"Mapping Potential Septic Contamination in Household Groundwater Sources Using GIS: A Case Study of Trento, Agusan del Sur"

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ABSTRACT

This study examines the potential contamination of water sources by septic systems used by households in Trento, Agusan del Sur, where site-specific conditions and local groundwater flow are often overlooked when installing septic systems and wells. The research focuses on the risks posed to household water sources by potential septage contamination, with water source and septic system locations identified through a ground survey. The radial distances between septic systems and water sources were analyzed using Geographic Information System (GIS) techniques, specifically Multiple Ring Buffer Analysis. Risk assessments were based on the minimum standard distance of 10 to 30 meters, as outlined in the Code on Sanitation of the Philippines, P.D. 856. The results reveal on a potential risk analysis using thematic mapping and multiple-ring buffer analysis further illustrates that approximately 84% of wells are situated within a 10-meter radius of septic tanks, classifying them as Very High Risk for contamination. In addition, only 6.64% of households surveyed are aware of the standard septic-to-water source distance, suggesting a significant gap in public awareness regarding sanitation safety standards. The study also highlights the reliance on water refilling stations (62.1%) as the primary drinking water source, with 16.7% of households still depending on wells, which are vulnerable to contamination. These findings highlight the necessity of stronger legislation, increased public awareness, and better sanitary infrastructure in order to avoid waterborne illnesses and protect public health.

Keywords: Septage Contamination, Septic System, Radial Distance, Risk

INTRODUCTION

Groundwater is a dependable water source every human can use. It is a critical source of drinking water, particularly in developing countries where surface water may be inaccessible or unsafe (Carrard et al., 2019). However, with humans' right to access this water source, these groundwater resources were exposed to threat such as overutilization and is vulnerable to contamination from septic systems, which are widely used for onsite wastewater disposal in peri-urban and rural areas. Septic systems are one of the groundwater sources' most commonly recognized pollutants and contaminants. Inadequate construction, lack of lining, and proximity to wells increase risks of groundwater pollution especially in in areas where property lots are limited with considerably high densities of septic systems, shallow domestic wells and groundwater contamination are susceptible to septic system leachate (Bremer & Harter, 2012).

In the Philippines, over 80% of households rely on septic. However, a significant portion of these systems do not meet the standards outlined in the Revised National Code on Sanitation of the Philippines, P.D. 856 or the Water Code of the Philippines. The Code specifies requirements such as watertight tanks, appropriate size, a minimum distance of 25 meters from any well, and provisions for regular desludging through access ports or manholes (USAID & DOH, 2008). Many of these are undersized, unlined, and poorly maintained, which leads to untreated effluent leaching into aquifers (Bowyer, 2007). While previous research has

addressed groundwater contamination risks (Bremer & Harter, 2012; Ochieng et al., 1992), few studies in the Philippines have applied GIS-based spatial analysis to systematically evaluate household-level risks. Additionally, the role of public awareness regarding sanitation standards remains underexplored.

The gap addressed by this study lies in the (1) lack of comprehensive risk assessments and data on the potential contamination of water sources by mapping the proximity of septic tanks to wells in Trento using GIS, (2) investigating and analyzing the distance between septic systems and household wells by categorizing contamination risks based on distance thresholds and (3) analyzing household awareness of septic-to-water source standards. By linking spatial and social dimensions of sanitation, this research provides evidence for both academic discourse and local governance.

METHODOLOGY

Respondents and Study Area

The study was conducted in the Municipality of Trento, Agusan del Sur. Figure 1 shows the boundary layer of Trento, Agusan del Sur- It has a land area of 555.70 square kilometers, constituting 5.56% of the province's total area. The study's respondents were selected from the total household population of the Municipality by employing stratified random sampling. This sampling method involved dividing a population in the Municipality into smaller sub-groups known as strata or barangays. On the recent Census of 2020, its population was 54,492; considering a 95% confidence level and 5 % marginal error, a sample size of 467 household respondents was chosen as the study's respondents.

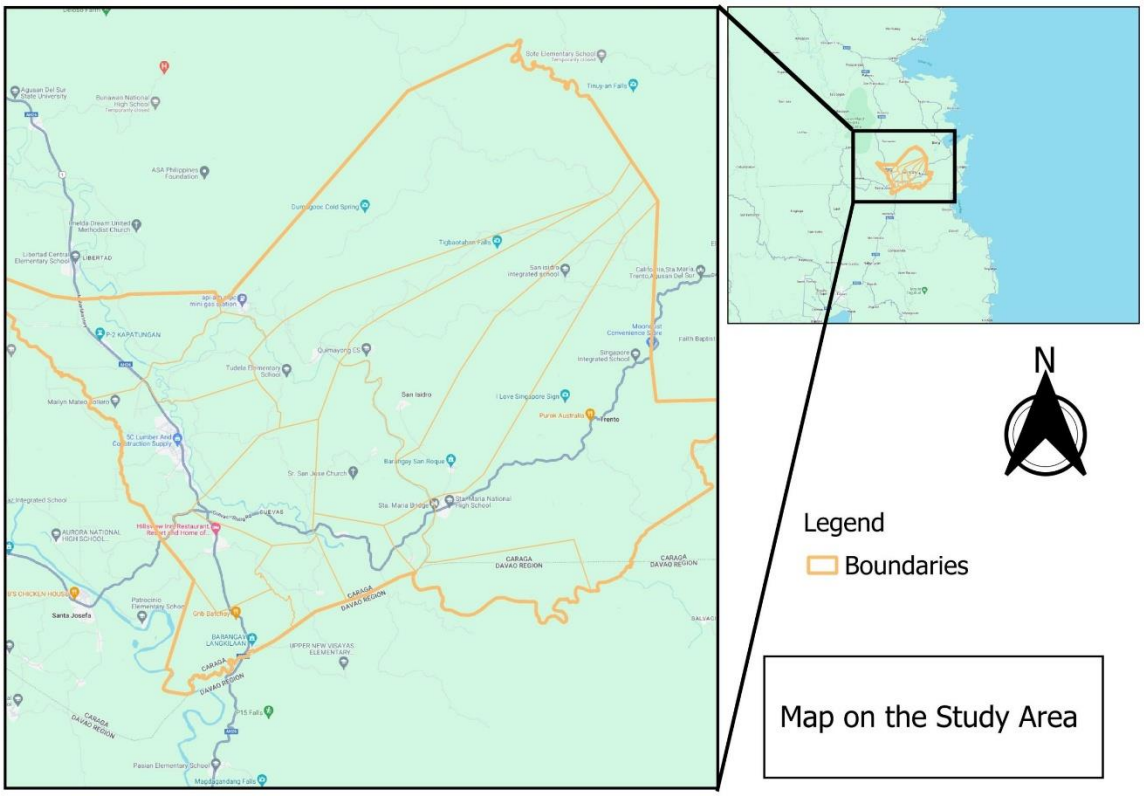


Figure 1. Map of Trento, Agusan del Sur

Data Preparation and Collection

The study's data collection includes a GPS field survey and responses from a semi-structured interview questionnaire. A ground/field survey was conducted to identify the location of the water source and the septic tanks using GPS to obtain their coordinates. The coordinates were inputted into the GIS platform in

CSV format. These inputs were processed, transformed into shapefile, and then analyzed using the multiple-ring buffer to generate a risk map for the potential contamination of the water well from the septic sources. The ring buffer levels were established based on the Code on Sanitation of the Philippines on the standard distance of septic tanks from the wells or any water sources. Three Risk Levels were considered in the analysis: Very High Risk represented the 10 m radial distance between the septic and wells, High Risk for 20 meters, and Low to No risk corresponds to 30 meters. Further, data obtained from the survey questionnaire were summarized using basic statistical techniques used for the descriptive analysis such as frequency count and percentage. A correlation analysis (Chi-square test) was used to analyze the influence of level of awareness to the choice of water source used by the respondents

RESULTS AND DISCUSSION

Household Latrine Facilities

Table 1 provides data on the types of latrine facilities used by households in various barangays, categorizing them into different types based on the presence of septic tanks (ST), lining, or whether the facility is a pour/flush latrine. The results indicate that a significant proportion of respondents already have access to sanitation facilities. However, an alarming 73% of these facilities are either unlined or are considered open-bottom septic systems. This condition mirrors national findings (USAID & DOH, 2008), where undersized and poorly constructed septic tanks dominate. Such facilities directly increase risks of effluent seepage into groundwater, as noted by Bremer & Harter (2012).

Furthermore, the absence of adequate lining in these systems may potentially allow untreated waste to seep into the groundwater source and may pose severe public health risks, which can lead to the spread of waterborne diseases. This underscores the urgent need for improved sanitation infrastructure and stricter regulation to ensure that septic systems are properly constructed and maintained to safeguard public health and the environment.

Table 1. Types of Households Latrine Facilities

	PL² w/o Septic	PL² with ST¹ w/out lining	PL² with ST¹ w/ lining	Pour/ Flush w/o ST¹	Pour/ Flush w/ ST¹ w/ lining	Pour/ Flush w/ ST¹ w/o lining	Nothing
Total	3	2	2	8	106	327	1
Percentage (%)	0.67	0.44	0.44	1.78	23.61	72.83	0.22

1 ST = Septic Tank; 2 PT= Pit Latrine % = Percentage of total respondents (n=467)

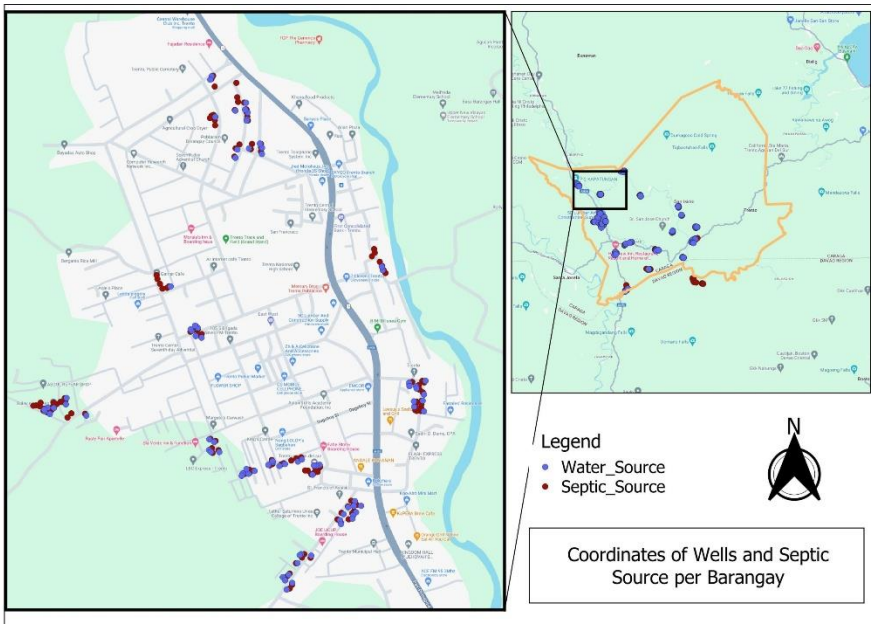
Multiple Ring Buffer Analysis Between Wells and Septic Units

The Potential Risk Analysis for households in the municipality was conducted using thematic mapping, which defined the boundaries of each barangay. The analysis employed the geographic coordinates of wells (water sources) and septic tanks, as depicted in Figure 2.a, where blue dots represent water sources and red dots represent septic tanks. To assess the proximity between these two critical elements, multiple-ring buffer

analysis was applied, as shown in Figure 2.b, which interpolates the distance between the water sources and septic tank locations.

The analysis reveals significant overlap between the buffers of septic tanks, neighboring septic systems, and wells, suggesting that many water sources are dangerously close to septic tanks. This phenomenon can be attributed to the limited lot space and high neighborhood density in the area, which restricts the placement of water sources and septic systems at adequate distances from one another. Given the high density and small lot sizes, it is highly likely that septic systems and water sources are often located in close proximity within the same household premise, exacerbating the risk of cross-contamination and potentially compromising the safety of drinking water. This emphasizes the urgent need for urban planning and stricter regulations regarding the spatial arrangement of sanitation systems and water sources to protect public health.

(a)



(b)

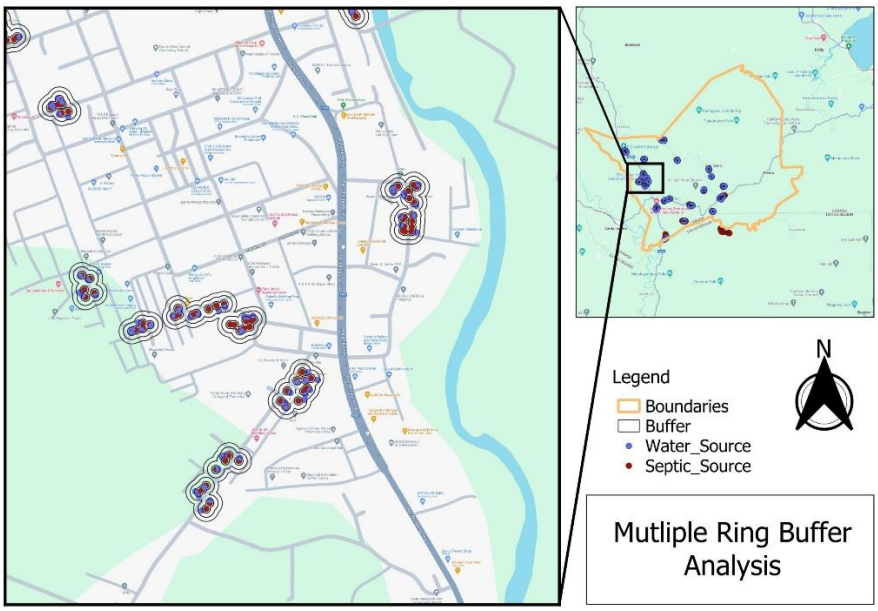


Figure 2. Coordinates of Water Source and Septic tanks of Households (a), Multiple Ring Buffer Analysis of the Barangays (b)

Risk Distribution of Wells

Figure 3 illustrates the wells categorized according to various risk levels, while Table 2 presents the estimated percentages of wells assigned to each risk level based on the analysis. GIS buffer analysis revealed that 84% of wells are within 10 meters of septic tanks, indicating Very High Risk (Table 2). Only 1% were safely beyond 30 meters. Compared to U.S. and African studies (Bremer & Harter, 2012; Ajayi et al., 2022), the contamination risk in Trento is significantly higher due to smaller residential lot sizes. Statista (2024) reports that more than half of Filipino households occupy lots under 50 m², limiting spatial separation between sanitation systems and water sources.

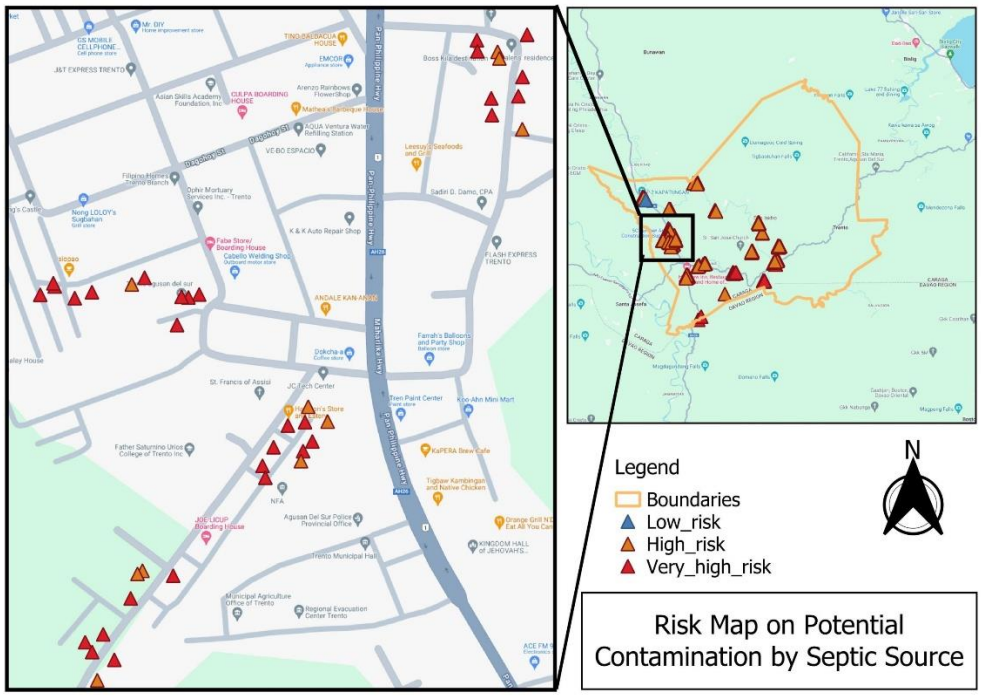


Figure 3. Map on the Risk Analysis of Wells

Table 2. Risk Distribution of Wells (n=467)

Risk Level	Percentage (%)
Very High Risk	84
High Risk	15
Low Risk	1
Total	100

Septic-Water Source Distance Awareness

Table 3 shows the responses of the household of barangays on their awareness to Septic-Water Source Distance based from the Code on Sanitation of the Philippines. Only 6.64% of the total households surveyed are aware of the standard distance between water sources and septic tanks, amounting to 31 households out of a total of 467 households.

Table 3. Household Responses Awareness

Response	**Aware (%)**	**Not Aware (%)**
Total	6.64	93.36

% = Percentage of total respondents (n=467)

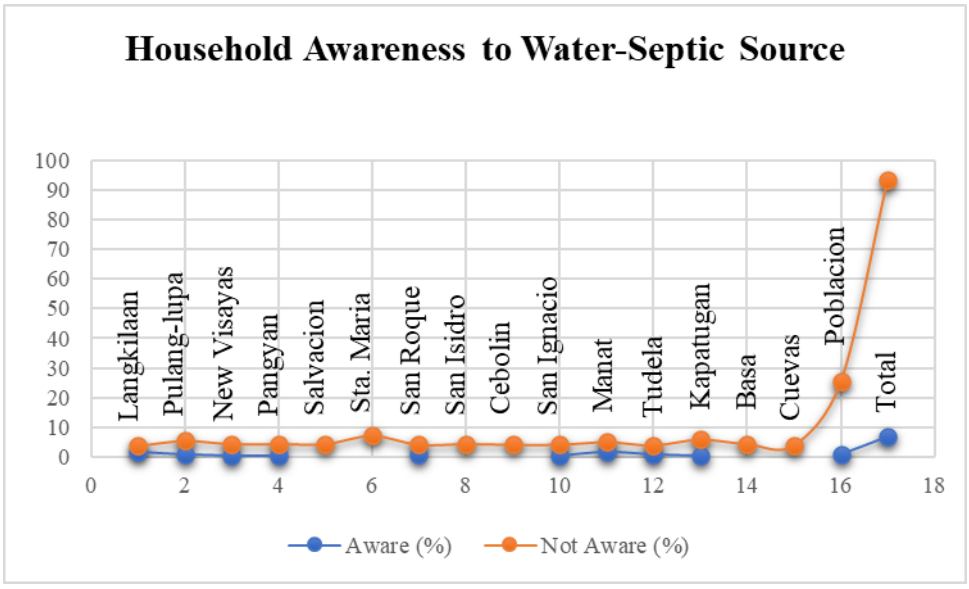


Figure 4. Household Awareness of Required Septic–Water Source Distance (n = 467)

Further, this suggests that a significant majority of households (93.36%) are not aware of these important safety standards as shown in figure 4, which could lead to health risks due to contamination. Several barangays, such as Salvacion, Santa Maria, San Isidro, Cebolin, San Ignacio, Basa, Cuevas, and Poblacion, have a large number or even all households unaware of the standard distance. Notably, Poblacion has 118 households (25.27%) unaware, which is the highest in the table. The fact that Poblacion, a more urbanized area, has such a high proportion of unaware households raises concerns about the adequacy of awareness programs and the risks that might arise from such a lack of knowledge.

Drinking Water Source Used by Households

Figure 5 presents data on the primary sources of drinking water for different barangays (neighborhoods or villages).

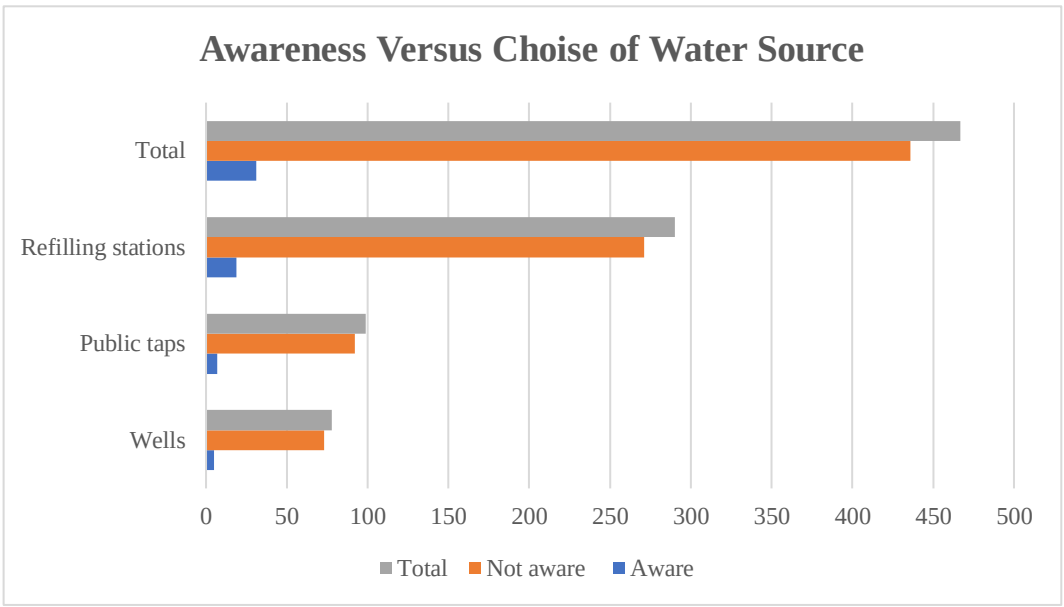


Figure 5. Correlation Between Water Source Preference and Level of Awareness

This breaks down these sources into three categories: Public Taps, Water Refilling Stations, and Wells. The data showed that Water Refilling Stations are the most commonly used water source across all barangays, contributing 62.1% (290 instances out of 467 total). Many barangays have a higher reliance on water

refilling, including areas like Kapatungan (25) and Poblacion (82), likely due to factors like local water quality issues or insufficient public tap infrastructure. However, a manifestation of 16.7% reliance on wells for drinking water is still a significant concern, particularly because wells are vulnerable to contamination from septage and other pollutants.In addition, figure 4 also shows the distribution of drinking water sources according to household awareness of the 25-meter sanitation standard. At first glance, households that are aware and not aware of the standard appear to have very similar patterns of water source use: most rely on refilling stations, followed by public taps, with wells being the least common. This visual impression is confirmed by the chi-square test of independence, which indicated no significant association between awareness and drinking water source, $\chi^2(2, N = 467) = 0.04$, $p = .98$. The negligible effect size (Cramer's V = 0.009) further suggests that awareness had virtually no influence on household water source choices.

This finding highlights a critical knowledge–practice gap in water, sanitation, and hygiene (WASH) interventions. While awareness campaigns are intended to encourage safer water use, previous research shows that knowledge alone rarely produces behavioral change in contexts where infrastructure, affordability, and convenience strongly constrain options (Mosler, 2012). For example, even when families understand the risks associated with wells near septic tanks, the lack of affordable alternatives and the convenience of having an on-site source may compel them to continue using wells (Carrard, Foster, & Willetts, 2019).

The dominance of refilling stations as the main drinking water source across both awareness groups also reflects broader trends in the Philippines, where households increasingly purchase treated water due to declining trust in groundwater quality (WHO & UNICEF, 2021). However, reliance on refilling stations is closely tied to household income. Poorer families may still depend on wells and public taps despite awareness of contamination risks, as has been documented in other Southeast Asian communities (Ercumen et al., 2017).

Finally, the absence of a strong statistical relationship suggests that structural and socioeconomic constraints outweigh awareness. Without stronger policy enforcement, expanded public water infrastructure, or subsidies for safe alternatives, awareness campaigns alone may not meaningfully reduce groundwater reliance in areas like Trento, Agusan del Sur. Similar findings have been noted in other WASH studies, where enforcement and enabling environments are necessary to convert knowledge into sustainable practice (USAID & DOH, 2008).

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

The analysis presented several key findings on sanitation facilities, water sources, and related public health risks in the municipality. A significant proportion of households (73%) rely on unlined or open-bottom septic systems, which can lead to potential contamination of both soil and water sources and may increase the risk of waterborne diseases. This situation aligns with earlier findings by USAID (2008) highlighting issues with poorly constructed septic systems in the Philippines. A potential risk analysis using thematic maps revealed that many wells are located within close proximity to septic tanks, with 84% of wells classified as Very High Risk due to their location within a 10-meter radius of septic systems. The data also showed that a lack of awareness about proper septic-to-water source distance is prevalent, with only 6.64% of households aware of the standard distance requirements. Most households rely on water refilling stations (62.1%) as their primary drinking water source, though 16.7% still depend on wells, further raising concerns about the vulnerability of water sources to contamination.

Conclusion

This study demonstrates that improperly constructed and closely located septic systems may pose severe contamination risks to household wells in Trento. With 84% of wells in Very High-Risk zones and only

6.64% of households aware of sanitary distance standards, groundwater contamination poses a significant public health threat. The high percentage of unlined septic tanks and the close proximity of septic systems to wells emphasize the necessity for imperative action to improve septic infrastructure practices and management. Furthermore, the lack of public awareness regarding the standard septic-to-water source distance compounds the risks, as many households are unaware of the necessary safety protocols. Additionally, while water refilling stations are commonly used, the continued reliance on wells for drinking water, particularly in high-risk areas, remains a concerning factor for public health.

The study achieved its objectives by mapping contamination potential, analyzing risk categories, and linking results with awareness data. The novelty lies in integrating GIS risk mapping with household knowledge, bridging spatial and social dimensions of sanitation research. Findings underscore the urgency for action in infrastructure, regulation, and community engagement.

Recommendations:

Based on the results the following recommendation below maybe considered:

1. **Enhanced Public Awareness Campaigns**: This is a low-cost but high impact stategy. Implement extensive community education programs to raise awareness about the risks associated with improper septic system construction and the importance of maintaining the correct distance between septic tanks and water sources. This can be done through local workshops, informational materials, and media outreach. Conduct barangay-level workshops, distribute IEC materials, and use radio/TV campaigns.
2. **Monitoring and Compliance**: Strengthen the monitoring and enforcement of sanitation codes, particularly those that regulate the construction and maintenance of septic systems, ensuring that all systems comply with established standards to safeguard public health.
3. **Expansion of Safe Water Access**: For a long-term plan and investment, provision and improvement of public water infrastructure, particularly in barangays with high reliance on wells, to ensure the availability of safe and potable drinking water. This could include expanding the coverage of public taps and water refilling stations, or constructing additional water treatment facilities to reduce dependency on potentially contaminated water sources.

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