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

**MARKJAN V. PACILAN**

**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.

**I. INTRODUCTION**

Access to clean and safe drinking water is a fundamental human right and essential for public health and socio-economic development. However, microbial contamination and imbalanced physicochemical properties in potable water continue to pose significant risks to human health, particularly in rural and underserved communities (Zamorska et al., 2023). The World Health Organization (WHO) highlights that millions of people worldwide still consume contaminated water, leading to outbreaks of gastrointestinal diseases, typhoid, and other waterborne illnesses (WHO, 2022).

Physicochemical parameters such as pH, turbidity, and dissolved solids are critical indicators of water quality as they influence taste, odor, and overall safety (Hile et al., 2020). Simultaneously, microbial indicators like coliforms and Escherichia coli serve as vital markers for fecal contamination, which is often a precursor to the presence of pathogens like Salmonella spp. and Vibrio cholerae (Ramírez-Castillo et al., 2020; Zamorska et al., 2023). Studies have consistently shown that untreated or poorly managed water sources can harbor high microbial loads, compromising public health and well-being (Nongrum & Lyngdoh, 2022).

In Barangay Orok, Surigao City, access to clean water is crucial due to the community's dependence on natural water sources, which may be vulnerable to contamination from human activities, agricultural runoff, and natural factors. Analyzing both microbial and physicochemical characteristics of potable water in this locality is essential to determine its suitability for consumption and to address potential health hazards (Farhadkhani et al., 2021). Innovative methods, including flow cytometry and traditional culture techniques, enable researchers to detect contaminants effectively, enhancing water quality monitoring strategies (Zamorska et al., 2023; Przystaś et al., 2023).

This study aims to comprehensively assess the microbial and physicochemical quality of potable water sources in Barangay Orok, providing actionable insights for local stakeholders, health officials, and policymakers to ensure water safety and mitigate contamination risks.

**II. METHODS AND MATERIALS**

The study was conducted in Barangay Orok, Surigao City, a rural area dependent on natural water sources for drinking and domestic use. Water samples were systematically collected from five identified sources using sterilized 500 mL glass bottles, which were rinsed three times with the water source prior to collection to avoid contamination. The samples were preserved in insulated coolers at 4°C and transported to the laboratory within six hours to maintain integrity, following APHA (2022) standards. Microbial analysis was performed to assess contamination, particularly targeting Escherichia coli, total coliforms, and heterotrophic plate counts (HPC). The membrane filtration technique was used, where 100 mL of water was passed through 0.45 µm pore-size filters, incubated on m-Endo agar for total coliforms and m-FC agar for fecal coliforms at 35°C and 44.5°C, respectively. HPCs were determined using the spread plate method on R2A agar incubated at 20°C for up to seven days (Ramírez-Castillo et al., 2020; 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, while nitrate, sulfate, and chloride concentrations were analyzed using spectrophotometry and ion chromatography. Heavy metal analysis, including lead, arsenic, and cadmium levels, was performed using Atomic Absorption Spectroscopy (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to ensure compliance with WHO (2022) standards. Data analysis involved calculating descriptive statistics, including mean and standard deviation, and Pearson's correlation coefficient was used to identify relationships between microbial contamination and physicochemical parameters such as turbidity and coliform levels (Zamorska et al., 2023; Przystaś et al., 2023). The results were compared with the Philippine National Standards for Drinking Water (PNSDW) and WHO guidelines, providing essential insights into water quality and potential public health risks.

III. **RESULTS AND DISCUSSION**

# Microbial Analysis

## *Table 1. Sample 1*

|  |  |  |
| --- | --- | --- |
| 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 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). These findings raise significant health concerns, as discussed below:

**Heterotrophic Plate Count (HPC)**

The HPC result exceeded 5,700 CFU/mL, surpassing the standard limit of 500 CFU/mL. Heterotrophic bacteria are not inherently harmful; however, elevated counts indicate a lack of proper water disinfection or biofilm formation in water distribution systems (Farhadkhani et al., 2021; Zamorska et al., 2023). High HPC levels can compromise water quality, reduce the efficacy of chlorine disinfection, and act as an indicator of microbial regrowth in the system (Nongrum & Lyngdoh, 2022). According to Ramírez-Castillo et al. (2020), HPC levels exceeding permissible limits may harbor opportunistic pathogens, posing risks to immunocompromised individuals.

**Total Coliforms**

The result of >8.0 MPN/100 mL far exceeds the acceptable limit of <1.1 MPN/100 mL. Total coliforms serve as key indicators of water quality, reflecting contamination from environmental sources such as soil, surface water infiltration, or poorly maintained water systems (Hile et al., 2020). While not all coliform bacteria are harmful, their presence suggests pathways for contaminants, indicating potential exposure to harmful pathogens like E. coli (Zamorska et al., 2023; WHO, 2022).

**Thermotolerant (Fecal) Coliforms**

The thermotolerant coliform levels were recorded at >8.0 MPN/100 mL, exceeding the safe limit of <1.1 MPN/100 mL. This result signifies fecal contamination, likely originating from human or animal waste (Przystaś et al., 2023; Ramírez-Castillo et al., 2020). Fecal coliforms, particularly Escherichia coli, are critical markers for the presence of enteric pathogens, including bacteria (Salmonella, Shigella), viruses (norovirus, rotavirus), and protozoa (Giardia lamblia, Cryptosporidium) (WHO, 2022). Exposure to such contaminants can cause severe gastrointestinal illnesses, including diarrhea, dysentery, and infections (Farhadkhani et al., 2021).

Based on the results, the water sample is marked as FAILED against microbial quality standards. This highlights the water's unsuitability for consumption without proper treatment. According to Zamorska et al. (2023) and WHO (2022), water contamination at this scale requires immediate intervention, including disinfection, improved sanitation infrastructure, and routine monitoring to mitigate health risks.

**Public Health Implications**

The microbial results reflect a critical need for intervention. HPC levels indicate poor maintenance of water distribution systems, while elevated coliform counts suggest pathways of fecal contamination, which may expose the community to waterborne diseases. Studies from 2020–2025 emphasize that unsafe drinking water remains a significant concern in rural areas with limited water treatment infrastructure (Hile et al., 2020; Nongrum & Lyngdoh, 2022; Ramírez-Castillo et al., 2020). The contamination may stem from improper septic tank management, agricultural runoff, or cross-connections in the water system, as reported in similar studies across developing regions (Przystaś et al., 2023; WHO, 2022).

Immediate measures, including chlorination, filtration, and public education on safe water handling, are vital to address the findings and ensure compliance with national and global water safety standards (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

# *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 |

The water temperature recorded in Sample 1, ranging from 29.10°C to 29.36°C, is typical of tropical and subtropical environments. While this temperature is within acceptable ranges for most aquatic life, higher temperatures can lower the solubility of oxygen, which may stress aquatic organisms and accelerate the decomposition of organic material (Boyd, 2021; Wetzel, 2020). The dissolved oxygen (DO) measurements, ranging from 9.08 mg/L to 9.66 mg/L, indicate well-oxygenated water. These values are suitable for supporting most freshwater aquatic organisms, as the ideal DO concentration for most aquatic species is above 5 mg/L (Chapman & WHO, 2023; Fondriest Environmental, 2023). The average DO value of 9.34 mg/L reflects optimal conditions for biological life (EPA, 2021).

The pH values of 5.19 to 5.24 indicate slightly acidic water. Water with a pH below 6.5 can have harmful effects on aquatic ecosystems, including impaired fish reproduction and growth (Hem, 2020). Acidic conditions may arise from natural sources like acid rain or from human activities such as industrial waste discharge (Drever, 2022). The average pH value of 5.22 is relatively low for freshwater ecosystems, potentially indicating some level of environmental stress (EPA, 2021).

The total dissolved solids (TDS) values, ranging from 0.104 g/L to 0.151 g/L, suggest low concentrations of dissolved materials, which is characteristic of clean, unpolluted water (WHO, 2023). This suggests that the sample's water is relatively free from contaminants like salts, minerals, and metals (Tchobanoglous & Schroeder, 2022). The electrical conductivity (EC) values, ranging from 0.160 mS/cm to 0.233 mS/cm, also point to low levels of ionic content, supporting the idea that the water sample is not heavily influenced by pollution or high mineral content (Fondriest Environmental, 2023).

The oxidation-reduction potential (ORP) values, ranging from 326 mV to 335 mV, suggest moderate oxidizing conditions. A high ORP generally indicates good water quality, with minimal pollution and sufficient oxygen for oxidation processes (Stumm & Morgan, 2021). The turbidity measurements, ranging from 43.4 NTU to 60.5 NTU, indicate moderate to high levels of suspended particles. High turbidity can reduce light penetration and affect aquatic plant growth, as well as harbor pollutants such as bacteria, viruses, and organic compounds (EPA, 2020). The average turbidity of 49.5 NTU suggests that the water may be impacted by sedimentation or pollution, which could affect the ecosystem's health (McCutcheon, Martin, & Barnwell, 2022).

While 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).

# *Table 2. Water Quality Analysis - Sample 2*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Date & Time** | **Temperature (°C)** | **DO (mg/L)** | **pH** | **pH mV** | **ORP mV** | **Conductivity (mS/cm)** | **Turbidity (NTU)** |
| **2024/11/13 18:24:10** | 30.04 | 9.66 | 5.04 | 118 | 299 | 0.041 | 30.2 |
| **2024/11/13 18:23:32** | 30.41 | 9.77 | 5.29 | 103 | 293 | 0.043 | 26.2 |
| **2024/11/13 18:22:27** | 30.52 | 7.59 | 5.86 | 68 | 284 | 0.054 | 0.0 |

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).

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, 2020).

**IV. CONCLUSION**

The results of this study clearly demonstrate that the potable water samples from Barangay Orok, Surigao City, fail to meet the microbial quality standards set by both the World Health Organization (WHO, 2022) and the Philippine National Standards for Drinking Water (PNSDW). Elevated Heterotrophic Plate Count (HPC), as well as the presence of Total Coliforms and Thermotolerant (Fecal) Coliforms, indicate significant microbial contamination. The HPC levels of >5,700 CFU/mL suggest poor maintenance and disinfection of the water supply system, while coliform results (>8.0 MPN/100 mL) confirm pathways for environmental and fecal contamination. These findings underscore the critical need for immediate intervention to prevent the spread of waterborne diseases such as diarrhea, typhoid, and cholera (Farhadkhani et al., 2021; Ramírez-Castillo et al., 2020).

The observed contamination may be attributed to factors such as poor sanitation infrastructure, improper water source protection, and inadequate water treatment processes. Similar studies have highlighted that rural and underserved communities are at higher risk due to limited access to clean water and proper sanitation (Hile et al., 2020; Nongrum & Lyngdoh, 2022). The presence of fecal coliforms, in particular, points to human or animal waste intrusion, necessitating immediate corrective actions, including water disinfection, infrastructure repairs, and enhanced community education on water hygiene 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).

### References

1. Boyd, C. E. (2021). Water quality: An introduction (4th ed.). Springer.
2. Chapman, D., & World Health Organization. (2023). Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring (3rd ed.). WHO/UNEP.
3. Drever, J. I. (2022). The geochemistry of natural waters: Surface and groundwater environments (4th ed.). Prentice Hall.
4. Environmental Protection Agency (EPA). (2020). National primary drinking water regulations: Turbidity. U.S. Environmental Protection Agency. Retrieved from <https://www.epa.gov>
5. Environmental Protection Agency (EPA). (2021). 2016 Edition of the drinking water standards and health advisories. U.S. Environmental Protection Agency.
6. Fondriest Environmental, Inc. (2023). Water quality parameters. Retrieved from <https://www.fondriest.com>
7. Hem, J. D. (2020). Study and interpretation of the chemical characteristics of natural water (4th ed.). U.S. Geological Survey.
8. House, M. A., & Ellis, J. B. (2021). The hydrological and water quality impact of urban stormwater. The Science of the Total Environment, 795, 148842. <https://doi.org/10.1016/j.scitotenv.2021.148842>
9. Langmuir, D. (2023). Aqueous environmental geochemistry (4th ed.). Wiley-Interscience.
10. McCutcheon, S. C., Martin, J. L., & Barnwell, T. O. (2022). Water quality modeling (3rd ed.). CRC Press.
11. Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2021). Chemistry for environmental engineering and science (6th ed.). McGraw-Hill.
12. Stumm, W., & Morgan, J. J. (2021). Aquatic chemistry: Chemical equilibria and rates in natural waters (4th ed.). Wiley-Interscience.
13. Tchobanoglous, G., & Schroeder, E. D. (2022). Water quality: Characteristics, modeling, modification (2nd ed.). Addison-Wesley.
14. Wetzel, R. G. (2020). Limnology: Lake and river ecosystems (4th ed.). Academic Press.
15. World Health Organization (WHO). (2023). Guidelines for drinking-water quality (4th ed.). WHO Press.
16. Boyd, C. E. (2021). Water quality: An introduction (4th ed.). Springer.
17. Chapman, D., & World Health Organization. (2023). Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring (3rd ed.). WHO/UNEP.
18. Drever, J. I. (2022). The geochemistry of natural waters: Surface and groundwater environments (4th ed.). Prentice Hall.
19. Environmental Protection Agency (EPA). (2020). National primary drinking water regulations: Turbidity. U.S. Environmental Protection Agency. Retrieved from <https://www.epa.gov>
20. Environmental Protection Agency (EPA). (2021). 2016 Edition of the drinking water standards and health advisories. U.S. Environmental Protection Agency.
21. Fondriest Environmental, Inc. (2023). Water quality parameters. Retrieved from <https://www.fondriest.com>
22. Hem, J. D. (2020). Study and interpretation of the chemical characteristics of natural water (4th ed.). U.S. Geological Survey.
23. House, M. A., & Ellis, J. B. (2021). The hydrological and water quality impact of urban stormwater. The Science of the Total Environment, 795, 148842. <https://doi.org/10.1016/j.scitotenv.2021.148842>
24. Langmuir, D. (2023). Aqueous environmental geochemistry (4th ed.). Wiley-Interscience.
25. McCutcheon, S. C., Martin, J. L., & Barnwell, T. O. (2022). Water quality modeling (3rd ed.). CRC Press.
26. Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2021). Chemistry for environmental engineering and science (6th ed.). McGraw-Hill.
27. Stumm, W., & Morgan, J. J. (2021). Aquatic chemistry: Chemical equilibria and rates in natural waters (4th ed.). Wiley-Interscience.
28. Tchobanoglous, G., & Schroeder, E. D. (2022). Water quality: Characteristics, modeling, modification (2nd ed.). Addison-Wesley.
29. Wetzel, R. G. (2020). Limnology: Lake and river ecosystems (4th ed.). Academic Press.
30. World Health Organization (WHO). (2023). Guidelines for drinking-water quality (4th ed.). WHO Press.
31. Fondriest Environmental, Inc. (2014). Water Quality Parameters. Retrieved from <https://www.fondriest.com>.
32. U.S. Geological Survey. (2020). Water Quality Information. Retrieved from <https://www.usgs.gov>.
33. Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems (3rd ed.). Academic Press.
34. World Health Organization. (2017). Guidelines for Drinking-water Quality (4th ed.). WHO Press.
35. APHA. (2022). Standard Methods for the Examination of Water and Wastewater (23rd ed.). American Public Health Association.
36. Farhadkhani, M., et al. (2021). Biofilm formation and microbial water quality. Water Quality Journal, 35(4), 127-136.
37. Hile, S., Ramírez-Castillo, F. Y., & Martinez, J. L. (2020). Microbial contamination of drinking water in underserved communities. Environmental Science & Technology, 54(6), 3264–3271.
38. Nongrum, S., & Lyngdoh, W. (2022). Microbiological and physico-chemical analysis of potable water from elite regions of Meghalaya, India. International Journal of Scientific Research in Biological Sciences, 9(5), 46–51.
39. Przystaś, W., Zamorska, J., & Karwowska, E. (2023). Microbial contamination and disinfection efficiency in drinking water. Water, 15(23), 4077.
40. Ramírez-Castillo, F. Y., et al. (2020). Microbial pathogens in drinking water sources: A public health concern. Journal of Water and Health, 18(1), 67-78.
41. World Health Organization. (2022). Guidelines for drinking-water quality (4th ed.). WHO.
42. Zamorska, J., Karwowska, E., & Przystaś, W. (2023). A comparative assessment of microbiological quality in drinking water. Water, 15(23), 4077.