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Assessment of the Impact of Water Storage Systems on Plumbing Hygiene and Efficiency

Ayrin Grace N. Niadas[1], Dustine P. Conchas[2], Lloyd Alsen A. Delos Reyes[3], Mikaella D. De Jesus[4], Herron B. Geronimo[5], Missy Kianilee A. Manialong[6], Marc Ely M. Salayog[7], Kevin Lester L. Mabalay[8], Jose Joaquin Valerio[9]

[1,2,3,4,5,6,7] Student, Civil Engineering Department, Nueva Ecija University of Science and Technology

[8,9] Faculty, Civil Engineering Department, Nueva Ecija University of Science and Technology

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. Correlation analysis revealed that environmental risk factors showed no statistically significant relationship with plumbing hygiene and system efficiency, whereas maintenance practices demonstrated statistically significant positive relationships with water quality and system 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: Water Storage Systems, Hygiene, Efficiency, Water Quality, Maintenance Practices, Environmental Risk Factors

I. INTRODUCTION

Water is a fundamental resource necessary for everyday activities, and its availability and quality are essential for maintaining proper sanitation and efficient plumbing systems. In areas where water supply is inconsistent or unreliable, water storage systems are commonly used to ensure a continuous supply of water. These systems play a vital role in supporting residential and institutional water needs, particularly during supply interruptions or periods of low water pressure. Despite their importance, poorly managed water storage systems can lead to water contamination due to the accumulation of sediments, microbial growth, and exposure to environmental pollutants. Issues such as improper installation, inadequate storage capacity, and lack of regular maintenance may result in reduced water pressure, inefficient flow, and overall poor plumbing performance.

Water storage systems serve as essential components in regulating water supply, especially in regions with intermittent distribution, but their effectiveness largely depends on proper design and maintenance practices (Manga et al., 2021). Similarly, Chalchisa et al. (2018) found that water stored in tanks is often more susceptible to contamination than water from the original source, primarily due to poor sanitation practices and inadequate storage conditions. These findings highlight the importance of proper management of water storage systems to ensure both safety and efficiency. By examining different storage types, maintenance practices, and installation conditions, the study seeks to provide insights and recommendations that can improve water safety and system efficiency.

This study is anchored on Systems Theory by Ludwig von Bertalanffy (1968), which explains that water storage systems function as interconnected parts of a larger plumbing and sanitation system. The type, material, capacity, and environmental exposure of storage tanks directly affect plumbing hygiene, water quality, and system efficiency. Recent studies support that proper integration and management of water systems improve reliability and sanitation outcomes (Valcourt et al., 2023; UN-Water & WHO-UNICEF, 2026)

The study is also supported by Public Health Theory, which emphasizes the importance of proper sanitation and safe water management in preventing contamination and health risks. Yazawa et al. (2026) stated that improper household water storage may lead to secondary microbial contamination even when the source water is safe. Likewise, poor maintenance and unsafe storage conditions may negatively affect plumbing hygiene and water quality.

In addition, the study applies Reliability-Centered Maintenance (RCM) Theory (Geisbush and Ariaratnam, 2023), which highlights the importance of preventive maintenance in maintaining system performance and reliability. Regular cleaning, inspection, and proper maintenance of water storage systems help improve water pressure, flow consistency, efficiency, and overall plumbing performance.

The scope of this study is to assess the impact of various water storage systems on plumbing hygiene and efficiency in Cabanatuan City, Nueva Ecija. The research will focus on the connection between the physical and operational characteristics of storage systems and their resulting efficiency. However, this study has several delimitations that should be taken into account. While it assesses plumbing hygiene, this research does not involve microbial or chemical testing of water samples. The study relies on user-reported data, such as survey questionnaires. Plumbing hygiene is evaluated based on residents' observations and experiences. Furthermore, the study excludes accurate technical measurements. It is also noted that the study will have unequal sample sizes across different building types and system profiles, as it reflects the actual occurrence of specific housing and storage types within the local setting.

In the Philippines, water storage systems serve as a direct response to unreliable centralized distribution networks and water scarcity, acting as essential infrastructure to ensure a continuous supply during periods of low pressure or service interruptions (Palanca-Tan, 2020). While national efforts aim for universal access to safe water and sanitation through improved standards, significant gaps persist, with nearly 50% of grade schools still lacking adequate facilities (Bartolata, 2020; Lomboy et al., 2017). This reliance on domestic storage is mirrored globally, where systems are recognized as critical for supply resilience in intermittent networks. However, international research by Howard et al. (2021) emphasizes that these necessary systems often introduce secondary contamination risks, such as microbial growth and sediment accumulation, due to environmental exposure and poor maintenance. Similarly, Yazawa et al. (2017) observed that stored water in urban communities frequently exhibits degraded quality compared to its source, highlighting an urgent global need for strict sanitation protocols and improved management practices to safeguard plumbing hygiene.

The transition of water from source to consumption is often compromised by improper storage and handling, which facilitate secondary microbial contamination even when the initial source is safe (Yazawa, Watanabe et al., 2026). This is particularly evident in the Philippine context, where recent findings have identified the presence of biological contaminants within stored household water (Masangkay, Almeda et al., 2025). The hygiene of these systems is heavily dependent on structural integrity and technical maintenance, as poorly managed tanks can become breeding grounds for pathogens if safety protocols and regular cleaning are neglected (Firstank, 2024). Internationally, Chalchisa, Megersa, and Beyene (2018) reinforce that tank-stored water is significantly more susceptible to quality deterioration than direct source water due to inadequate cleaning and exposure to pollutants. Consequently, global standards such as the International Plumbing Code, the Uniform Plumbing Code, and World Health Organization guidelines emphasize that water safety is a function of both the source and the condition of the plumbing system (Johnson & Kalkowski, 2017). Furthermore, factors such as corrosion and disinfection agent decay can considerably impact water quality regardless of storage location (Slavik et al., 2020), necessitating rigorous compliance with national and international regulations to protect public health.

Water storage systems are pivotal for disaster management and residential supply resilience, yet their contribution to water availability must be balanced with meticulous design to ensure operational efficiency (Pantaleon et al., 2024). Beyond sanitary concerns, the efficiency of these systems is measured by pressure stability, flow consistency, and reliability. Hydraulic modeling by Zhang et al. (2022) demonstrates that poorly maintained tanks significantly diminish pressure and flow uniformity, suggesting that system reliability is inextricably linked to preventive maintenance. While storage improves resilience during supply interruptions, improper sizing or installation can trigger significant pressure fluctuations that disrupt domestic performance (Ferrer et al., 2016). To mitigate these technical failures, the application of Reliability-Centered Maintenance (RCM) has been highlighted as a better approach to enhancing infrastructure performance by reducing downtime and ensuring consistent flow rates (Wang et al., 2016). Collectively, these studies indicate that achieving high-performance plumbing requires a synthesis of strong technical design, accurate tank sizing, and discipline.

II. METHODOLOGY

This study employs a descriptive-correlational research design to assess the impact of water storage systems on plumbing hygiene and efficiency in Cabanatuan City, Nueva Ecija. The descriptive aspect of the design is used to systematically present the existing conditions of water storage systems, including their type, material, capacity, and exposure to environmental factors. It also describes the level of plumbing hygiene, as well as the perceived efficiency and performance of the systems in terms of water pressure, flow consistency, and reliability. Meanwhile, the correlational aspect of the study aims to determine the relationship between the characteristics and maintenance practices of water storage systems and their corresponding hygiene and efficiency outcomes. This design is appropriate for the study as it allows the researcher to analyze existing conditions and identify possible associations among variables without manipulating them.

The study focuses on Cabanatuan households that have an active water storage system having a population of estimated 80,000 whole. To meet the objectives of the study, a non-probability sampling method is used, the study employed purposive sampling to select respondents who met the inclusion criteria. Because non-probability sampling was used, findings are interpreted within the context of selected respondents and generalization to the entire population should be done cautiously. The use of purposive sampling may limit representativeness and external validity. To determine the appropriate number of respondents for the study, the Slovin’s Formula was utilized. This formula is commonly applied when the total population is known, and the researcher aims to obtain a representative sample within a specified margin of error (10%) to determine the target sample (100), a 10% margin of error was selected due to time limitations and accessibility constraints during data collection. The participants of this research consist of one hundred two (102) heads of households or adult residents within Cabanatuan City, Nueva Ecija. An inclusion standard was applied to ensure data relevance, requiring all participants to have an active water storage system that is integrated into their home plumbing system.

The primary data collection for this study was conducted using a structured survey questionnaire, developed through an extensive review of related literature to ensure alignment with the research objectives and the specific assessment of plumbing hygiene and efficiency. This instrument was designed to capture the qualitative perceptions and experiences of respondents regarding their water storage systems. The data gathering process followed a systematic procedure, beginning with expert validation and pilot testing to verify the clarity and reliability of the questions. A hybrid approach was utilized for data collection, combining online survey forms for broader reach with face-to-face administration in selected barangays, including Sumacab Este, Magsaysay Sur, and Kapitan Pepe. Ethical standards were strictly maintained throughout this process, ensuring voluntary participation, providing informed orientations, and guaranteeing the absolute confidentiality of all personal responses. Upon completion, all gathered data were meticulously cross-checked for consistency, coded, and organized into a master database in preparation for statistical analysis. To ensure the internal consistency of the survey questionnaire, Cronbach’s Alpha was used. This statistical measure determines how closely related a set of items are as a group and is commonly applied to Likert-scale instruments.

The study utilizes both descriptive and inferential statistics to analyze the impact of water storage systems. Descriptive tools include Frequency and Percentage for respondent profiles, and the Weighted Mean and Overall Mean to interpret a 5-point Likert Scale, and Inferential tools including Pearson Correlation Coefficient, and One-Way ANOVA (F-Test). These tools quantify the levels of agreement regarding hygiene and system performance.

The following formulas are utilized for data analysis:

a. Slovin's Formula (Sample Size):

$$n = \frac{N}{1+N\,e^2}$$

***b. Percentage*:**

$$P = \left(\frac{f}{n}\right) \times 100$$

***c. Weighted Mean*:**

$$\bar{x} = \Sigma \frac{(f \times x)}{n}$$

***d. Overall Mean*:**

$$\bar{X} = \frac{\Sigma \bar{x}}{k}$$

***e. Pearson Correlation Coefficient (r)*:**

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

***f. One-Way ANOVA (F-test)*:**

$$F = \frac{[\,\Sigma\, nj(\bar{X}j - \bar{X})^2 / (k - 1)\,]}{[\,\Sigma\Sigma\,(Xij - \bar{X}j)^2 / (N - k)\,]}$$

***g. Cronbach’s Alpha Coefficient*:**

$$a = \frac{k}{(k-1)}\left[1 - \frac{\Sigma \sigma_i^2}{\sigma_t^2}\right]$$

Variable	No. of Items	Cronbach’s Alpha	Interpretation
Environmental Risk factors	5	0.7778	Acceptable
Maintenance Practices	5	0.7654	Acceptable
Water Quality	5	0.7472	Acceptable
Efficiency Metric: pressure and Flow	5	0.9194	Excellent
Efficiency Metric: Reliability	5	0.8468	Good

The reliability of the research instrument was assessed using Cronbach’s Alpha to determine the internal consistency of the survey items across all variables. The results show that all values 0.7472 (Hygiene Efficiency), 0.7654 (Maintenance Practices), and 0.7778 (Environmental Risk factors), which are interpreted as acceptable. On the other hand, 0.8468 (Performance metric: Reliability) and 0.9194 (Performance Metric:

pressure and Flow), are interpreted as good and excellent, respectively.

III. RESULTS & DISCUSSIONS

Profile of Water Storage Systems

The study reveals that water storage practices in Cabanatuan City are predominantly characterized by residential applications, with 55.9% of respondents residing in single-family houses. Ground-level tanks are the most prevalent system (66.7%), reflecting a localized preference for accessible infrastructure. Material selection shows a strong inclination toward stainless steel. The majority of systems use a moderate storage capacity ranging from 500 to 1,000 liters and are integrated into relatively new plumbing systems (less than 5 years old).

TABLE 1. ENVIRONMENTAL RISK FACTORS

Statement	Mean	Verbal Interpretation
1. The tank is located in a spot where it receives direct sunlight.	3.24	Sometimes
2. The tank is exposed to high outdoor temperatures.	3.33	Sometimes
3. There are visible sources of pollution near the tank.	2.42	Rarely
4. Dust and debris accumulate on or around the tank area.	3.12	Sometimes
5. Water stays in the tank for more than 3 days before being refilled.	2.69	Sometimes

The evaluation of environmental risk factors in Table 1 indicates that water storage systems are regularly subjected to direct sunlight and elevated outdoor temperatures under typical conditions. While visible sources of pollution are encountered near the tanks from time to time, the accumulation of dust and debris remains uncommon among the surveyed households. Furthermore, extended water retention exceeding three days before refilling does not frequently take place. These findings reveal that while the city's climate exposes storage infrastructure to consistent sunlight and heat, the systems are generally well-protected from external pollutants and prolonged stagnation.

Plumbing Hygiene

TABLE 2: MAINTENANCE PRACTICES

Statement	Mean	Verbal Interpretation
1. The water storage tank is cleaned and scrubbed regularly.	3.54	Often
2. The tank is properly sealed to prevent entry of dust or insects.	4.38	Always
3. The tank is inspected for leaks, cracks, or corrosion.	3.83	Often
4. The surrounding plumbing pipes are checked for damage.	3.91	Often
5. The tank cover is secured immediately after inspection.	4.18	Often

The overall maintenance reflects a proactive maintenance habits that aligns with Wang et al. (2016), where the widespread use of smooth stainless-steel tanks simplifies maintenance. The higher rating for tank sealing supports Manga et al. (2021), demonstrating that residents excel at defending against highly visible external threats like dust and insects. The lower compliance for internal scrubbing and irregular pipe inspections validates the warnings of Yazawa et al. (2026) and Ferrer et al. (2016); because sub-surface biofilm and minor pipe wear are invisible to the naked eye, households default to reactive care rather than systematic tracking. This reveals that while external barriers are strictly managed, the community lacks the standardized, routine internal protocols necessary to eliminate hidden biological and structural risks before they compromise water quality.

TABLE 3: WATER QUALITY

Statement	Mean	Verbal Interpretation
1. The water coming from the tank is clear and free from sediment.	4.48	Always
2. The water is free from any unusual odor.	4.22	Always
3. There is an absence of slime or biofilm growth on the inner walls.	3.79	Often
4. Water is free from any floating particles or insects.	4.26	Always
5. The color of the water remains consistent and natural.	4.39	Always

The findings show an excellent standard of perceived water quality, indicating that households consistently receive clear, odorless, and debris-free water. This aligns with Chalchisa et al. (2018) and Manga et al. (2021), confirming that consumers judge safety through physical clarity and that local setups effectively block external debris. However, the slightly lower score for the absence of biofilm or slime suggests potential invisible bacterial growth on tank surfaces.

Plumbing Efficiency

TABLE 4: WATER PRESSURE

Statement	Mean	Verbal Interpretation
1.The strength of flow from faucets and showers during peak hours.	3.97	High
2. The steadiness of water supply when the main line pressure is low.	3.78	High
3. The amount of water delivered in a short period (flow rate).	3.79	High
4. Stability of pressure when multiple taps are open simultaneously.	3.71	High
5. How quickly the flow returns to normal after heavy use.	3.72	High

The evaluation of water pressure and flow indicates that respondents generally perceive their system's water pressure to be sufficient. The highest rating demonstrates that the storage systems excel at maintaining adequate flow during peak demand conditions. The slightly lower mean scores for pressure stability during simultaneous fixture usage and system recovery after heavy use reveal that increased usage intensity causes minor, localized drops in pressure.

TABLE 5: RELIABILITY

Statement	Mean	Verbal Interpretation
1. The ability of the tank to provide water during supply cut-offs.	3.69	High
2. How quickly water reaches the outlet when turned on.	4.02	High
3. The frequency of having water available when needed.	4.13	High
4. The system’s ability to hold water without loss/leakage.	4.16	High
5. Speed of the system in replenishing stored water after use.	4.05	High

The data indicates that the storage systems effectively fulfill their primary purpose of bridging municipal supply gaps. The highest mean score was recorded for the system’s ability to hold water without loss or leakage, suggesting that the physical installation and material quality of the predominantly stainless-steel tanks perform at a superior level. However, the study noted slightly lower performance during prolonged supply cut-offs, suggesting that while the systems are efficient, current storage capacities may not fully sustain households during extended municipal service interruptions.

TABLE 6: RELATIONSHIP BETWEEN ENVIRONMENTAL RISK FACTORS AND MAINTENANCE PRACTICES AND THEIR RESULTING PLUMBING EFFICIENCY

Variables Correlated	Pearson *r* value	Strength	P-Value
Environmental risk factors and water quality	0.07911	No Correlation	0.43
Environmental risk factors and System efficiency	0.17098	No Correlation	0.09
Maintenance practices and water quality	0.34696	Weak Positive Correlation	0.0003
Maintenance practices and System efficiency	0.53440	Moderate Positive Correlation	7.258×10^{-9}

Correlation analysis showed that maintenance practices have statistically significant positive relationships with plumbing hygiene and system efficiency, whereas environmental risk factors showed no significant relationships. This suggests that sunlight and heat do not automatically degrade water quality if the system is well-managed. Maintenance practices were seen to have a positive relationship with plumbing hygiene and have a strong, moderate positive correlation with system efficiency. So, these findings point to maintenance as the key factor, where better maintenance directly the technical base for higher hydraulic performance and efficiency. Consistent maintenance practices serve as the technical foundation for high-performing domestic water systems. Activities such as regular sealing and inspection help prevent contamination and catch mechanical failures. The data suggests a direct link: more consistent maintenance equals better water quality and smoother flow rates.

Difference Among Building Type & System profiles

The One-Way ANOVA analysis identifies specific profile variables that significantly impact performance.

Building type showed a significant difference in system efficiency (p = 0.00018, F = 2.8895), suggesting that occupancy density affects operational flow. Similarly, storage type significantly influenced water quality (p = 0.008), confirming that tank placement (e.g., elevated vs. ground-level) is a critical factor in perceived hygiene. However, no significant differences were found based on tank material (p = 0.35), storage capacity (p = 0.76), or plumbing system age (p = 0.51), leading to the acceptance of the null hypothesis for these variables. This concludes that while placement and building context matter, the material and volume of the tank do not significantly alter the perceived hygiene or efficiency outcomes.

IV. CONCLUSION

Based on the findings of the study, the following conclusions were drawn:

1. Typically, the system profile includes single-family homes using relatively modern stainless steel tanks, which usually hold between 500 and 1,000 liters.
2. Even though the systems often face tropical weather, like direct sunlight and high temperatures, other environmental threats such as pollution, dust, or prolonged water stagnation are minimal.
3. Perceived water quality is very high, consistently clear, odorless, and free from visible sediments. This directly results from diligent maintenance habits, including regular cleaning and systematic tank inspections.
4. The systems are reliable, even during municipal supply interruptions or peak household demand, it maintains stable water pressure and steady flow.
5. Weather and environmental factors barely affect water quality when structural defenses are solid. Instead, regular maintenance and tank cleaning are the main drivers behind water safety and plumbing efficiency.
6. Perceptions of hygiene and efficiency don't vary based on tank material, capacity, or age. The differences are more structural: the type of building significantly impacts water pressure efficiency, while storage placement, overhead or ground, affects vulnerability to water quality issues.

Recommendations

Based on the findings, it is recommended that:

1. For Household Residents: Regularly clean and inspect tanks, and fix leaks quickly to keep water pressure steady. Make sure tanks are sealed tight to block contaminants, shield them from sunlight, avoid stagnant water for more than three days, and pick a tank size that fits your actual household needs.
2. For Local Authorities and Agencies: Start community programs and campaigns that educate residents on how to maintain water storage properly and follow sanitation rules. Since various tank types function similarly, the focus should be on enhancing household maintenance habits while offering technical help on system sizing, placement, and installation.
3. For Future Researchers: Incorporate lab-based tests for microbial presence in water and objective tools to back up consumer views. Broaden the study's reach and sample size, and look into other factors like cost-effectiveness, environmental effects, and how long materials last.

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