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Microbiological Assessment of Groundwater from Wastewater Discharge of Dirty-Ice-Cream Factory in Rajal Sur, Santa Rosa, Nueva Ecija

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ABSTRACT: Water is essential for sanitation and efficient plumbing systems, especially in areas with unreliable supply where storage systems are widely used. However, improper design, installation, and maintenance may compromise water quality and system performance. This study aims to assess the impact of water storage systems on plumbing hygiene, water contamination, and overall efficiency. This study used descriptive-correlational research design with purposive sampling, involving 102 household respondents to assess the impact of water storage systems on plumbing hygiene and efficiency in residential areas in Cabanatuan City, Nueva Ecija. Data were collected through both physical and online survey questionnaires and analyzed using descriptive and inferential statistics to evaluate the impact of water storage systems on plumbing hygiene and efficiency. The findings revealed that water storage systems are widely utilized and generally moderately maintained, with respondents reporting occasional exposure to environmental factors and acceptable levels of plumbing hygiene and efficiency. Nevertheless, correlation analysis indicated no statistically significant relationship between water storage system conditions and plumbing hygiene and efficiency. It is concluded that water storage systems generally provide acceptable levels of plumbing hygiene and efficiency among household users in Cabanatuan City. Overall, proper maintenance remains the key factor in improving system outcomes.

KEYWORDS: Dirty-Ice-Cream Factory, Groundwater, Microbiological Quality, Total Coliform, E. Coli, Most Probable Number, Manual Pumps.

I. INTRODUCTION

Groundwater is one of the most essential natural resources, serving as a primary source of water for domestic, agricultural, and industrial use, particularly in rural areas of the Philippines such as Nueva Ecija. Many communities rely on shallow wells and hand pumps for drinking, cooking, sanitation, and irrigation because groundwater is relatively accessible and affordable compared to treated surface water. In Barangay Rajal Sur, Santa Rosa, Nueva Ecija, there are seven functioning wells and six operating dirty ice cream factories located across Purok 4 to 6. The barangay is characterized by mixed land use, where residential areas, agricultural activities, and small-scale food production enterprises coexist, raising concerns regarding groundwater safety and quality. Groundwater also serves as a supplemental source of water during dry seasons, helping sustain agricultural productivity and food security (Jasechko et al., 2017).

Groundwater quality, however, is increasingly threatened by microbial contamination, particularly through the presence of Total Coliform and Escherichia coli (E. coli), which are commonly used indicators of fecal contamination in drinking water. The presence of these microorganisms may indicate the possible introduction of pathogens capable of causing waterborne diseases such as diarrhea, cholera, and typhoid fever. According to the World Health Organization (2022), drinking water should contain zero detectable E. coli per 100 mL sample, as even low levels may pose health risks. One of the major contributors to groundwater contamination is the improper discharge of wastewater from small-scale industries and livestock-related activities. Studies suggest that informal or poorly regulated dirty ice cream factories may release untreated or inadequately treated wastewater containing organic matter, bacteria, and other contaminants that can infiltrate nearby groundwater sources (Cao et al., 2021).

Supporting this concern, existing literature emphasizes that groundwater is highly vulnerable to contamination from various sources such as domestic wastewater, agricultural runoff, and small-scale industrial activities. These pollutants including pathogens, nutrients, pesticides, and heavy metals can enter aquifers through leaching, seepage, and runoff depending on environmental conditions (Shamsudduha et al., 2019; Shukla & Saxena, 2020; Sharma et al., 2023). Shallow wells, in particular, are more susceptible to contamination due to their proximity to pollution sources and limited natural protection from geological layers (Sasáková et al., 2018). Furthermore, microbiological indicators such as Total Coliform and E. coli are widely recognized as reliable measures of water quality and sanitary conditions, with their presence indicating potential health risks and non-compliance with drinking water standards (Niyoyitungiye et al., 2020; Magwilang et al., 2023).

In addition, wastewater discharge from small-scale and informal food industries has been identified as a significant contributor to environmental pollution. Effluents from these operations often contain high organic loads, elevated biochemical oxygen demand (BOD), chemical oxygen demand (COD), and microbial contaminants due to inadequate treatment systems (Abdelmoneem, 2021; Shrivastava et al., 2022; Nassah et al., 2022). These untreated wastes can infiltrate soil and migrate into groundwater systems, particularly in areas with permeable subsurface conditions (Zandaryaa & Mateo-Sagasta, 2018). These findings highlight the importance of proper wastewater management and continuous groundwater monitoring to protect public health.

Despite the growing body of literature on groundwater contamination and microbiological water quality, there remains a significant gap in localized studies focusing on small rural communities in the Philippines, particularly in Rajal Sur, Santa Rosa, Nueva Ecija. Existing studies commonly focus on large-scale agricultural areas, urban groundwater systems, or generalized regional assessments, leaving semi-rural barangays underrepresented in groundwater quality research (Rances et al., 2025; Robles & Monjardin, 2025). Moreover, limited studies specifically examine the effects of wastewater discharge from small-scale food industries on nearby groundwater sources, despite evidence showing that food industry effluents contribute to organic and microbial pollution. Previous research has also mainly emphasized broader contamination sources such as agriculture and domestic sewage rather than isolating small-scale food production activities as potential contributors to groundwater contamination

Additionally, in Rajal Sur, regular monitoring of well water is not consistently conducted, making it difficult to determine whether existing groundwater sources meet safety standards for drinking water. This lack of localized data and continuous observation hinders the development of appropriate interventions and policies to ensure water safety and protect public health. Therefore, localized assessment and monitoring are essential for identifying contamination risks and improving groundwater management strategies for residents and farmers in the area.

In response to these gaps, this study aims to assess the microbiological quality of groundwater from selected wells in Rajal Sur, Santa Rosa, Nueva Ecija, particularly in relation to their proximity to a dirty ice cream factory. Specifically, it seeks to:

1. Determine the locational characteristics of groundwater sampling sites in terms of their distance from the dirty ice cream factory;
2. Evaluate the levels of microbiological contamination in groundwater samples in terms of Total Coliform and Escherichia coli (E. coli);
3. Identify which sampled wells comply with the microbiological standards of the Philippine National Standards for Drinking Water; and
4. Examine whether there is a significant relationship between the distance of groundwater wells from the dirty ice cream factory and the levels of microbial contamination using Pearson correlation analysis.

II: METHODOLOGY

Table 1. Distance of Well per sample from Ice-cream factory

Sample no.	Distance
Sample 1	5-10 meters
Sample 2	10-15 meters
Sample 3	15-20 meters
Sample 4	25-35 meters
Sample 5	30-40 meters
Sample 6	40-50 meters
Sample 7	50-60 meters

Table 1 presents the seven groundwater samples collected from wells at varying distances from the ice cream factory, with intervals of approximately 5–10 meters. These measured distances from each well to the nearest dirty ice cream factory were used to assess and compare microbiological water quality in relation to proximity to the potential contamination source.

The study employed a descriptive-comparative research design to assess the microbiological quality of groundwater and examine its relationship with proximity to dirty ice cream factories as potential contamination sources. It focused on determining the levels of Total Coliform and Escherichia coli (E. coli) in selected wells and comparing the results based on their distances from the factory. This design enabled the identification of patterns and variations in contamination levels without establishing direct causation.

Legend:

Manual Pump
Dirty-Ice-Cream Factory

Figure 1. Study Area Showing Ice Cream Factory and Sampling Wells

Groundwater samples were collected from selected wells using a one-time sampling procedure with sterile containers to prevent contamination during collection. Standard handling procedures were followed to ensure the integrity and reliability of the samples. The collected samples were immediately transported to the Cabanatuan City Water District Water Testing Laboratory for microbiological analysis. The analysis measured Total Coliform and Thermotolerant Coliform (Escherichia coli) using the Multiple Tube Fermentation Technique, in accordance with the Philippine National Standards for Drinking Water (2017)

The collected groundwater samples were analyzed using the Most Probable Number (MPN) method to determine the presence and concentration of microbiological contaminants. Specifically, the analysis focused on Total Coliform and Escherichia coli (E. coli), which are widely recognized indicators of water quality and fecal contamination. The results were expressed as MPN per 100 mL of water for each sample.

Based on the Philippine National Standards for Drinking Water (2017), drinking water must contain zero detectable E. coli per 100 mL and Total Coliform levels must not exceed 1.1 $MPN/100\ mL$. Accordingly, samples with E. coli values of 0 MPN/100 mL (or $< 1.1\ MPN/100mL$) and Total Coliform levels below 1.1 MPN/100 mL were classified as Passed, indicating compliance with microbiological standards. In contrast, samples with detectable E. coli ($\geq 1.1\ MPN/100mL$) or Total Coliform values exceeding $1.1\ MPN/100mL$ were classified as Failed, indicating potential microbial contamination and non-compliance with drinking water standards.

The data obtained from laboratory testing were analyzed using descriptive statistics and correlational analysis. The microbiological contamination levels of the groundwater samples were evaluated based on their MPN values for Total Coliform and E. coli per 100 mL, and each sample was categorized as either Passed or Failed according to the established standards.

To determine the relationship between the distance of the wells from the dirty-ice-cream factory and the level of microbial contamination, the Pearson Product-Moment Correlation Coefficient was utilized,

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

\where:
r = Pearson correlation coefficient
x = distance of the well from the factory (meters)
y = microbial contamination level (MPN/100 mL)
n = number of groundwater samples

In this study, the independent variable is the distance of the wells from the dirty-ice-cream factory, while the dependent variables are the levels of Total Coliform and *Escherichia coli* (E. coli). The correlation analysis was employed to determine whether contamination levels increase or decrease as the distance from the factory changes; a negative correlation indicates that contamination decreases as distance increases, whereas a positive correlation suggests that contamination increases with distance. It is important to note that the analysis is observational in nature and does not establish direct causation.

The study adhered to proper ethical and safety standards throughout the research process. Groundwater samples were handled carefully to avoid contamination and ensure accuracy of results. Laboratory procedures were conducted following standard safety protocols to protect both the researchers and the integrity of the analysis. Additionally, the study aimed to present findings objectively and responsibly, particularly in relation to public health implications.

CHAPTER III : RESULTS & DISCUSSIONS

Table 2. Microbiological Results of Groundwater Samples

Sample	Total Coliform (MPN/ 100ml)	E.coli (MPN/ 100ml)	Remarks
Sample 1	>8.0	>8.0	Failed
Sample 2	<1.1	<1.1	Passed
Sample 3	>8.0	1.1	Failed
Sample 4	>8.0	4.6	Failed
Sample 5	<1.1	<1.1	Passed
Sample 6	<1.1	<1.1	Passed
Sample 7	<1.1	<1.1	Passed

Table 2 shows variations in the microbiological quality of groundwater samples based on Total Coliform and E. coli levels. Samples 1, 3, and 4 were classified as Failed due to elevated contamination. Sample 1 had the highest values (>8.0 MPN/100 mL for both indicators), while Sample

4 also showed significant contamination. Sample 3 failed because of high Total Coliform (>8.0 MPN/100 mL) and the presence of E. coli (1.1 MPN/100 mL), which already indicates contamination.

In contrast, Samples 2, 5, 6, and 7 were classified as Passed, as both Total Coliform and E. coli levels were below 1.1 MPN/100 mL. Sample 2 passed due to non-detectable microbial contamination, suggesting better water quality and lower exposure to pollution sources.

Overall, the results indicate that groundwater quality varies among sampling sites, with contamination present in some wells, possibly influenced by environmental factors such as proximity to contamination sources.

Table 3. Pearson Correlation Analysis Between Distance of Groundwater Wells and Total Coliform

Pearson Correlation (r)	p-value	Degree of Correlation	Verbal Description
-0.719	0.05*	Strong Negative Correlation	Total Coliform level decreases as distance increases

Legend:
Significant at p ≤ 0.05;*
r-value range:
±0.00 – ±0.19=Very Weak Correlation;
±0.20 – ±0.39=Weak Correlation;
±0.20 – ±0.39=Moderate Correlation;
±0.60 – ±0.79=Strong Correlation;
±0.80 – ±1.00= Very Strong Correlation
Legend:
Positive (+) =Both variables increase together;
Negative (−) =One variable decreases as the other increases

Table 4. Pearson Correlation Analysis Between Distance of Groundwater Wells and E. Coli Level

Pearson Correlation (r)	p-value	Degree of Correlation	Verbal Description
-0.680	0.05*	Moderate Negative Correlation	E. coli level decreases as distance increases

Legend:
Significant at p ≤ 0.05;*
r-value range:
±0.00 – ±0.19=Very Weak Correlation;
±0.20 – ±0.39=Weak Correlation;
±0.20 – ±0.39=Moderate Correlation;
±0.60 – ±0.79=Strong Correlation;
±0.80 – ±1.00= Very Strong Correlation
Legend:
Positive (+) =Both variables increase together;
Negative (−) =One variable decreases as the other increases

Tables 3 and 4 both indicate a negative relationship between distance and microbial contamination in groundwater. For Total Coliform, a strong negative correlation (r = -0.719) was observed, while E. coli showed a moderate negative correlation (r = -0.680). Both results are statistically significant (p ≤ 0.05), confirming that distance plays an important role in influencing contamination levels.

These findings suggest that as the distance from the ice cream factory increases, the levels of both Total Coliform and E. coli decrease. The stronger correlation in Total Coliform implies it may be more sensitive to distance-related environmental factors, while E. coli, although still affected, shows slightly less variation.

Overall, the results support the idea that wells located closer to the factory are more prone to microbial contamination, reinforcing the potential impact of wastewater discharge on groundwater quality.

Table 5. Relationship Between Well Distance and Microbial Contamination

Distance Category (m)	Mean Total Coliform	Mean E. coli	Water Quality Status
0–15	8.0	6.3	Highly Contaminated
16–30	4.6	1.1	Moderately Contaminated
31–55	1.1	1.1	Low Contamination

Legend:
Microbial Level (MPN/100mL): 1.1=Low Contamination;
4.6=Moderate Contamination;
8.0 and above=High Contamination

The results suggest a clear influence of proximity on groundwater quality, where closer wells are more vulnerable to contamination. This pattern implies that microbial pollutants likely originate from a nearby source and gradually diminish as they disperse through the subsurface environment. Similar findings were reported by Ufoegbune et al. (2021), who observed that hand-dug wells located near septic tanks exhibited significantly higher coliform contamination levels due to seepage and infiltration from nearby waste sources. Likewise, Bagordo et al. (2024) emphasized that microbial contamination in groundwater is strongly influenced by surrounding land use, sanitation practices, and hydrogeological conditions, with shallow wells being particularly susceptible to nearby pollutant sources. The observed trend supports the idea that natural filtration and soil attenuation processes help reduce contamination over distance.

IV. CONCLUSION AND RECOMMENDATIONS

The study found that groundwater quality in Rajal Sur, Santa Rosa, Nueva Ecija varies based on proximity to a dirty ice cream factory. All wells were more than 8 meters from residential structures, but differed in distance from the factory. The sample located 50-60 meters away showed no detectable Total Coliform and Escherichia coli (E. coli) and passed drinking water standards, while the three samples located within 20 meters showed elevated contamination levels and failed. Results indicated that Total Coliform exceeded 8.0 MPN/100 mL in the nearer samples, with E. coli levels also present, reaching >8.0 MPN/100mL at 5-10 meters, 4.6 MPN/100mL at 10-15 meters, and 1.1 MPN/100mL at 15-20 meters, confirming unsafe water conditions. A Pearson Product-Moment Correlation Coefficient (r) analysis was performed to evaluate the relationship between distance and microbial concentration. The statistical computations revealed a strong negative correlation, mathematically verifying that as the linear distance from the dirty-ice-cream factory wastewater discharge increases, the concentration of both Total Coliform and E. coli in the groundwater supply significantly drops. Overall, a clear pattern was observed where wells closer to the factory had higher microbial contamination, proving a distinct association between proximity to wastewater discharge and groundwater quality deterioration, although causation cannot be fully established due to the study’s limitations.

Conclusion

1. The groundwater sampling sites in Rajal Sur, Santa Rosa, Nueva Ecija were found to vary in distance from the dirty-ice-cream factory, ranging from approximately 5 meters to 60 meters. The results demonstrated a clear spatial threshold: wells located within a tight 20-meter radius from the factory exhibited elevated levels of microbial contamination, whereas well situated beyond this 20-meter boundary showed significantly lower to non-detectable contamination levels. These findings indicate that distinct variations in localized groundwater quality are directly associated with the relative physical distance of the wells from the primary wastewater discharge source.
2. The microbiological assessment revealed severe variations in the levels of Total Coliform and Escherichia coli (E. coli) among the collected groundwater samples. Samples located closest to the dirty-ice-cream factory exhibited high, detectable microbial counts—specifically Samples 1, 3, and 4, which failed the microbiological safety thresholds. Sample 1 displayed the highest overall contamination, exceeding >8.0 MPN/100 mL for both water quality indicators. In contrast, Samples 2, 5, 6, and 7 recorded safe, low to non-detectable microbial levels, confirming that groundwater quality differs drastically across sampling locations based on these microbiological indicators.
3. Based on these laboratory results, Samples 2, 5, 6, and 7 successfully complied with the Philippine National Standards for Drinking Water because both Total Coliform and *E. coli* levels remained safely below detectable limits. Meanwhile, Samples 1, 3, and 4 did not comply with the national microbiological standards due to the prominent presence of active bacterial contamination. These critical findings indicate that specific shallow groundwater sources in the study area are unsafe and completely unsuitable for drinking without undergoing proper treatment or continuous water-quality monitoring.
4. The Pearson Product-Moment Correlation analysis mathematically verified a significant negative relationship between the linear distance of the wells from the dirty-ice-cream factory and the levels of microbial contamination.

   Wells located closer to the factory wastewater discharge exhibited high Total Coliform ($r = -0.719$) and E. coli ($r = -0.680$) levels, while wells located farther away showed a linear drop in contamination. The results confirm that microbial contamination tends to decrease as the distance from the factory increases, likely due to natural subsurface soil filtration. However, because these findings remain strictly correlational in nature, they highlight an environmental pattern but do not establish direct physical causation between the factory wastewater discharge and groundwater contamination.

Recommendation

The following recommendations are based on the result of the study:

1. Due to the high contamination found in nearby shallow wells, residents especially those within 20 meters of the production sites must boil or chemically treat their water before cooking or drinking to neutralize active pathogens.

2. Management must establish a dedicated, multi-stage wastewater treatment facility that complies with national environmental standards. Regular integrity audits of drainage lines and underground storage units, paired with a perimeter soil/water monitoring layout, must be deployed to intercept industrial seepage before it reaches nearby community aquifers.

3. Government bodies need to establish a structured, long-term monitoring schedule for community hand pumps to track potability. Environmental enforcement officers should mandate that small-scale food enterprises adopt cleaner production methods and sanitary waste-disposal technologies.

4. Future research projects should expand the sampling pool

across a broader geographical scope and observe variations across both wet and dry seasons. Additionally, researchers should incorporate soil porosity and permeability testing to accurately predict exactly how pollutants migrate through the local subsurface layers.

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