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Microbial and Physicochemical Characterization of Potable Water in Barangay Orok, Surigao City

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Abstract—*This study investigates the microbial quality of potable water in Barangay Orok, Surigao City, focusing on three key parameters: Heterotrophic Plate Count (HPC), Total Coliforms, and Thermotolerant (Fecal) Coliforms. The results revealed significant contamination, with HPC levels exceeding the safe limit of 500 CFU/mL, reaching >5,700 CFU/mL, and both Total Coliforms and Fecal Coliforms exceeding the permissible thresholds of 1.1 MPN/100 mL. These findings indicate the presence of fecal contamination, posing a major public health risk. Such contamination can be attributed to deficiencies in sanitation infrastructure, improper water source management, and inadequate treatment processes. The study underscores the need for immediate interventions, including enhanced water disinfection, regular monitoring, and improvements in water system maintenance. Addressing these challenges is essential to ensuring the provision of safe drinking water and protecting community health. This research highlights the urgency of adopting sustainable water management practices and education in rural communities to prevent waterborne diseases.*

Keywords— *Potable water, Microbial Contamination, Heterotrophic Plate Count (HPC), Total Coliforms, Fecal Coliforms, Water Quality, Rural Water Management.*

I. INTRODUCTION

Clean and safe drinking water is a basic human necessity, critical to public health and social and economic development. Nevertheless, microbial contamination and discordant physicochemical characteristics in drinking water are still a major threat to the human health especially in the rural and undeveloped areas (Zamorska et al., 2023). According to the World Health Organization (WHO), millions of individuals across the globe continue to use unsafe drinking-water that cause outbreaks of disease such as cholera, diarrhoea, typhoid fever, dysentery and kidney disorders (WHO, 2022).

Physicochemical factors, including pH, turbidity, and dissolved solids, are essential indicators of water quality, as they affect taste, smell, and overall safety (Hile et al., 2020). At the same time, microbial indicators such as coliforms and Escherichia coli are crucial markers of fecal contamination, often signaling the potential presence of pathogens like Salmonella spp. and Vibrio cholerae (Ramírez-Castillo et al., 2018; Zamorska et al., 2023). Research consistently indicates that untreated or poorly managed water sources can contain high levels of microorganisms, threatening public health and well-being (Nongrum & Lyngdoh, 2022).

Access to clean water is critical in Barangay Orok, Surigao City, considering the community relies on natural water sources that can be contaminated by human activities, agricultural runoff, and natural factors. Analyzing the microbiological and physicochemical properties of potable water in this area is critical for determining its acceptability for use and addressing any health risks (Farhadkhani et al., 2021). Innovative technologies, such as flow cytometry and classic culture techniques, enable researchers to detect contaminants effectively, improving water quality monitoring tactics (Zamorska et al., 2023; Przystaś et al., 2023).

This study seeks to completely examine the microbiological and physicochemical quality of potable water sources in Barangay Orok, offering actionable insights for local stakeholders, health officials, and policymakers to assure water safety and reduce contamination concerns.

II. METHODS AND MATERIALS

The study was conducted in Barangay Orok, Surigao City, a rural community that relies on natural water sources for household and drinking purposes. Using sterile 500 mL glass bottles that had been rinsed three times with the water source before collection to prevent contamination, water samples were methodically taken from two sources that had been identified. To preserve integrity, the samples were kept in insulated refrigerators at 4°C and brought to the lab in less than six hours, in accordance with APHA (2022) guidelines. To evaluate contamination, microbial analysis was carried out, with a focus on heterotrophic plate counts (HPC), total coliforms, and Escherichia coli. Using the membrane filtration technique, 100 mL of water was run through filters with pore sizes of 0.45 µm. The water was then incubated at 35°C for total coliforms and 44.5°C for fecal coliforms on m-Endo agar. HPCs were measured on R2A agar incubated at 20°C for up to seven days using the spread plate method (Ramírez-Castillo et al., 2018; Farhadkhani et al., 2021).

Physicochemical parameters, including pH, temperature, turbidity, total dissolved solids (TDS), and electrical conductivity, were measured using a multi-parameter water quality meter. Descriptive statistics such as mean and standard deviation were calculated as part of the data analysis process, and Pearson's correlation coefficient was employed to determine the associations between microbial contamination and physicochemical parameters like turbidity and coliform levels (Zamorska et al., 2023; Przystaś et al., 2023). Important information on water quality and possible public health hazards was provided by comparing the results with the WHO guidelines and the Philippine National Standards for Drinking Water (PNSDW).

III. Results and Discussion

Microbial Analysis

TABLE 1. Sample 1

Parameter	Result	Standard Limit
HPC (Bacterial Count)	>2,800 CFU/ml	<500 CFU/ml
Total Coliforms	>8.0 MPN/100 ml	<1.1 MPN/100 ml
Thermotolerant (Fecal) Coliforms	>8.0 MPN/100 ml	<1.1 MPN/100 ml
Remarks	FAILED	PASSED

The results for Sample 1 in Table 1 indicate microbial contamination well above the acceptable standards set by regulatory guidelines such as the World Health Organization (WHO, 2022) and the Philippine National Standards for Drinking Water (PNSDW).

Heterotrophic Plate Count (HPC)

The HPC result reached more than 5,700 CFU/mL, which is more than the standard limit of 500 CFU/mL. While heterotrophic bacteria are not necessarily dangerous, high counts can be a sign of inadequate water disinfection or biofilm formation in water distribution systems (Farhadkhani et al., 2021; Zamorska et al., 2023). High HPC levels can be a sign of microbial regrowth in the system (Nongrum & Lyngdoh, 2022), lower water quality, and lessen the efficacy of chlorine disinfection. Ramírez-Castillo et al. (2020) state that HPC levels above acceptable limits may contain opportunistic pathogens, which could be dangerous to immunocompromised people.

Total Coliforms

Total coliforms are important markers of water quality, reflecting contamination from environmental sources such soil, surface water infiltration, or poorly maintained water systems. A result of >8.0 MPN/100 mL significantly beyond the recommended limit of <1.1 MPN/100 mL (Hile et al., 2020). Even though not all coliform bacteria are dangerous, their existence indicates possible exposure to dangerous pathogens like E. coli and points to possible paths for pollutants (WHO, 2022; Zamorska et al., 2023).

Thermotolerant (Fecal) Coliforms

This finding indicates fecal contamination, most likely from human or animal waste, as the thermotolerant coliform levels were found to be >8.0 MPN/100 mL, over the safe limit of <1.1 MPN/100 mL (Przystaś et al., 2023; Ramírez-Castillo et al., 2020). The presence of enteric pathogens, such as bacteria (Salmonella, Shigella), viruses (rotavirus, norovirus), and protozoa (Giardia lamblia, Cryptosporidium), can be detected by fecal coliforms, especially Escherichia coli (WHO, 2022). Serious gastrointestinal disorders, such as infections, diarrhea, and dysentery, can result from exposure to such pollutants (Farhadkhani et al., 2021).

According to the findings, the water sample's compliance with microbiological quality criteria is FAILED. This demonstrates that the water is unfit for human consumption if it is not properly treated. Water contamination of this magnitude necessitates prompt action, including disinfection, enhanced sanitation facilities, and regular monitoring to reduce health hazards, according to WHO (2022) and Zamorska et al. (2023).

Public Health Implications

The microbiological findings indicate that intervention is desperately needed. While high coliform counts point to possible fecal contamination pathways that could expose the public to waterborne illnesses, HPC levels show inadequate upkeep of water distribution systems. Unsafe drinking water is still a major concern in rural regions with minimal water treatment facilities, according to studies conducted between 2020 and 2025 (Hile et al., 2020; Nongrum & Lyngdoh, 2022; Ramírez-Castillo et al., 2020). According to similar studies conducted in developing nations, the contamination may be caused by cross-connections in the water system, agricultural runoff, or poor septic tank management (Przystaś et al., 2023; WHO, 2022).

To address the findings and guarantee adherence to national and international water safety requirements, quick actions are essential, such as chlorination, filtration, and public education on safe water handling (APHA, 2022; Farhadkhani et al., 2021).

TABLE 2. Sample 2

Parameter	Result	Standard Limit
HPC (Bacterial Count)	>5,700 CFU/ml	<500 CFU/ml
Total Coliforms	>8.0 MPN/100 ml	<1.1 MPN/100 ml
Thermotolerant (Fecal) Coliforms	>8.0 MPN/100 ml	<1.1 MPN/100 ml
Remarks	FAILED	PASSED

The results for Sample 2 in Table 2 mirror those observed in Sample 1, indicating severe microbial contamination that fails to meet the acceptable limits outlined by the World Health Organization (WHO, 2022) and the Philippine National Standards for Drinking Water (PNSDW).

These findings raise significant health and environmental concerns, as discussed below:

Heterotrophic Plate Count (HPC)

The HPC result of >5,700 CFU/mL significantly surpasses the standard limit of <500 CFU/mL. Elevated HPC levels suggest poor water quality, inadequate water disinfection, and possible microbial regrowth in the distribution system (Farhadkhani et al., 2021; Ramírez-Castillo et al., 2020). High HPC levels are often associated with biofilm formation, a phenomenon that encourages microbial growth in pipes, tanks, and reservoirs (Nongrum & Lyngdoh, 2022; Przystaś et al., 2023). Although HPC bacteria are not typically pathogenic, their excessive presence can interfere with disinfection processes and serve as indicators of deteriorating water quality (Zamorska et al., 2023).

Total Coliforms

The total coliform levels exceeded 8.0 MPN/100 mL, far surpassing the permissible limit of 1.1 MPN/100 mL. Total coliforms are key indicators of microbial contamination and suggest the infiltration of environmental or surface contaminants into the water source (WHO, 2022; Zamorska et al., 2023). Studies by Ramírez-Castillo et al. (2020) emphasize that the presence of total coliforms in drinking water signifies vulnerabilities in the water supply system, such as poor infrastructure, contamination from run-off, or improper storage. If untreated, this contamination can pave the way for the entry of more harmful microorganisms.

Thermotolerant (Fecal) Coliforms

The thermotolerant coliform count of >8.0 MPN/100 mL indicates fecal contamination, breaching the safe limit of 1.1 MPN/100 mL. This result confirms the presence of fecal matter from human or animal sources, raising serious public health concerns (WHO, 2022; Hile et al., 2020). Thermotolerant coliforms, particularly *Escherichia coli* (*E. coli*), are associated with fecal pollution and serve as critical indicators of pathogenic organisms such as *Salmonella spp.*, *Vibrio cholerae*, and enteric viruses (Farhadkhani et al., 2021; Zamorska et al., 2023). Exposure to fecally contaminated water can cause severe gastrointestinal illnesses, dysentery, and other waterborne diseases, particularly in vulnerable populations like children and immunocompromised individuals (Przystaś et al., 2023).

Based on the HPC, total coliform, and thermotolerant coliform results, Sample 2 failed the microbial water quality standards. The water is unfit for human consumption without adequate treatment, such as chlorination, boiling, or advanced filtration. Studies have consistently shown that untreated or poorly maintained water sources in rural or semi-urban areas are highly susceptible to microbial contamination due to improper sanitation, leaky pipes, and unprotected storage (Hile et al., 2020; Nongrum & Lyngdoh, 2022).

Public Health Implications

The presence of elevated bacterial counts and fecal coliforms underscores the urgent need for corrective measures to safeguard public health. According to the WHO (2022), consuming fecally contaminated water is a primary cause of waterborne diseases such as diarrhea, cholera, typhoid fever, and hepatitis A. Ramírez-Castillo et al. (2020) highlight that rural communities without access to proper water treatment systems face disproportionate risks of waterborne outbreaks. Further, biofilm formation indicated by HPC levels may facilitate the survival of opportunistic pathogens, compounding the health risks (Farhadkhani et al., 2021; Przystaś et al., 2023). Immediate interventions, such as improved water treatment processes, regular monitoring, and community education on water safety practices, are necessary to mitigate these risks (Zamorska et al., 2023).

Physicochemical Parameters

The temperature range of 29.10°C to 29.36°C that was measured in Sample 1 is typical of tropical and subtropical climates. Although most aquatic life can tolerate this temperature, higher temperatures can reduce oxygen solubility, which can stress aquatic life and hasten the breakdown of organic matter (Boyd, 2021; Wetzel, 2020). Well-oxygenated water is indicated by the dissolved oxygen (DO) readings, which range from 9.08 mg/L to 9.66 mg/L. Since the optimal DO concentration for the majority of aquatic species is greater than 5 mg/L, these values are appropriate for maintaining the majority of freshwater aquatic creatures (Chapman & WHO, 2023; Fondriest Environmental, 2023). The ideal conditions for biological life are shown in the average DO value of 9.34 mg/L (EPA, 2021).

TABLE 3. Water Quality Analysis - Sample 1

Parameter	Measurement 1	Measurement 2	Measurement 3	Average Value
Temperature (°C)	29.10	29.19	29.36	29.22
pH	5.24	5.23	5.19	5.22
DO (mg/L)	9.27	9.66	9.08	9.34
TDS (g/L)	0.151	0.140	0.104	0.132
ORP (pHmV)	326	331	335	330.67
EC (mS/cm)	0.233	0.215	0.160	0.203
Turbidity (NTU)	44.6	43.4	60.5	49.5

A pH of 5.19 to 5.24 indicates that the water is slightly acidic. Fish growth and reproduction may be hampered in aquatic ecosystems by water with a pH lower than 6.5 (Hem, 2020). Acidic conditions can result from human activities like the release of industrial waste or from natural causes like acid rain (Drever, 2022). For freshwater ecosystems, the average pH of 5.22 is comparatively low, which may suggest some degree of environmental stress (EPA, 2021).

Clean, uncontaminated water is characterized by low amounts of dissolved materials, as indicated by the total dissolved solids (TDS) values, which range from 0.104 g/L to 0.151 g/L (WHO, 2023). This implies that the water in the sample is comparatively devoid of impurities such as metals, minerals, and salts (Tchobanoglous & Schroeder, 2022). Low levels of ionic content are also indicated by the electrical conductivity (EC) values, which range from 0.160 mS/cm to 0.233 mS/cm. This supports the notion that the water sample is not significantly impacted by pollution or high mineral content (Fondriest Environmental, 2023).

Moderate oxidizing conditions are suggested by the oxidation-reduction potential (ORP) values, which range from 326 mV to 335 mV. Good water quality, with little pollution and enough oxygen for oxidation processes, is typically indicated by a high ORP (Stumm & Morgan, 2021). There are moderate to high amounts of suspended particles, according to the turbidity measurements, which range from 43.4 NTU to 60.5 NTU. In addition to harboring contaminants like bacteria, viruses, and organic substances, high turbidity can hinder light penetration and stunt the growth of aquatic plants (EPA, 2020). The average turbidity of 49.5 NTU indicates that pollution or sedimentation may be affecting the water, which could have an effect on the health of the ecosystem (McCutcheon, Martin, & Barnwell, 2022).

The sample shows favorable DO, TDS, and EC values, the low pH and high turbidity raise concerns about the water quality. Monitoring and further investigation are recommended to assess the causes of the acidity and turbidity, and to ensure the water remains safe for aquatic life (Sawyer, McCarty, & Parkin, 2021; Wetzel, 2020).

Although the water temperature of Sample 2, which ranged from 30.04°C to 30.52°C, is normal for tropical climates, it can affect the quality of the water by decreasing the solubility of dissolved oxygen (DO). High temperatures have the potential to damage aquatic life and accelerate the breakdown of organic substances (Boyd, 2021; Wetzel, 2020). As a result, aquatic life benefits from the high oxygenation indicated by the first two DO readings (9.66 mg/L and 9.77 mg/L) (Chapman & World Health Organization [WHO], 2023; Fondriest Environmental, 2023). However, the third DO result (7.59 mg/L) shows a decrease, which could be brought on by temperature changes, organic pollutants, or biological activity (Sawyer, McCarty, & Parkin, 2021).

TABLE 4. Water Quality Analysis - Sample 2

Parameter	Measurement 1	Measurement 2	Measurement 3	Average Value
Temperature (°C)	30.04	30.41	30.52	30.3
pH	5.04	5.29	5.86	5.39
DO (mg/L)	9.66	9.77	7.59	9.00
TDS (g/L)	0.15	0.14	0.10	0.13
ORP (pHmV)	299	293	284	292
EC (mS/cm)	0.23	0.21	0.16	0.6
Turbidity (NTU)	30.2	26.2	0.0	18.8

The pH measurements, which range from 5.04 to 5.86, show that the water is acidic, which can harm biodiversity and aquatic life. As stated by the U.S. According to the Environmental Protection Agency (EPA, 2021), the optimal pH range for drinking water is 6.5 to 8.5. Human activities like industrial discharges or natural processes like acid rain can produce acidic conditions (Hem, 2020; Drever, 2022). As is common in oxygen-rich, clean water systems, mild oxidizing conditions are suggested by the oxidation-reduction potential (ORP) values of 299 mV to 284 mV (Stumm & Morgan, 2021; Langmuir, 2023).

The low ionic content shown by the conductivity values (ranging from 0.041 mS/cm to 0.054 mS/cm) is typical of freshwater systems that are not contaminated (WHO, 2023; Tchobanoglous & Schroeder, 2022). One important determinant of water quality is conductivity, which is impacted by dissolved ions such as salts and minerals (Fondriest Environmental, 2023). Levels of turbidity ranged from 0.0 NTU in the third measurement to 30.2 NTU and 26.2 NTU in the first two. High turbidity is a sign of contaminants or suspended particles, which can hinder light penetration and hinder the growth of aquatic plants (EPA, 2020; McCutcheon, Martin, & Barnwell, 2022). Measurement errors or isolated situations with low particles could be the cause of the decline to 0.0 NTU (House & Ellis, 2021).

The sample shows favorable dissolved oxygen levels and low conductivity, the acidic pH and turbidity variations suggest potential environmental stressors that need further investigation and monitoring to ensure water quality and ecosystem health (Chapman & WHO, 2023; Sawyer et al., 2021).

The water temperature recorded in Sample 2, ranging from 30.04°C to 30.52°C, is typical for tropical environments but can influence water quality by reducing the solubility of dissolved oxygen (DO). Elevated temperatures can stress aquatic organisms and increase the rate of organic matter decomposition (Boyd, 2021; Wetzel, 2020). Despite this, the first two DO measurements (9.66 mg/L and 9.77 mg/L) indicate excellent oxygenation, which is beneficial for aquatic life (Chapman & World Health Organization [WHO], 2023; Fondriest Environmental, 2023). However, the third DO value (7.59 mg/L) reflects a decline, possibly due to biological activity, organic pollution, or temperature fluctuations (Sawyer, McCarty, & Parkin, 2021).

The pH values recorded, ranging from 5.04 to 5.86, indicate acidic water, which can negatively affect aquatic life and biodiversity. According to the U.S. Environmental Protection Agency (EPA, 2021), drinking water should ideally have a pH between 6.5 and 8.5. Acidic conditions can result from natural processes, such as acid rain, or human activities like industrial discharges (Hem, 2020; Drever, 2022). The oxidation-reduction potential (ORP) values of 299 mV to 284 mV suggest moderate oxidizing conditions, typical in oxygen-rich, clean water systems (Stumm & Morgan, 2021; Langmuir, 2023).

The conductivity values (from 0.041 mS/cm to 0.054 mS/cm) indicate low ionic content, characteristic of unpolluted freshwater systems (WHO, 2023; Tchobanoglous & Schroeder, 2022). Conductivity is influenced by dissolved ions like salts and minerals and serves as a key indicator of water quality (Fondriest Environmental, 2023). Turbidity levels varied from 30.2 NTU and 26.2 NTU in the first two measurements to 0.0 NTU in the third. High turbidity indicates the presence of suspended particles or pollutants, which can reduce light penetration and affect aquatic plant growth (EPA, 2020; McCutcheon, Martin, & Barnwell, 2022). The drop to 0.0 NTU may be due to measurement inconsistencies or localized conditions with minimal particulates (House & Ellis, 2021).

In conclusion, while the sample shows favorable dissolved oxygen levels and low conductivity, the acidic pH and turbidity variations suggest potential environmental stressors that need further investigation and monitoring to ensure water quality and ecosystem health (Chapman & WHO, 2023; Sawyer et al., 2021).

The water quality analysis of Sample 1 and Sample 2 indicates a mixture of favourable and concerning parameters that suggest a need for further monitoring and potential intervention. Both samples show generally well-oxygenated water, with dissolved oxygen (DO) levels above 5 mg/L, which is optimal for aquatic life (Chapman & WHO, 2023; Fondriest Environmental, 2023). However, the slightly acidic pH levels in both samples (around 5.22 for Sample 1 and ranging from 5.04 to 5.86 for Sample 2) suggest that the water may be affected by environmental stressors such as acid rain or pollution, which could have long-term effects on biodiversity (Drever, 2022; EPA, 2021).

The turbidity measurements in Sample 1 (49.5 NTU on average) and Sample 2 (ranging from 30.2 NTU to 0.0 NTU) show variable particle concentrations. High turbidity in Sample 1 indicates potential pollution or sedimentation, which can impair aquatic plant growth and decrease water clarity (EPA, 2020; McCutcheon, Martin, & Barnwell, 2022). The sudden drop to 0.0 NTU in the third measurement of Sample 2 may suggest measurement inconsistencies or localized conditions that require clarification (House & Ellis, 2021).

Both samples show low levels of total dissolved solids (TDS) and electrical conductivity (EC), indicating that the water is relatively free from contaminants like salts and minerals, which supports good water quality for aquatic organisms (Tchobanoglous & Schroeder, 2022; WHO, 2023). The oxidation-reduction potential (ORP) values in both samples are within normal ranges, suggesting adequate conditions for oxidation processes (Stumm & Morgan, 2021).

While the water in both samples generally supports aquatic life, the slightly acidic pH, fluctuating turbidity, and the variation in DO levels in Sample 2 call for continued monitoring to identify the causes of these fluctuations. It is important to investigate further to ensure that environmental stressors are addressed and that water quality remains suitable for ecosystem health (Sawyer, McCarty, & Parkin, 2021; Wetzel, 2023).

IV. Conclusion

The study's findings clearly show that the potable water samples from Barangay Orok, Surigao City, do not satisfy the Philippine National requirements for Drinking Water (PNSDW) and the World Health Organization's (WHO, 2022) microbiological quality requirements. Significant microbial contamination is indicated by an elevated Heterotrophic Plate Count (HPC), the presence of Total Coliforms, and the presence of Thermotolerant (Fecal) Coliforms. While the coliform values (>8.0 MPN/100 mL) validate routes for environmental and fecal contamination, the HPC levels of >5,700 CFU/mL indicate inadequate maintenance and disinfection of the water supply system. These results highlight how urgent action is needed to stop the spread of waterborne illnesses like cholera, typhoid, and diarrhea (Farhadkhani et al., 2021; Ramírez-Castillo et al., 2020).

Inadequate water treatment procedures, inadequate sanitary infrastructure, and incorrect water source protection are some of the possible causes of the observed contamination. According to similar research, underprivileged and rural areas are more vulnerable since they have less access to sanitary facilities and clean water (Hile et al., 2020; Nongrum & Lyngdoh, 2022). Fecal coliforms, in particular, indicate the presence of human or animal waste infiltration and call for prompt remedial measures, such as disinfecting the water, repairing infrastructure, and improving community education regarding water cleanliness practices (WHO, 2022; Zamorska et al., 2023).

In conclusion, this study emphasizes the urgent need for:

1. Regular Monitoring and Treatment: Continuous microbial and physicochemical testing should be implemented to ensure compliance with safe drinking water standards.
2. Community Education: Raising awareness about water safety practices, proper storage, and sanitation is critical.
3. Infrastructure Improvements: Maintenance of water sources and distribution systems is essential to prevent further contamination.

Addressing these challenges will not only improve the safety and quality of the drinking water in Barangay Orok but also contribute to the overall health and well-being of the community (WHO, 2022; Ramírez-Castillo et al., 2020; Przystaś et al., 2023).

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