Based on PNSDW2017

Table 4. *Quality of the Groundwater as Drinking Water Resource in Barangay Poblacion Physicochemical Analysis Result (Rainy Days)*

Parameter	Unit	Method	Limits*	Results			Mean
				Sample No. 1 *Well 1*	Sample No. 2 *Well 2*	Sample No. 3 *Well 3*	
Potential hydrogen(pH)		Electrometric(SMEWW Part 4500-H+)	6.5-8.5	5.8	-	-	5.8
Total dissolved Solids(TDS)	mg/L	Conductometric Method	600	101	-	-	101
Color (Apparent)	CU	Visual Comparison (SMEWW2120B)	10	<1	-	-	<1
Nitrate	mg NO_3-N /L	Nitrate Electrode Method(SMEWW 4500-NO3- D)	50	1.2	-	-	1.2
Turbidity	NTU	Photometric (Nephelometric Method, SMEWW 2130B)	5.0	<1	-	-	<1
Arsenic	mg/L	ICP Method(SMEWW 3120B)	0.01	<0.01	-	-	<0.01
Cadmium	mg/L	ICP Method(SMEWW 3120B)	0.003	<0.005	-	-	<0.005
Lead	mg/L	ICP Method(SMEWW 3120B)	0.01	<0.01	-	-	<0.01
Total hardness	mg $CaCO_3$/L	EDTA Titration (SMEWW Part 2340C)	300	66	-	-	66

*Based on PNSDW2017; -sampling is not possible

The results indicate that Well 1 has a higher pH value during the rainy season compared to the dry period. One factor contributing to this difference is the decreased rainfall during the dry season, which reduces groundwater recharge. This reduction leads to a higher concentration of dissolved substances, including acids, thereby lowering the pH (Winter, 2000). Research suggests that the oxidation of pyrite, triggered by exposure to oxygen during periods of lowered water tables, contributes to groundwater acidification. This process intensifies during dry

seasons when reduced water tables expose more sulfide minerals to atmospheric oxygen (Medawela & Indraratna, 2024).

Furthermore, acidic water can lead to metal leaching from pipes and pose significant health risks. Research has linked it to digestive issues and metal toxicity, particularly in vulnerable groups such as children and pregnant women (Chima et al., 2020). Likewise, a study by Saalidong et al. (2022) reported similar findings, showing that 36 water samples from both groundwater and surface water had pH levels outside the acceptable standards. Ayeni et al. (2023) also conducted a monthly assessment of shallow-well water during the rainy and dry seasons and observed consistently acidic pH values. Their study also found a direct correlation between pH levels and the number of rainy days in a month.

Total Dissolved Solids (TDS) levels ranged from 101 to 156 mg/L, remaining well within the 600 mg/L limit set by the Philippine National Standards for Drinking Water (PNSDW). These levels indicate a safe amount of dissolved minerals, which can enhance taste and reduce scaling in pipes (Pushpalatha et al., 2022). Notably, Well 1 had a higher TDS value during the dry season (15 mg/L higher than in the rainy period), possibly due to less recharge from rain fall and lowered water tables (Muselli et al., 2021; Medawela & Indararatna, 2024). Furthermore, a study by Shah et al. (2022) found an average TDS value of 444 mg/L in Pakistan, which also met the standard limit. However, TDS levels alone do not confirm water safety, as harmful substances such as heavy metals and nitrates may still be present (Ahmad et al., 2023).

The water's color was consistently below 1 CU, within the 10 CU limit set by PNSDW, meaning it appears clear. Similar results were found in a study by Magwilang et al. (2023), where water samples had an apparent color of 0 CU, meeting the standard. Having clear water, however, does not always mean it is free from harmful substances. Nitrate levels (as NO3-N) were low; however, it can be observed that the values are <1 during the dry season while the rainy season has a value of 1.2. This increase in nitrate values can be due to the runoff from nearby households or agricultural areas. Studies have found that nitrogen from agricultural activities is the primary source of nitrates in rivers and groundwater (Wang et al., 2020; Yang et al., 2020; Chegbeleh, et al., 2020). On the other hand, though nitrates were detected, the nitrate level still did not reach the maximum allowable limit established by DOH and PNSDW. This suggests that the water is not significantly affected by agricultural runoff or wastewater contamination (Patel et al., 2022). A study by Van den Brand et al. (2020) found similar low nitrate concentrations in water samples from the Netherlands. While current levels are safe, continuous monitoring is necessary as land use changes could increase nitrate contamination over time.

Turbidity levels were consistently below 1 NTU, within the 5 NTU limit set by PNSDW. Low turbidity implies that the water is visually clear and free from large suspended particles. These findings correspond with the studies by Senapilo et al. (2024) and Fetrat and Islam (2024), which reported similar turbidity levels. However, turbidity alone does not confirm water safety, as suspended particles can shield pathogens from disinfection (Muoio et al., 2020). Heavy metals, including arsenic, cadmium, and lead, were all below detection limits, meaning the groundwater does not currently pose a risk from these contaminants. Saalidong et al. (2022) found an average arsenic concentration of 0.005 mg/L in their study, also within safe limits. In contrast, Poonia et al. (2021) observed arsenic levels as high as 1.36 mg/L, which is over a hundred times higher than the limit. Similarly, cadmium concentrations in this study were <0.005 mg/L, aligning with the results of Besagas et al. (2022), who recorded 0.002 mg/L in Cagayan de Oro. For lead, levels remained <0.01 mg/L, which agrees with Senapilo et al. (2024) but contrasts with Chegbeleh et al. (2020), who found much higher concentrations of 0.04 mg/L. Since lead contamination can come from industrial activities and old pipes (Madhav et al., 2021), regular monitoring is necessary.

Total hardness levels ranged from 57 mg/L to 86 mg/L, staying well below the 300 mg/L limit. This means the water has hardness but not harmful. By examining the results, Well 1 has a higher total hardness value of 4 during rainy season compared to the dry period. In congruent to the study, a study by Ayeni et al. (2023) also found that hardness was observed to be highest on rainy and lowest on dry period from hand-dug wells. Similar results, which passed the DOH standard and PNSDW, were also found in the study by Chegbeleh et al. (2020), where the total hardness was 205 mg/L. While hard water is not a health risk, it can cause scaling in pipes. Some studies even suggest that calcium and magnesium in hard water may have health benefits (Kozisek, 2020).

The results presented in Table 5 show that during both the rainy and hot/dry periods, there was an absence of bioindicators in all samples from the three wells in Barangay Poblacion, as indicated by the "A" (absence) results. The absence of bioindicators suggests that the groundwater in the area is not contaminated by pathogenic microorganisms or pollutants that would typically support the growth of such organisms. This is a positive indication of the water's microbiological safety, and it reflects favorable conditions for human consumption. The result aligns with the study by Teixeira (2020) who revealed that the absence of visible bioindicators during both seasonal periods indicates a low risk of biological contamination in the water sources of the barangay, which is crucial for the health and safety of the local population.

Table 5. *Quality of the Groundwater as Drinking Water Resource in Barangay Poblacion: Bioindicators*

Period	Method	Results			Average	Maximum Level or Characteristics
		Sample No. 1 *(Well 1)*	Sample No. 2 *(Well 2)*	Sample No. 3 *(Well 3)*		
Rainy Days	Observation	A	-	-	A	-
Hot/Dry Period	Observation	A	A	A	A	-
Average	**Observation**	**A**	**A**	**A**	**A**	**-**

A-absence of bioindicators; P- presence of bioindicators; -sampling is not possible

The results from Table 1 to Table 5 collectively highlight a concerning pattern of groundwater quality issues in Barangay Poblacion. The microbiological analyses in Table 1 and Table 2 reveal consistent failures in meeting safety standards due to the presence of total coliform and thermotolerant coliform during both rainy and hot/dry periods, indicating fecal contamination risks. Despite the absence of bioindicators (Table 5), which typically signal the presence of living organisms that could pose additional threats, the high coliform levels signal potential human health risks, such as waterborne diseases. Furthermore, Tables 3 and 4, which contain physicochemical analyses of parameters, provided important insights into the water's overall safety. These parameters mostly meet the required standards for drinking water, with values either falling within acceptable limits or passing the test, which indicates that the physical properties of the water, such as taste and appearance, are less of a concern compared to the microbiological safety.

The overall water quality concerns raised by the microbiological tests in Tables 1 and 2 are reinforced by the pH value of the physicochemical results in Tables 3 to 5, especially when considering the human health impacts of microbiologically unsafe water. Although the physical and chemical parameters of the water meet the safety guidelines (except for pH) of the DOH and PNSDW for drinking water, the persistent contamination by coliforms indicates that the water pose a health risk, particularly in terms of gastrointestinal diseases. While no significant bioindicators were observed, the high coliform levels in the groundwater necessitate further intervention to ensure the safety of drinking water and the health of the community. Regular monitoring, coupled with proper water treatment measures, would be essential to mitigate these risks and provide safe drinking water to the residents of Barangay Poblacion.

4.0 Conclusion

Access to potable water is essential for public health, yet many communities face challenges in maintaining water quality and awareness of related issues. This study assessed the groundwater quality in Barangay Poblacion in Ayungon. While groundwater met several key parameters of the 2017 Philippine National Standards for Drinking Water (PNSDW), the presence of coliform bacteria and low pH values signals potential health risks. Ensuring access to clean water directly supports Sustainable Development Goal 3 (Good Health and Well-being) by preventing waterborne diseases and promoting healthier living conditions. Clean water is not just a necessity; it is a safeguard against disease and a foundation for a healthier future. By ensuring the sustainability of safe water practices, communities can protect public health, enhance educational outcomes, and contribute to long-term development. The commitment to clean water must remain a shared responsibility, reinforcing the vital role of proper sanitation and hygiene education in achieving both health and educational goals.

5.0 Contributions of Authors

The authors confirm their equal contribution to every part of this research. All authors reviewed and approved the final version of this paper.

6.0 Funding

This research did not receive funding from any funding agency.

7.0 Conflict of Interests

This study has no conflict of interest of any sort.

8.0 Acknowledgment

The authors will be forever grateful to all persons who contributed to the success of this study, especially the field workers and contractors.

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