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Assessment of the quality of groundwater wells in the island Municipality of Panglao, Bohol, Philippines

Ma. Grace C. Sumaria[1]*

ABSTRACT

The study was conducted in the Municipality of Panglao, Bohol, Philippines to investigate water quality in 81 wells using parameters such as pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), sodium chloride (NaCl), temperature, and nitrate-N. Spatial variation is analyzed through ArcGIS 10.6 and regression analyses.

Results showed that about 40% of the study area's nitrate concentration exceeded the maximum contaminant level (MCL) of 10mg L^{-1} as set by US EPA under the Safe Drinking Water Act. The water quality was poor mostly in barangays with high-density built-up and along the foreshore. On the average, pH was 7.44, DO was 4.27mg L^{-1}, EC was 3,954.82µS cm^{-1}, TDS was 3,480.60mg L^{-1}, NaCl was 4,377.50ppm, temperature was 29.36°C and nitrate was 11.05mg L^{-1}.

The multiple regression analysis showed that nitrate is significantly predicted by well to shoreline distance and 2D inverse distance weight. The T-test results indicated that the level of nitrate concentration differed significantly between the types of well where it was found to be higher in shallow wells and lower in deep wells.

Based on the overall results, the following recommendations were drawn for the Municipality of Panglao to implement: a) install a wastewater treatment facility to address the unfavorable presence of nitrate and other contaminants in the groundwater, and b) enact

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[1]Department of Agricultural and Biosystems Engineering, Visayas State University, Baybay City, Leyte, Philippines

***Corresponding Author.** Address: Department of Agricultural and Biosystems Engineering, Visayas State University, Baybay City, Leyte, Philippines; Email: grace.sumaria@vsu.edu.ph

relevant ordinances to stop the rising influences of nitrate concentration and other water contaminants in the groundwater which are detrimental both to the growing population and to the environment.

Keywords: groundwater water quality, nitrate level, nitrate contamination

INTRODUCTION

Groundwater, situated beneath the water table (Younger 2009), is a vital and reliable source of water essential for human survival, serving diverse purposes including domestic use, agriculture, and industry (Varis 2014). Globally, over 97% of freshwater resources come from groundwater, providing half of the world's drinking water and nearly half of irrigation water (Jakeman et al 2016). Arid Asian countries heavily depend on groundwater, with consumption for irrigation ranging from 87% to 94% (Margat & Gun 2013).

In the Philippines, 50% of the population relies on groundwater for drinking. The National Water Resources Board allocates usage, with households at 49%, agriculture at 32%, industry at 15%, and other sectors at 4%. However, 60% of groundwater extraction occurs without proper licensing (World Bank Group 2003). Water quality is a global concern, with untreated wastewater disposal threatening human health, agriculture, and ecosystems. Approximately 80% of wastewater from developed and emerging countries enters the environment untreated (Thomas 2021).

The quality of the water supply has been a recent global challenge for many countries as it has a negative impact, mostly on human health and the livestock industry. Hence, it is important to assess the water characteristics, especially in coastal belts, where these areas can be urbanized rapidly and where the groundwater is also continuously threatened by sea mixing caused by overexploitation or excessive withdrawal of groundwater. Depletion and contamination reduce water availability for domestic usage, including drinking, as well as agricultural use.

The study area for this research was the Municipality of Panglao. This rapidly growing tourist area has experienced an increase in population and tourist arrivals over the last decade. This island is located at the southwestern tip of Bohol Province and to the east of Cebu. With rapid development, the demand for groundwater resources has increased tremendously to meet domestic needs. Panglao sits on a small freshwater lens, a naturally occurring underground reservoir of freshwater that floats above the denser saltwater in the island's porous limestone bedrock. It can be depleted in the dry season and easily over-pumped, causing salinization. There have been many complaints by the residents over water shortage and quality. In the study of Husana (2013), it was found that 38.7% of the respondents use a municipal water supply, which is from a centralized deep well, followed by those using purified water (33.8%) and those using water from private deep wells for their daily consumption (18.2%). Purified water has undergone treatment to remove impurities, contaminants, and pathogens, making it safe for drinking. This shows a high dependence on groundwater. Due to this fact, it is very important to find out the groundwater condition, especially in the wake of the increasing population in coastal areas of Panglao (Mondal et al 2014).

The Municipality of Panglao has a total land area of about 4,779 hectares with an estimated total of 9,781 septic tanks (according to the number of houses digitized from high-resolution satellite images) (OpenStreetMap 2020). Due to the lack of good surface water sources, the municipality's water supply comes from wells, which show a significant groundwater demand. The geology of the island is composed mostly of limestone which is known to be karstic in nature and highly vulnerable to contamination (Husana 2013), resulting in a high potential for human and ecosystems exposure to contaminants.

Most households with toilets are connected to poorly designed septic tanks, in which effluent is discharged without treatment. If poorly managed, septic tanks may release nutrients such as nitrate, phosphorus, bacteria, and other chemical substances into the groundwater, thereby causing significant water quality problems. This requires assessing the water quality of those drinking wells to ensure that this common practice does not pose any hazard to users. With the rapidly increasing demand for domestic water supply and the high reliance on the limited and vulnerable groundwater supply, the characterization of the groundwater condition, particularly the water quality condition and potential sources of contamination is imperative. Thus, this study aims to characterize the spatial variation of groundwater quality, with emphasis on nitrate concentration in the Island Municipality of Panglao.

METHODOLOGY

Sampling Sites

On May 2020, 81 wells (Figure 1) in the Island Municipality of Panglao, Bohol were sampled for various parameters, including temperature, pH, dissolved oxygen (DO), sodium chloride (NaCl), electrical conductivity (EC), total dissolved solids (TDS) and nitrate-N levels. The location of the wells was determined using Global Positioning System (GPS) and the coordinates of the wells were recorded simultaneously with the gathering of data for the selected parameters. Selected parameters were measured in situ using EUTECH PCD650 waterproof portable water quality meter, MW 600 Smart DO meter, Hanna Combo pH and EC meter, and V2000 Multi-Analyte Photometer shown in Figure 2. The devices used were calibrated first before being used in the field. Samples were collected as per standard methods.

Collecting of Physicochemical Parameters

In May 2020, a total of eighty-one artesian wells were measured on-site for the groundwater quality. This comprehensive data collection was conducted three times during this driest month of the year to investigate the spatial variations of nitrate and other water parameters.

A water quality meter measured the pH, total dissolved solids (TDS), sodium chloride (NaCl), and temperature. A smart DO meter was used to measure dissolved oxygen. Electrical conductivity (EC) in μS/cm was tested by an EC meter. Nitrate-nitrogen in mg/L was tested and analyzed by the Cadmium Reduction Method using a V2000 Multi-Analyte Photometer. The methods used to analyze the nitrate-N were based on ASTM D 3867-09. The figures of all instruments used in this research are shown in Figure 2.

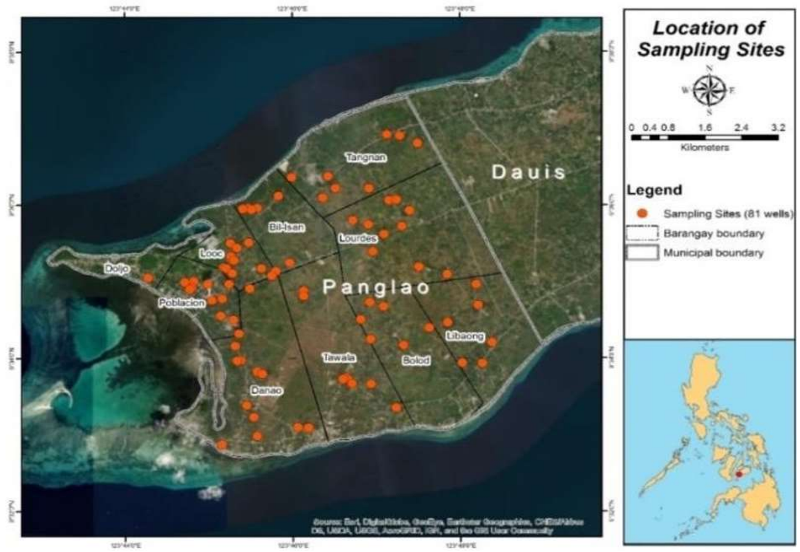


Figure 1. Map of the Municipality of Panglao indicating the location of the sampling sites per barangay

Figure 2. Water quality sampling instruments:(A) V2000 Multi-Analyte Photometer, (B) EUTECH PCD650 waterproof portable water quality meter, (C) MW 600 Smart DO meter, (D) Hanna Combo pH and EC meter

Interview Survey

Interviews with the well users, aged 35 to 80, were conducted after every sampling. Eighty-one (81) well users were interviewed regarding general information about the well; its condition and the maintenance of septic tanks, which can affect the nitrate levels in groundwater; the disposal of their solid waste and wastewater that can affect groundwater and seawater; and their environmental and economic points of view about the Municipality of Panglao. Responses were recorded on paper.

GIS Data Analysis

Buildings, septic tanks, and coastal locations were manually digitized from satellite images using Google Earth and OpenStreetMaps.com. QGIS and ArcGIS was used to process and analyze the spatial data. The points recorded in the Excel file were converted to a vector file (shapefile). The density map, created with ArcGIS using the Heatmap Kernel Density tool, was used to show hotspots and clusters of points. Higher values on the map indicate areas with more closely grouped points ("Kernel Density (Spatial Analyst)—ArcGIS Pro | Documentation," nd).

Watershed Delineation. Watershed delineation is essential to establishing the boundaries of the research area (Basnet et al 2019). Figure 3 illustrates the delineated watershed boundaries within the study area.

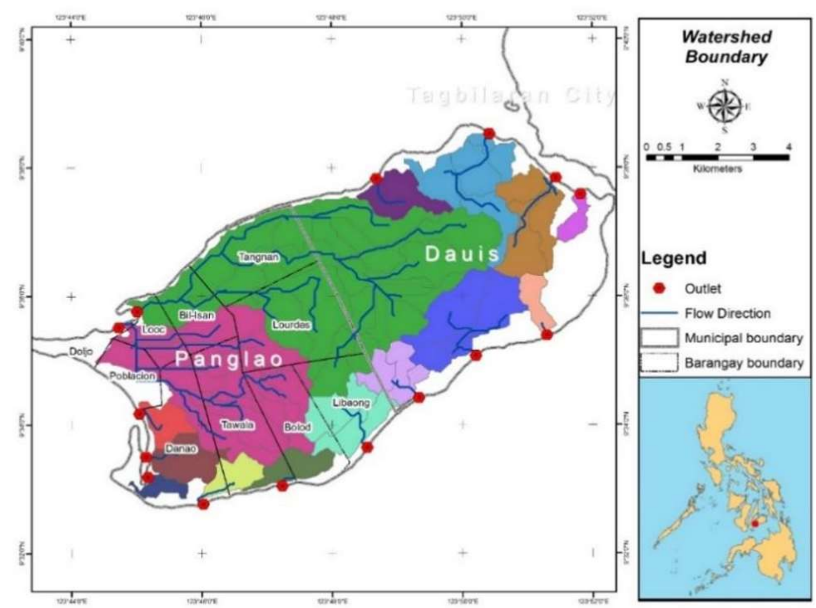


Figure 3. Delineated watershed boundaries of the study area indicating the flow direction and outlets.

Septic Tank Density Analysis

The kernel density tool was utilized to calculate the quantity per unit area based on point or polyline features. A gently tapered surface using a kernel function represented each feature. The analysis utilized a shapefile indicating septic tank positions, inferred from building locations, as input (Murad and Khashoggi 2020). The resulting 50m search radius output raster depicted septic tank density. Figure 4 indicates the flow of the septic tank density analysis process.

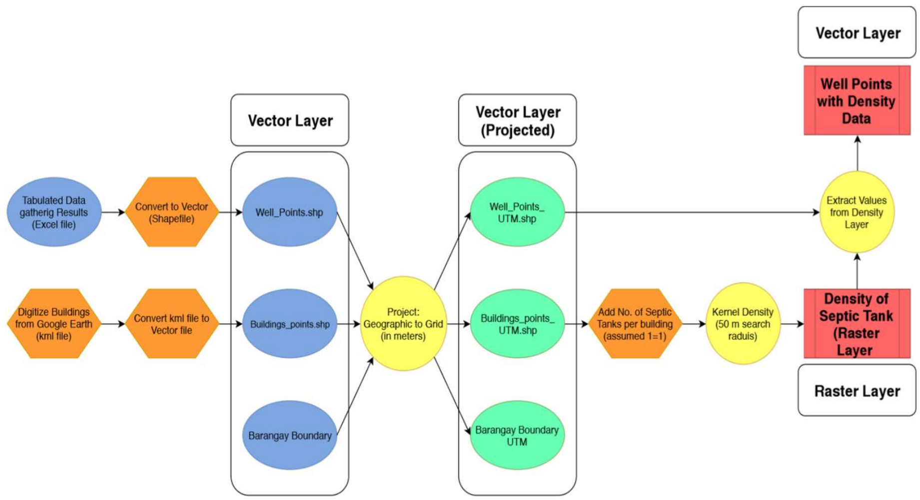


Figure 4. Flowchart of septic tank density analysis process in ArcGIS 10.8

Inverse Distance Weight Analysis in Two-Dimensions

The inverse distance weight (IDW) method was used to determine if the nitrate level in each sampling well was affected by the number and distance of the surrounding septic tanks. In this case, the search radius was 50 meters. The weight is a sum of the inverse distance between a well and septic tank within a 50-meter buffer. This method assumed that the points that are close to a reference point tend to have more influence than the ones that are farther away by using the following equation:

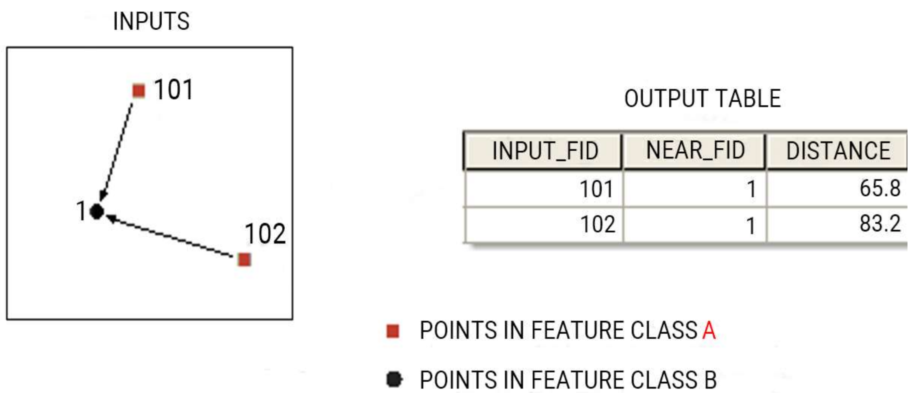
$$W_J = \sum_{i=1}^{n} \frac{1}{D_i}$$

$$D = \sqrt{(X_2 - X)^2 + (Y_2 - Y_1)^2}$$

Where:

W_J= inverse distance weight of a sampling well
n = specific number of septic tanks within the buffer radius
D = distance from a well to a septic tank
X and Y = spatial coordinate

The "Point Distance" spatial analyzer also determines the distance. This program calculates the separations between all points in the near features within a given search radius and the supplied point features. The tool produces a table showing the separations between two sets of points. Distances from all input points to all nearby points are computed when the default search radius is utilized. Only entries having a nearby point inside the search radius are included in the result table ("Point Distance (Analysis)—ArcMap | Documentation" nd).



INPUT_FID	NEAR_FID	DISTANCE
101	1	65.8
102	1	83.2

Figure 5. Illustration of point distance analyst tool ("Point Distance (Analysis) —ArcMap | Documentation"

Statistical Analysis

The obtained matrix of the dataset was analyzed using correlation analysis, T-test, ANOVA and multiple regression analysis using hierarchical regression. These techniques help to find the relationship between two or multiple factors and simplify large data sets in order to make useful generalizations and insight.

Multiple Regression Using Hierarchical Regression

Multiple statistical regression is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. Typically, multiple regression is used as a data-analytic strategy to explain or predict a criterion (dependent) variable with a set of predictors (independent) variables. This was used in the study to examine and explore the spatial relationships between any parameters that have a significant relationship to nitrate. In this study, hierarchical step-wise multiple regression was used. Stepwise regression involves choosing which predictors to analyze based on statistics. Hierarchical regression involves theoretically based decisions for how predictors are entered in the analysis.

Regression is the process of fitting an equation to the data. Sometimes, regression is called curve fitting or parameter estimation. Empirical models are widely used in engineering. Regression provides the means for selecting the complexity of the French curve that can be supported by the available data (Berthouex & Brown 2002). A multiple regression model that might describe this relationship is:

$$\gamma = \beta_0 + \beta_1\chi_1 + \beta_1\chi_2 + \ldots + \beta_n\chi_n + c$$

where:

γ = dependent variable or what are you trying to predict
χ = Explanatory variables that may help to explain the dependent variable
β = Coefficients or values that will reflect the relationship and strength of each explanatory variable to the dependent variable.
c = the residual or the portion of the dependent variable that is not explained by the model.

RESULTS AND DISCUSSION

Septic Tank System

The majority of the residents in Panglao use septic tanks to dispose of their household wastewater instead of a sewage system. Septic systems are examples of anthropogenic sources of nitrogen contamination of the groundwater (Haller et al 2013). In this system, wastes are discharged into a tank and then into an underground disposal field. Nitrogen remains in ammonium and organic forms until it reaches the aerobic zone below the disposal field. Once the aerobic zone is reached, oxidation will follow to form nitrate. Oxidized product is transported by water into the groundwater system.

As of May 2020, the Municipality of Panglao has a total land area of about 4,779 hectares and 9,781 septic tanks (according to the number of houses digitized from a high-resolution satellite image). If those septic tanks fail to perform efficiently, they can release nutrients such as nitrate and phosphorus, bacteria and other chemical substances into the groundwater, thereby causing more significant water quality problems.

Chapter 17, Section 75 (c) of Presidential Decree 856, Code on Sanitation of the Philippines, issued in 1975, mandates that septic tanks be positioned at a minimum distance of 25 meters from any well, spring, cistern, or other drinking water supply source (Presidential Decree No. 856, S. 1975 | GOVPH 1975). However, in the study area, it was observed that the actual distances between septic tanks and such water sources often deviated from this requirement, varying from 6 to 10 meters inside a 15-meter buffer zone (Figure 6).

Moreover, from random interviews, it was found out that residents never pumped their septic tanks even though they have used their septic tanks in more than 5 years. According to EPA guidelines in 2005, septic tanks should be pumped regularly (generally between 3 to 5 years) together with the inspection for leaks, scum and sludge layers in the septic tank. The poor awareness of how wastewater can be pose a threat to human health needs management strategies and mitigations to improve awareness and solve the problems.

Spatial Variation of Water Quality in the Study Area

The spatial variability of water quality entails variations in water quality characteristics among distinct locations within a designated study area. An essential aspect is comprehending the spatial variation of water quality across diverse temporal and spatial scales. This requires regular monitoring of surface water to capture both spatial and temporal fluctuations in water quality. This monitoring process plays a significant role in identifying potential sources of pollution (Chong et al 2022).

In this study, eight parameters were examined to assess spatial variation. These parameters include pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), Sodium Chloride (NaCl), total dissolved solids (TDS), and nitrate-N. Each parameter was investigated to understand its distribution and variations across different locations.

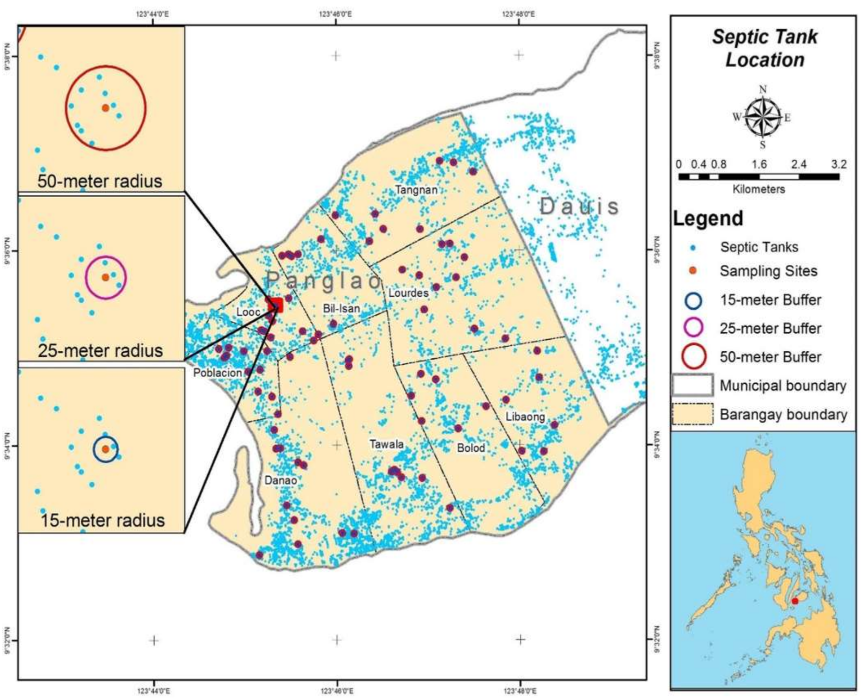


Figure 6. Septic tank location of Panglao indicating one of the wells in Brgy. Looc to septic tank distance with 50-meter, 25-meter and 15-meter search radius

Hydrogen Potential (pH)

The optimal pH range for drinking water falls within the bracket of 6.5 to 8.5, according to the World Health Organization (WHO). This pH range of water is regarded as acceptable for ingestion by people and is unlikely to have any negative health effects. As per the guidance from the United States Environmental Protection Agency (EPA), the pH of municipal water supplies is between 6.5 and 8.51 (US EPA 2015). Surface water systems often have pH ranges of 6.5 to 8.5, whereas groundwater systems typically have pH ranges of 6 to 8.52. Under the Philippine National Standards for Drinking Water (PNSDW), the pH range for drinking water is 6.0 to 8.5 (PNSDW 2017).

During the sampling period, the pH levels ranged from 6.49 to 7.9. The pH values of this sampling period indicated the study area's bicarbonate environment that may be due to the carbonate nature of the Maribojoc limestone that underlies Panglao. The Maribojoc limestone, known for its porous and coralline characteristics, likely contributes to the presence of calcium (Ca) and magnesium (Mg) along with the other anions and cations such as Na^+, K^+, Cl^-,SO^{2-} and HCO^- (Hounslow 1995).

Temperature

Throughout the sampling period in May 2020, the temperature of the water samples ranged from 25°C to 35.4°C. The highest temperature was recorded at Brgy. Looc with an average temperature of 35.1°C. At high temperatures, water, particularly groundwater, dissolves more minerals from the surrounding rock resulting in enhanced electrical conductivity. On the other hand, warmer temperatures cause less solubility of gases in water, resulting in lower dissolved oxygen levels compared to colder water (Water Science School 2018).

As per the guidelines set by the Philippine National Standards for Drinking Water (PNSDW), the acceptable drinking water temperature range falls between 10°C and 25°C. However, based on the temperature measured during the study, it is evident that the recorded value exceeds the established standard limits.

Nitrate-N

The nitrate-nitrogen values from the sampled wells ranged from 6.725mg L^{-1} to 20.115mg L^{-1} with an average of 11.095mg L^{-1}. Nitrate levels increased as the location of the wells became closer to Panglao town proper, where there is high population density. As a result, 31 out of 81 wells (38%) have nitrate concentrations exceeding the USEPA Maximum Contaminant Level (MCL) of 10mg L^{-1}. Acceptable nitrate levels in wells were found in Barangay Lourdes, but high nitrate levels were found in the town proper wells like Brgy. Poblacion, Brgy. Danao, and Brgy. Looc. This high concentration of nitrate poses a serious threat to human health especially to infants less than six months of age. Nitrate-nitrogen levels at 10 to 20mg L^{-1} is known to cause illness and even death (Rios et al 2011).

Furthermore, the average concentration level from the 81 sampled wells exceeded the Maximum Contaminant Level (MCL) for nitrate-N which is 10mg L^{-1} as set by the US EPA under the Safe Drinking Water Act (Taylor 2003). As the municipality has no industrial factories or agricultural land areas, the elevated concentrations of nitrate-nitrogen can be attributed to other anthropogenic activities, specifically leakage from septic tanks that could produce these contaminants as byproducts or waste products.

Haller et al (2013) pointed out that septic tanks are the direct point sources of nitrate which can enter the groundwater. Moreover, based on the field observations, the distance between the septic tanks and the wells is not compliant with the standard distance recommended by the Philippine Department of Health. The recommended distance from a well to a nearest septic tank is 25 meters. However, in most cases, it varies from 6 to 15 meters in the study area.

Figures 7 and 8 illustrate the spatial distribution of nitrate-nitrogen in the study area, distinguishing between deep and shallow wells. Shallow wells, defined as those with a depth of 1 to 6 meters from the surface, are particularly vulnerable to nitrate contamination due to their proximity to surface activities. In contrast, deep wells extending beyond 6 meters below the surface are generally less susceptible to such contamination. The majority of wells that exceeded the Maximum Contaminant Level (MCL) for nitrate-nitrogen were shallow wells, indicating a higher risk of contamination.

Assessment of the quality groundwater wells

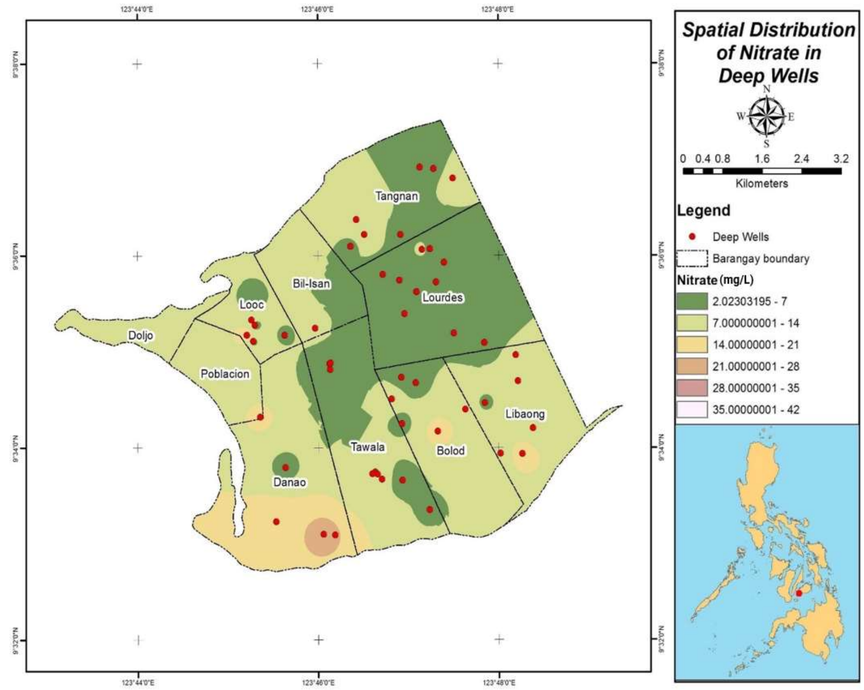


Figure 7. Spatial distribution of nitrate-nitrogen (mg L^{-1}) indicating the sampled deep wells

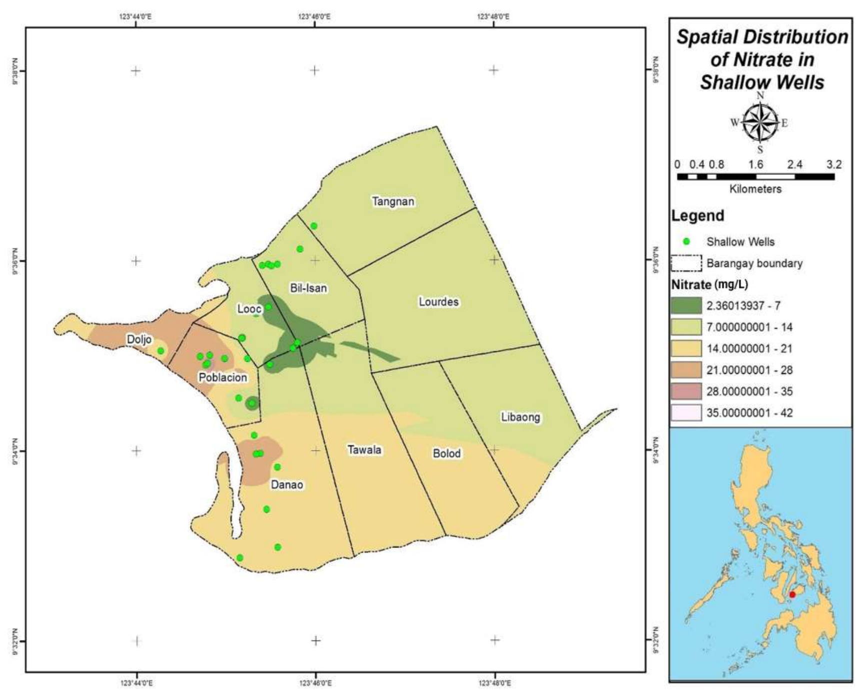


Figure 7. Spatial distribution of nitrate-nitrogen (mg L^{-1}) indicating the sampled shallow wells

Notably, the shallow wells in Barangay Poblacion, Danao, and Tawala showed elevated concentrations of nitrate-nitrogen, as seen in Figure 8. A high density of tourist resorts characterizes these areas and are also closer to the shoreline, further contributing to the vulnerability of shallow wells to contamination from human activities and potential runoff.

Dissolved Oxygen (DO)

DO ranged from 1.4mg L^{-1} to 6.8mg L^{-1} with an average DO of 4.226mg L^{-1}. The highest DO was found in Barangay Libaong, where the distribution of houses is sparse. DO dropped below 4mg L^{-1} in or nearby the town and kept decreasing until below 2mg L^{-1} towards the shoreline. The lowest DO was found in Barangay Danao with a concentration level of 1.4mg L^{-1}. Figure 9 shows the spatial distribution of DO in the study area indicating the wells with DO concentration of less than 4mg L^{-1}. The noted trend is linked to the effect of water temperature, as it is the critical factor determining the capacity of water to retain dissolved oxygen. As water temperature increases, dissolved oxygen concentration tends to decrease, displaying an inverse relationship (Post et al 2018).

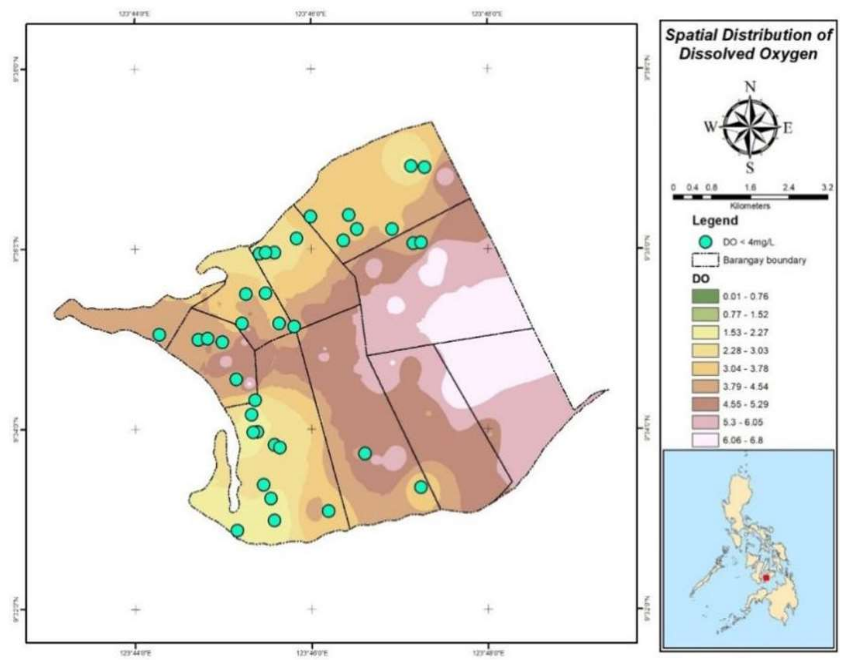


Figure 9. Spatial Distribution of DO (mg L^{-1}) in the Study Area

Most of the wells with lower DO concentration were found in crowded areas such as Barangay Danao, Poblacion, Looc, Bil-isan and Tangnan. Wells in Barangay Libaong and Bolod were better since none of them had a concentration below 4mg L^{-1}. The distribution of houses in these barangays is sparse. DO depletion indicates many oxygen-demanding materials from anthropogenic sources such as domestic wastewater, effluents from domestic sewage, and stormwater runoff in crowded areas. These materials increase the biochemical and chemical oxygen demand in groundwater. As these substances decompose or undergo chemical reactions, they consume dissolved oxygen, leading to lower DO levels in wells. Muñoz (2015) pointed out that DO values during dry periods are lower than during the rainy season.

Total Dissolved Solids (TDS)

The Total Dissolved Solids ranged from 698mg $L^{-1}$to 16,380mg L^{-1}, averaging 3,444mg L^{-1}. The potential impact on water quality is a cause for concern as the wells containing the highest TDS were found in Barangay Danao, a shallow type well. All the sampled wells exceeded the acceptable TDS value of 500mg L^{-1}, in which 75 out of 81 wells (93%) had a TDS concentration greater than 1000mg L^{-1}, which can be considered brackish wells. According to the World Water Quality Alliance (2021), the standard range for TDS in drinking water is 200mg $L^{-1}$to 2,500mg L^{-1}, indicating that all the wells exceeded the allowable standard limit for drinking water.

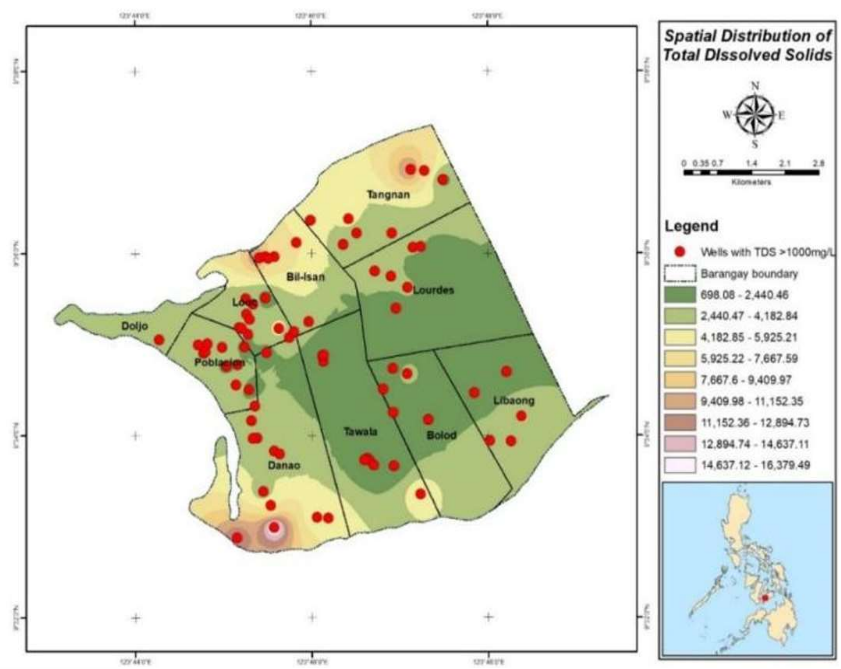


Figure 10. Spatial Distribution (mg L^{-1}) of TDS in the Study Area

Figure 10 shows the alarming spatial distribution of TDS in the study area, indicating the wells with TDS concentrations greater than 1,000mg L^{-1} (brackish wells). The TDS in the wells in Barangay Danao, Looc, Bil-isan, and Poblacion was relatively high, as shown on the map. Most of these wells are shallow, with a depth of 1.5 to 5 meters from the ground surface. A high amount of TDS indicates that the water contains a significant amount of dissolved minerals and salts, emphasizing the need for immediate action.

Electrical Conductivity (EC)

Electrical conductivity, also known as specific conductance, gauges the ability of a substance to conduct an electric current (Helmenstine 2018). The conductivity of water is affected by the existence of inorganic dissolved solids like chloride, nitrate, sulfate, and phosphate anions (negatively charged ions), as well as sodium, magnesium, calcium, iron and aluminum cations (positively charged ions) (US EPA 2012). The concentration of ions within the water solution influences its conductivity, with higher ion concentrations resulting in greater conductivity. In addition, water conductivity is influenced by temperature, with higher temperatures associated with elevated conductivity levels (US EPA 2018).

In this study, the average value of EC was 3,917 which ranged from 561µS cm^{-1} to 17,600µS cm^{-1}.

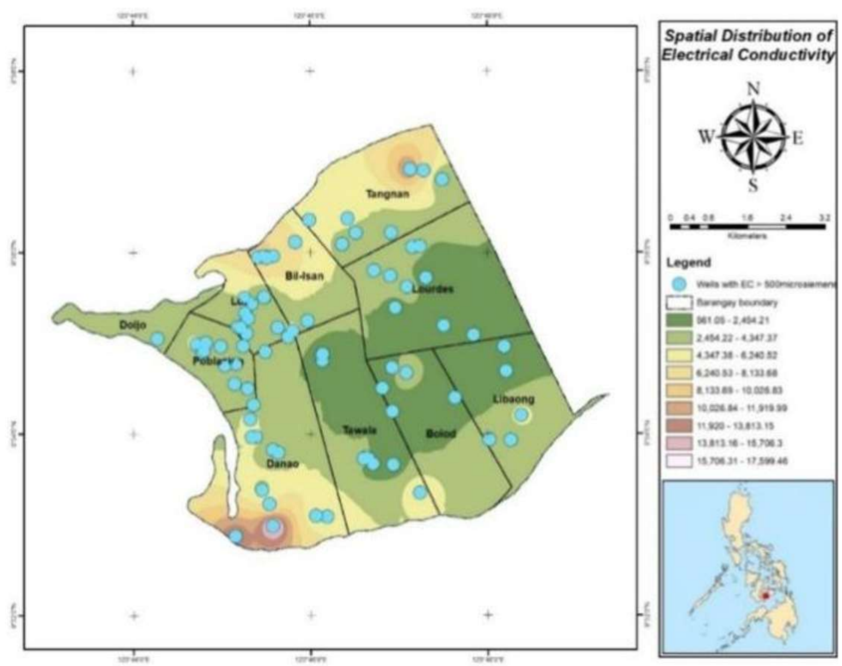


Figure 11 Spatial Distribution of EC (µs cm^{-1}) in the Study Area

Figure 11 shows the spatial distribution of EC in the study area indicating the wells with EC concentration of greater than 500µS cm^{-1}. Wells in Barangay Danao, Looc, Bil-isan and Poblacion have a relatively high EC concentration with a minimum of 2,400µS cm^{-1}. From the water quality standards, wells having over 2,500µS cm^{-1} of EC are not recommended for human consumption and not suitable for irrigation.

Sodium Chloride (NaCl)

The NaCl concentration ranged from 696mg L^{-1} to 23,960mg L^{-1} with an average value 4,340mg L^{-1}. The lowest NaCl was found in Barangay Lourdes, where the distribution of houses is sparse while the highest NaCl was found in a shallow well in Barangay Looc.

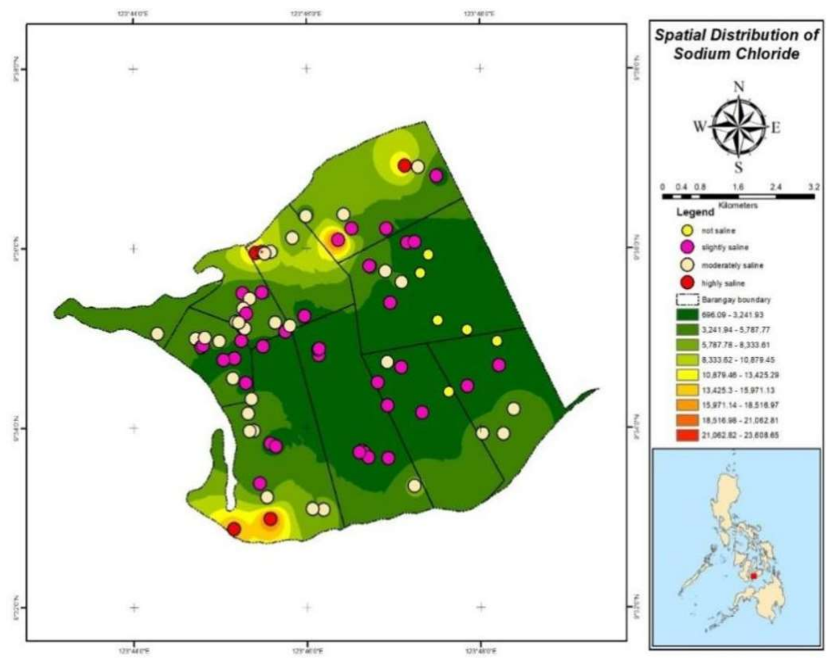


Figure 12. Spatial Distribution of NaCl in the Study Area

Figure 12 shows the spatial distribution of NaCl in the study area indicating the levels of wells salinity. In this study, there are 37 slightly saline wells having a concentration of NaCl ranging from 1,000mg L^{-1} to 3,000mg L^{-1}. There are 32 moderately saline wells in the study area with a ranging concentration of 3,000mg L^{-1} to 10,000mg L^{-1} of NaCl. Also, 6 highly saline wells were detected where the concentration was over 10,000mg L^{-1}. The results indicate a high probability of saltwater intrusion has affected the wells as over extraction of the wells in the area has happened due to the population having grown and the majority of inhabitants being dependent on the wells for their daily domestic consumption.

Factors Influencing the Nitrate-N Levels in Groundwater

Multiple linear regression analysis

Multiple linear regression was used to describe the data and explain the relationship between one dependent variable and two or more independent variables. Regression allowed us to find out which parameters significantly affect nitrate levels. All the variables were input into regression to select the best model to predict nitrate variation.

Nitrate with independent factors

After all the variables, including the water quality parameter, septic tank, well depth, distance from the shoreline, and the 2D inverse distance weight, were input together, there were two variables, the well to shoreline distance and 2D IDW, selected as the best explanatory variables for the model. It has a coefficient of determination R2=0.353, which means that the significant predictors can explain 35.3% of the variation in nitrate, and the other 64.7% is left unexplained and may be due to the other unidentified factors.

Table 1. Multiple Regression Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics					Durbin - Watson
					R^2 Change	hange	df1	Df2	Sig. F Change	
1	.519[a]	.270	.258	6.95	.270	23.273	1	63	.000	
2	**.594[b]**	**.353**	**.332**	**6.60**	**.083**	**7.945**	**1**	**62**	**.006**	**1.520**

a. Predictors: (Constant), Well to shoreline distance
b. Predictors: (Constant), Well to shoreline distance, 2D IDW
c. Dependent Variable: Nitrate-N

The multiple correlation of the dependent variable and the predictors is 0.594. The Durbin-Watson 1.52, which is between greater than 1 (>1) and less than 3 (<3), shows no autocorrelation, and the result is fairly standard.

Table 2 presents the results of the analysis of Variance (ANOVA), a statistical tool used to assess the levels of variability within a regression model and to form tests of significance. This analysis provides crucial information for our study.

Table 2: ANOVA Table of the Multiple Regression Model

	Model	Sum of Squares	df	Mean Square	F	P-value
1	Regression	1,125.263	1	1,125.263	23.273	.000[b]
	Residual	3,046.077	63	48.350		
	Total	4,171.340	64			
2	Regression	1,471.263	2	735.631	16.892	.000[c]
	Residual	2,700.077	62	43.550		
	Total	4,171.340	64			

a. Dependent Variable: NITRATE-N
b. Predictors: (Constant), Well to shoreline distance
c. Predictors: (Constant), Well to shoreline distance, 2D IDW

Based on the result of ANOVA in Table 3, the model provides a strong evidence that the two predictors namely: shoreline distance and 2D inverse distance weight account for 35.3% of the variation in nitrate where p-value is less than 0.001 (*p*-value<0.001) fit of the overall nitrate data.

Shallow Well vs. Deep Well

Based on the results shown in Table 3, the nitrate significantly (p- p-value <0.001) differed between the types of well. A higher nitrate concentration can be observed in the shallow wells, having a mean of 15.31mg L^{-1}, while a lower nitrate concentration in deep wells was 8.48mg L^{-1} on average.

Table 3. T-Test results of the analysis

Parameter?	Well	N	Mean	Std. Deviation	Std. Error Mean
Nitrate-N	Shallow	31	15.30726	9.3117	1.6724
	Deep	50	8.4838	5.7993	.8202

CONCLUSIONS

The study on groundwater quality in the island Municipality of Panglao, Bohol, underscores the significant impact of septic systems on contamination. The assessment of 9,871 households across the Panglao reveals potential risks to public health and the environment due to deviations from regulatory guidelines, inadequate maintenance, and spatial variations in water quality parameters, including nitrate levels.

Moreover, based on the assessment of groundwater quality, the following conclusions were drawn: forty percent (40%) of the nitrate level in the study area exceeded the Maximum Contaminant Level (MCL) of 10mg L^{-1}. Most of these shallow wells are located in built-up areas and foreshore areas. The highest nitrate was detected in Barangay Poblacion with 20.115mg L^{-1} nitrate-N. Water quality in the center of the town was found to be poor. This water quality degradation is proportional to the population density, indicating that human activities could release pollutants into the groundwater. However, besides human activity, the salinity of the wells in the municipality was also affected by seawater intrusion. On average, pH was 7.44, DO was 4.27mg L^{-1}, EC was 3,954.82µS cm^{-1}, TDS was 3,480.60mg L^{-1}, NaCl was 4,377.50ppm, temperature was 29.36°C and nitrate was 11.05mg L^{-1}.

Due to the karst type of geology with no rainfall, the nitrate concentration in the groundwater is highly correlated with the presence of domestic sewage from septic tanks. The coastal areas also exhibit high chloride content due to apparent seawater intrusion.

Based on the overall results, the following recommendations were drawn for the Municipality of Panglao to implement: a) install a wastewater treatment facility to address the unfavorable presence of nitrate and other contaminants in the groundwater, and b) enact relevant ordinances to stop the rising influences of nitrate concentration and other water contaminants in the groundwater which are detrimental both to the growing population and to the environment.

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AUTHOR CONTRIBUTIONS

MGCS designed the study and wrote the paper.

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AVAILABILITY OF DATA AND MATERIALS

All data presented in this undergraduate thesis are original, a testament to the author's dedication and hard work during the study.

ETHICAL CONSIDERATION

Not Applicable

COMPETING INTEREST

I hereby declare that there are no competing interests in the publication of this research.

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