Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 128-134 | ISSN:2251-6727

Groundwater Quality Assessment in Maluso, Basilan: Physico-Chemical and Microbiological Perspectives

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(Received: 16 July 2025   Revised: 20 August 2025   Accepted: 02 September 2025)

KEYWORDS

Maluso

Groundwater Quality

Microbiological

Physico-chemical

Basilan

ABSTRACT:

Access to clean and safe drinking water is crucial to public health, especially in rural and semi-urban areas in developing countries, including the Philippines, which face ongoing threats to groundwater quality. This study assessed the physico-chemical and microbiological characteristics of groundwater in Maluso Municipality, Basilan. The groundwater samples were collected from 4 groundwater wells and analyzed using standard methods outlined in the Philippine National Standards for Drinking Water (PNSDW, 2017) and American Public Health Association (APHA, 2017) protocols. Parameters evaluated included pH, total dissolved solids (TDS), electrical conductivity (EC), major ions (Cl^-, SO_4^{2-}, NO_3^-, Na^+, K^+, Mg^{2+}, Ca^{2+}), and microbiological indicators such as fecal and total coliforms.

The results showed that all measured physico-chemical parameters fell within acceptable limits set by both PNSDW and the World Health Organization (WHO, 2017), indicating geochemical stability and minimal contamination from anthropogenic sources. However, pH values in some samples were slightly acidic (6.00–7.04), and water hardness was classified as soft, which may increase corrosivity and reduce buffering capacity. Critically, all samples failed to meet microbiological safety standards, with fecal and total coliform counts significantly exceeding the permissible limit of <1.1 MPN/100 mL, indicating contamination likely due to inadequate sanitation and unprotected sources.

The findings underscore a dual narrative of chemical compliance and microbiological risk. While the groundwater meets physicochemical safety benchmarks, it is unsuitable for direct human consumption without treatment due to microbial contamination. These results require public health interventions, including point-of-use treatment, community-led water safety planning, and long-term source protection strategies. This study contributes essential baseline data for water quality management in underserved and environmentally vulnerable areas.

Introduction

Access to safe and clean drinking water is a fundamental human right and a critical factor in public health [1]. However, in many developing regions, groundwater, a primary source of drinking water, faces contamination from natural and anthropogenic sources, posing significant health risks [2]. The Philippines, particularly rural and conflict-affected areas like Maluso Municipality in Basilan, experiences challenges in water quality due to inadequate sanitation, agricultural runoff, and geological factors [3]. The groundwater serves as a vital source of drinking water, especially in rural and peri-urban areas where centralized water systems are lacking [4]. However, groundwater quality is increasingly threatened by natural and anthropogenic contaminants, including agricultural runoff, industrial discharges, and improper waste disposal [5]. In developing countries like the Philippines, groundwater pollution poses significant health risks due to inadequate water treatment infrastructure and weak regulatory enforcement [6].

Groundwater quality is determined by its physico-chemical properties (e.g., pH, turbidity, heavy metals) and bacteriological content, particularly the presence of coliform bacteria, which indicate fecal contamination [7]. Elevated levels of pollutants, such as nitrates, lead, and Escherichia coli, have been linked to diseases including methemoglobinemia, kidney damage, and gastrointestinal infections [8]. In Basilan, where groundwater is a major water source, assessing its safety is crucial for preventing waterborne illnesses and ensuring sustainable water management.

Previous studies in similar regions, such as Isabela City, Basilan, have reported high coliform counts [9]. However, limited research has been conducted on the groundwater quality in Maluso, Basilan, despite its vulnerability to contamination from agricultural activities and inadequate waste disposal. This study aims to evaluate the physico-chemical and bacteriological concentrations of Maluso's groundwater.

Objectives

This study aims to fill that gap by analysing physico-chemical and bacteriological parameters and comparing them with national (Philippine National Standards for Drinking Water [10] and international [1] guidelines.

Methods

Study Area

The Municipality of Maluso (Fig. 1), the southwestern part of Basilan Province, has a total land area of 304.14 square kilometers, approximately 8.81% of the province's total landmass [13]. The area falls under Type IV climate under the Modified Coronas Classification System by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This climate type is characterized by evenly distributed rainfall throughout the year, with no defined dry or wet season, making the region particularly favourable for year-round agricultural activities [14]. It experiences consistently warm temperatures, typically ranging from 24°C to 32°C, with an average relative humidity of around 77% [15-16]. According to assessments by the Bureau of Soils and Water Management (BSWM) and the Department of Agriculture Bureau of Agricultural Research (DA-BAR), vast areas of Basilan, including Maluso, are considered highly suitable for agricultural production, particularly for crops such as abaca, coconut, upland rice, fruit trees, and root crops. However, agricultural potential may vary depending on topographic and edaphic factors such as slope, drainage, elevation, and soil type [11-12]. Soil suitability maps have identified the presence of soil series such as Bancal clay loam and Louisiana clay loam, both recognized for their moderate to good drainage and adequate nutrient-holding capacity.

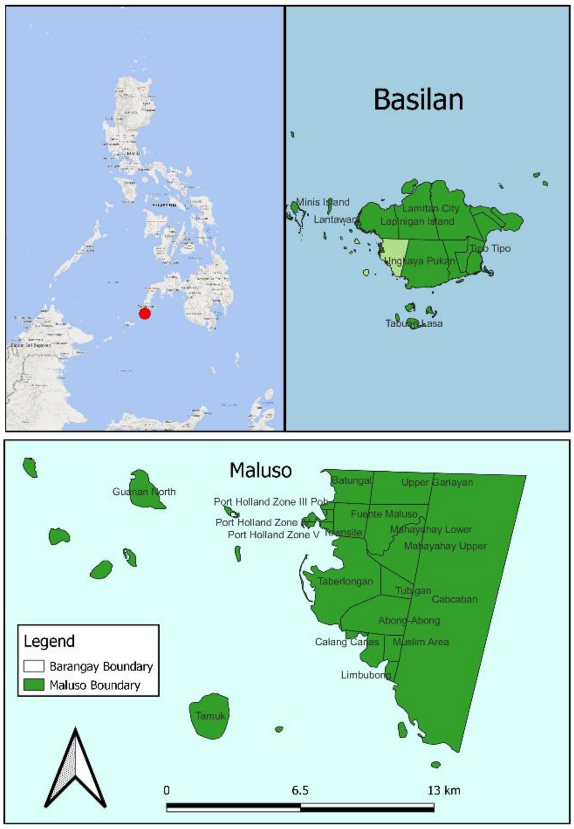

Figure 1. Map of the study area

Sampling and Analysis

The groundwater samples were collected once during high and low tides from twenty (20) existing groundwater wells in nine (9) municipalities and one (1) City. About two (2) minutes of purging were done before the sample collection. Before collecting the groundwater, the sampling bottles were thoroughly cleaned using a detergent. A total of 1.5 L of water samples were collected from each well. Following the standard procedures set by the Philippine National Standard for

Drinking Water [10], filled bottles were tightly capped and properly labeled with the following information: 1) the date and time of sampling, and 2) the sample source. Sampling bottles were placed in an icebox at a low temperature to prevent unnecessary chemical reactions. The water samples were transported to a laboratory for analysis. Unstable parameters such as pH, total dissolved solids (TDS), temperature, and electrical conductivity (EC) were measured directly in the field using a portable multimeter. At the same time, other analyzed physicochemical parameters are outlined in Table 1.

Table 1. Method of Testing the Groundwater Physico-Chemical and Microbiological Parameters

Parameters	**Test Method**
Chloride	4500-Cl-B. Argentometry
Sulfate	4500-SO42-E. Turbidity
Total Alkalinity	2310 B Titrimetry
Calcium	3030 F. Nitric Acid-Hydrochloric Acid Digestion, 3111 B. Acetylene Flame AAS
Magnesium	
Sodium	3030 F. Nitric Acid-Hydrochloric Acid Digestion, 3111 B. Direct Air-Acetylene Flame AES
Potassium	
Carbonate	Computation
Bicarbonate	
Total Dissolved Solids	Hand-held EC-meter (onsite)
pH	Hand-held EC-meter (onsite)
Electrical Conductivity	Hand-held EC-meter (onsite)
Temperature	Hand-held EC-meter (onsite)
Fecal Coliform Count	(9221 B-C) Multiple Tube Fermentation Technique
Total Coliform Count	

Results and Discussion

Table 2. Observed Concentration (mg/L) of Physico-chemical and Microbiological Groundwater Parameters of Maluso, Basilan, March 2022

SW	1	2	3	4
EC	41.6	60.8	71.68	20.48
pH	6	6.12	7.03	7.04
TDS	33	46	55	15
Cl	1	1.2	1.7	2.2
SO_4	10	21.4	23.5	22.9
TA	30.1	46.3	62.6	16.2
TH	22.6	41.1	57.5	26.7
NO_3	0.08	0.08	0.1	0.25
F	0.62	0.07	0.27	0.41
K	0.47	0.25	0.83	0.28
Na	2.9	4.2	3.8	2.3
Mg	2.8	4.64	6.42	1.17
Ca	0.2	0.42	0.93	0.68
F. Coli	>8.0	>8.0	>8.0	>8.0
T. Coli	>8.0	>8.0	>8.0	>8.0

Table 3. Observed Values of Physico-chemical Groundwater Parameters March 2022, and in comparison, with the WHO and PNSDW Standards for Drinking Water

Parameter	Observed Range (mg/L)	WHO Standard (mg/L)	PNSDW Standard (mg/L)	Status
EC	20.48 – 71.68	-	-	Acceptable
pH	6.00 – 7.04	6.5 - 8.5	6.5 - 8.5	Acidic (SW1, SW2)
Total Dissolved Solids (TDS)	15 – 55	500	600	Within Limit
Chloride (Cl)	1.0 – 2.2	250	250	Within Limit
Sulfate (SO_4)	10.0 – 23.5	250	250	Within Limit
Total Alkalinity (TA)	16.2 – 62.6	200	-	Acceptable
Total Hardness (TH)	22.6 – 57.5	60	300	Acceptable
Nitrate (NO_3)	0.08 – 0.25	50	50	Within Limit
Fluoride (F)	0.07 – 0.62	1.5	1.5	Within Limit
Potassium (K)	0.25 – 0.83	12	-	Within Limit
Sodium (Na)	2.3 – 4.2	200	200	Within Limit

Magnesium (Mg)	1.17 – 4.64	50	-	Within Limit
Calcium (Ca)	0.2 – 0.93	75	-	Within Limit

The physicochemical characteristics of the water samples, as presented in Tables 2 and 3, were analyzed to assess their suitability for domestic consumption by comparing observed values with international [17] and national [10] drinking water standards. Overall, the results indicate that the water samples fall within acceptable limits for most parameters, with a few notable deviations discussed in detail below.

Electrical Conductivity (EC)

The electrical conductivity (EC) values ranged from 20.48 to 71.68 µS/cm, indicating low levels of dissolved ionic species. While neither the WHO nor PNSDW provides a specific threshold for EC in drinking water, EC is often used as a proxy for total ionic concentration and potential salinity issues. According to [18], EC values below 250 µS/cm typically reflect freshwater conditions with low anthropogenic influence. The low EC observed here supports the assumption that agricultural or industrial inputs impact the sampled water.

pH

The pH ranged from 6.00 to 7.04, where the lower bound slightly falls below the WHO and PNSDW recommended range of 6.5 to 8.5. Low pH values may indicate natural soil acidity or CO_2 enrichment and can enhance the leaching of heavy metals like lead and copper [17]. In a comparable study by [19], groundwater in acidic volcanic terrains similarly exhibited pH values below 6.5, leading to plumbing corrosion issues. However, in contrast, [20] found that most groundwater sources in limestone-rich areas maintained neutral to alkaline pH, mitigating such risks.

Total Dissolved Solids (TDS)

TDS concentrations between 15 and 55 mg/L are well below the WHO (500 mg/L) and PNSDW (600 mg/L) limits. Low TDS values are indicative of excellent palatability and low contamination [17]. According to [21], TDS values below 100 mg/L are ideal for domestic use but may lack essential minerals, which can be a concern for dietary intake. Conversely, very low TDS, as observed here, may reduce the buffering capacity of water, increasing susceptibility to pH fluctuations [22].

Chloride (Cl^-) and Sulfate (SO_4^{2-})

Chloride levels ranged from 1.0 to 2.2 mg/L and sulfate from 10.0 to 23.5 mg/L, both well within the acceptable limit of 250 mg/L set by WHO and PNSDW. These values suggest the absence of saline intrusion or industrial contamination. Similar findings were reported in rural Indonesian groundwater by [23], where low Cl^- and SO_4^{2-} levels correlated with low population density and minimal fertilizer use. In contrast, [24] reported elevated chloride and sulfate in irrigated agricultural zones, demonstrating the impact of land use on ion concentrations.

3.5. Total Alkalinity (TA)

The TA values of 16.2 to 62.6 mg/L are below the general aesthetic limit of 200 mg/L. While WHO and PNSDW do not impose a health-based limit, alkalinity contributes to pH stability. As per [25], low alkalinity levels, such as those observed here, may lead to higher susceptibility to acidification. However, the current values still provide minimal buffering capacity, supporting acceptable pH stability in the short term.

Total Hardness (TH)

Total hardness ranged from 22.6 to 57.5 mg/L, classifying the water as "soft." Although [17] suggests a minimum of 60 mg/L for optimal plumbing integrity, PNSDW permits up to 300 mg/L. These results are consistent with soft water profiles observed in rain-fed catchments in Bangladesh [26]. However, soft water may increase corrosivity and reduce dietary calcium and magnesium intake, which are essential for human health.

Nitrate (NO_3^-)

The nitrate concentrations were between 0.08 and 0.25 mg/L, significantly below the maximum allowable limit of 50 mg/L. These low levels suggest minimal agricultural runoff or septic leakage. In agreement, [27] reported similar nitrate values in low-intensity farming regions of South Asia. However, studies in highly fertilized zones, such as those by [28], reported nitrate concentrations exceeding 20 mg/L, raising concerns over eutrophication and human health (e.g., methemoglobinemia in infants).

Fluoride (F^-)

Fluoride levels ranged from 0.07 to 0.62 mg/L, within the WHO and PNSDW recommended upper limit of 1.5 mg/L. These values are beneficial for preventing dental caries. However, excessive fluoride, as observed in parts of India and Kenya (up to 5 mg/L), has been associated with fluorosis [29]. The current range indicates a safe level for public health, particularly in fluoride-deficient areas.

3.9. Potassium (K^+) and Sodium (Na^+)

Potassium (0.25 to 0.83 mg/L) and sodium (2.3 to 4.2 mg/L) levels were both within safe limits (WHO recommends 12 mg/L for K and 200 mg/L for Na). Low potassium levels reduce health risks, particularly for renal patients. These values align with groundwater characteristics reported by [30] in unpolluted rural springs in Nepal. High sodium levels, particularly in coastal aquifers, have been shown to pose cardiovascular risks [31] but such concerns are not relevant to the current samples.

3.10. Magnesium (Mg^{2+}) and Calcium (Ca^{2+})

Magnesium and calcium concentrations ranged from 1.17 to 4.64 mg/L and 0.2 to 0.93 mg/L, respectively. These are well below WHO guidelines (50 mg/L for Mg, 75 mg/L for Ca). These values contribute to the water's low hardness and suggest minimal limestone dissolution or mineral input. Low levels of these nutrients, while not harmful, may be insufficient to meet daily dietary requirements if water is a major source of mineral intake [17].

Table 4. Fecal and Total Coliform Count of the Groundwater of Maluso, March 2022, and in comparison, with the WHO and PNSDW Standards for Drinking Water.

Parameter	Range of Values (mg/L)	WHO (mg/L)	PNSDW (mg/L)	Status
Fecal Coliform (F. Coli)	>8.0 – 2.6 MPN/100mL	<1.1	<1.1	Not compliant
Total Coliform (T. Coli)	>8.0 MPN/100m	<1.1	<1.1	Not compliant

Microbiological Quality: Fecal and Total Coliforms

Waterborne pathogens pose public health risks, particularly in developing regions where infrastructure and sanitation systems are inadequate. Among the most important microbiological indicators of drinking water safety are Fecal Coliform (FC) and Total Coliform (TC) bacteria. These organisms serve as surrogate indicators for the presence of fecal contamination, including viruses, protozoa, and bacterial pathogens.

Observed Values vs. Standards

In this study, Fecal Coliform concentrations ranged from 2.6 to >8.0 MPN/100 mL, while Total Coliforms consistently exceeded 8.0 MPN/100 mL. These values are well above the maximum permissible limits of <1.1 MPN/100 mL set by both the World Health Organization [17] and the Philippine National Standards for Drinking Water [10]. Therefore, the samples are classified as not compliant and unsafe for direct human consumption.

According to WHO guidelines, "Drinking water must not contain any detectable faecal indicator organisms (E. coli or thermotolerant coliform bacteria) in any 100 mL sample" [17]. The presence of coliforms strongly suggests contamination from human or animal waste and is associated with diseases such as cholera, typhoid fever, hepatitis A, and various diarrheal illnesses [32].

Several studies across Southeast Asia and Sub-Saharan Africa have reported similar levels of microbiological contamination, particularly in rural, semi-urban, and post-disaster areas. [33] found that 90% of well water samples in Tanzania exceeded the WHO standards for E. coli, which correlated with diarrheal outbreaks. [34] reported fecal coliform levels exceeding 5.0 MPN/100 mL in groundwater sources used for domestic purposes in Mexico, which were linked to proximity to latrines and unsealed wells. In the Philippines, [35] assessed water sources in Region II and found that 68% of samples exceeded microbiological limits, with a strong association to flooding events and poor sanitation. Conversely, studies conducted in regions with improved sanitation and protected sources have reported the absence of fecal contamination: [36] in Vietnam, found that deep borehole water sources treated with chlorination systems had no detectable coliforms. [37] Studying treated municipal water in Malaysia, researchers observed zero total and fecal coliforms in

post-treatment samples, emphasizing the importance of centralized disinfection and regulated distribution systems. These contrasting cases highlight the impact of source protection, point-of-use treatment, and community water management systems in achieving microbiologically safe water.

Conclusion

The comprehensive assessment of groundwater quality in Maluso, Basilan, using standard physico-chemical and microbiological testing methodologies, reveals a dual narrative of compliance and concern. On the one hand, the physico-chemical parameters such as electrical conductivity, total dissolved solids, major ions, and essential minerals largely conformed to both [17] and Philippine National Standards for Drinking Water [10], indicating the aquifer's geochemical stability and minimal influence from industrial or agricultural contaminants. However, the slight acidity in select samples, though marginal, may pose corrosive risks to plumbing infrastructure. Furthermore, while the low total hardness and alkalinity values indicate "soft" water quality, they may also lead to reduced buffering capacity and long-term corrosion issues. Likewise, the microbiological assessment presents a critical challenge. All groundwater samples tested were non-compliant with fecal and total coliform standards, with levels exceeding the allowable limit of <1.1 MPN/100 mL. The detection of fecal indicator organisms suggests fecal contamination, rendering the water unfit for direct human consumption, which includes high coliform counts to inadequate sanitation, unprotected wells, and proximity to human or animal waste sources. Thus, while the chemical safety of the groundwater appears satisfactory for most constituents, the microbiological quality poses significant public health risks. Immediate interventions are required, including point-of-use treatment (e.g., chlorination, filtration), source protection measures, and community-based water safety planning. Further longitudinal monitoring is also recommended to assess seasonal variations and the impact of local anthropogenic activities. Bridging the gap between water quality compliance and actual health safety will require integrative approaches involving environmental engineering, community education, and public health surveillance.

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