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Evaluation of groundwater quality for domestic purposes of Malamawi Island, Isabela City, Basilan, Philippines

Jalil, A. A. [1*], Luyun, R. A. Jr. [2], Delos Reyes, A. A. Jr. [2] and Bato, V. A. [3]

[1]Basilan State College, College of Agriculture and Fisheries, Santa Clara Campus, Lamitan City, Basilan, Philippines; [2]Land and water Res. Div., Inst. of Ag. Eng'g, College of Engineering and Agro-industrial Technology, University of the Philippines, Los Banos, Philippines; [3]Department of Soil Science, College of Agriculture, UPLB, Philippines.

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Abstract The groundwater samples taken from the study area had temperature, pH, and total dissolved solids (TDS) values ranging from 23.7˚C -25.2˚C, 5.7 - 7.2, and 43.05 -800.09 mg/L.respectively. Likewise, nitrate-N, chloride, and sodium ions concentrations ranged from 0.3 - 1.3 mg/L, 4.96 – 224.44 mg/L, and 5.98 - 50.14 mg/L respectively. The values of the parameters were within the ranges set by Philippine National Standard Drinking Water, groundwater in the northern part (SW4 and SW6) had higher concentrations of TDS, Sodium, and Chloride due to saltwater intrusion. For bacteriological examination, the result obtained that groundwater from the southern part (SW1, SW2, SW4, and SW5) had higher values of less than (<1.8 MPN/100 mL) for both total and fecal coliform count. However, in the northern part (SW3 and SW6), the total and fecal coliform counts were 16,000 MPN/100 mL and 1,100 MPN/100 mL, respectively. Therefore, the groundwater in the southern portion is safer to drink than the groundwater in the northern portion of the study area.

Keywords: Malamawi, Groundwater Quality, Basilan

Introduction

Water is a vital resource for human survival, drinking safe water is a fundamental need for good health, and it is also a right of humans (Meride and Ayenew, 2016). Groundwater is the most vital source for domestic, agriculture, and industrial activities and is considered pure water compared to other sources due to several filtration mechanisms in underground soil (Jamshidzadeh and Barzi, 2018; Thompson *et al.*, 2018; Khalid, 2019).

It is an essential resource for economic growth and human survival (Zhou *et al.*, 2016; Li *et al.*, 2017). It maintains soil moisture, wetlands, and streamflow (Beyene *et al.*, 2019). However, groundwater naturally contains impurities of various trace metals while passing downward as its naturally

[*] **Corresponding Author**: Jalil, A. A.; **Email:** aajalil@up.edu.ph

occurring contaminants are present within the rocks and sediments. Anthropogenic activities such as the use of agrochemicals (pesticides and fertilizers), combustion of coal, and other low quality fuel in brick kilns and other industries, untreated effluents discharge from processing plans, and improper disposal of solid wastes (Nawab *et al*., 2018; Vesali Naseh *et al*., 2018; Khalid, 2019). Likewise, as it flows through the soil, metals are dissolved and contribute to groundwater contamination (Moyo, 2013; Beyene *et al*., 2019). The mixture of any trace metals and other impurities in drinking water that exceeded the standard levels concentrations may result in health complications in the long term (Yousefi *et al*., 2018). water resources management since it is a primary source for drinking (Abbasnia *et al*., 2019). It makes it less likely to drink. Hence, it increases alkalinity and has proven to cause swelling of hair fibers and gastrointestinal irritation or higher acidity that could cause damage to cells of the mucous membrane, eyes, and skin irritation (WHO, 1986; Meinhardt, 2006). Also, acidic water contributes majorly to the corrosion of metals coupled with an indirect effect on human health (Popoola *et al*., 2019). It enhances the concentrations of TDS that confer unwanted taste, odor, and color of water, posing adverse reactions to the consumer (Spellman and Drinan, 2012; Saana *et al.*, 2016). Likewise, significant health implications due to an excess nitrate in water are hypertension in adults (Mkadmi *et al*. 2018) and methemoglobinemia in infants (Bruning-Fann and Kanaeme 1993; Popoola *et al*., 2019). An optimum amount of chlorides is essential to human body metabolism (Mohsin *et al*., 2013; Popoola *et al*., 2019). However, excessive chloride concentration in water could lead to laxative effects and metallic pipes damage (Raviprakash and Krishna 1989; Popoola *et al.*, 2019). The quantity of these constituents could be harmful if the concentrations are beyond the standard set for drinking. Poor quality of water adversely affects human health. It can cause human health problems through major water-borne diseases such as diarrhea, cholera, typhoid, and schistosomiasis. An increase in pH can be detrimental to disinfection and the aesthetic quality of the water. Many recent studies reported a high level of fluoride and its related adverse health consequences (Yousefi *et al*., 2019). The entire population on the Island is relying on the groundwater for domestic purposes. Therefore, it is imperative to characterize the groundwater quality parameters if they suit human consumption. The presence of physical and chemical elements affected the condition of the groundwater. Therefore, this research study aimed to assess the groundwater quality for drinking by quantifying various Physico-chemical groundwater parameters based on Philipines National Standards of Drinking Water (PNSDW, 2007), and to determine the extent of the spatial distribution of each groundwater quality parameter within the study area through generated a thematic map. The result of the research study could serve as the baseline data on the Physico-chemical and bacteriological contaminants of the groundwater on the Island as it is the first research study of this kind in Malamawi Island and the whole Basilan Province.

Materials and Methods

Study area

Malamawi Island (Figure 1) is about 300 m from the mainland of Basilan. It has a total delineated area of about 947 hectares. It is consists of seven different villages and located between $6^0$42'46" N and $6^0$44'45" N latitudes, $121^0$56'24" E, and $121^0$58'23" E longitudes. The general elevations ranged from 5 m to 103 m above sea level while and slopes ranged from 3% to 30%. It has a current population of 13,859 based on a 2015 survey, mostly they build their houses along the shoreline.

The land use of the study area is agricultural, with most areas planted with coconut with a few mangos, citrus, and rubber trees. Root crops and vegetables are regularly cultivated in hilly portions. The study area consists of medium to heavy texture soil types. The island has a type III climate classification, where the seasons are not very pronounced, relatively dry from November to April, and wet during the rest of the year (Bangsamoro Development Agency, 2016; Jalil *al et*., 2020). The annual mean temperature and precipitation are 26.6 ^{0}C and 1,100 mm, respectively (Bangsamoro Development Agency, 2016; Jalil *et al.*, 2020).

Acceptability level of groundwater quality for drinking

The resulting concentration of the groundwater parameters laboratory analysis is based on Philippine National Standards for Drinking Water (PNSDW, 2007) in Table 1. The table indicated the acceptability level or threshold values/concentration of physical and chemical groundwater parameters for drinking. Concentrations beyond the specified values are not suitable for drinking.

Groundwater sampling and analysis

Six groundwater shallows well samples were collected in March 2014. One sampling well was selected from each clustered well located within the island. Since the wells have similar depths, it was assumed that each well taps the same aquifer. The sample water taken from the well is representative of the groundwater quality within the clustered area. Purging of about two (2) minutes before the samples were collected. Before collecting the groundwater, the sampling bottles were thoroughly cleaned using a detergent. The water samples from all observation wells were stored in a plastic 1.5-liters container for detailed chemical analysis same as used by (Youse *et al*., 2017). Following the standard procedures set by the Philippine National Standard for Drinking Water (PNSDW, 2017), filled bottles were tightly capped and properly labeled with the following information: 1) date and time of sampling, and 2) source of the sample. Sampling bottles were placed in an icebox at low temperatures to prevent any unnecessary chemical reactions. The water samples were transported to the Department of Science and Technology (DOST)-IX, a regional standards and testing laboratory, Zamboanga City Water District, and Zamboanga State College of Marine Sciences and Technology for analysis. Sodium-ion was measured using a direct air-acetylene flame method (acid digestion)/ standard method 3111 B, Standard Methods for the Examination of Water and Wastewater (SMEWW), 21st ed. (2005). Chloride (Cl^-) and nitrate (NO_3-N) were measured using the standard Ethylene Diamine Tetra Acetic Acid (EDTA). The not stable parameters such as pH, total dissolved solids (TDS), and temperature were measured directly in the field using an HQ40D portable multimeter (HACH, USA) during the sample collection. Different groundwater parameters gathered from six sampling wells in the study area were mapped and interpolated using Inverse Distance Weighting (IDW) with the 2nd power. The number of columns and rows was set at 5000 for the output map to enhance the quality of the images Using QGIS software (Jalil *et al*., 2020).

Table 1. Standard values for physical and chemical quality for acceptability aspects

PARAMETER/CONSTITUENTS	MAXIMUM LEVEL
Na^{+1}l	200 mg/l
Cl^{-1}	250 mg/l
pH	6.5 – 8.5
TDS	500 mg/l
NO_3-N	10 mg/L
Fecal Coliform	<1 (MFT); <1.1 (MTFT)
Total Coliform	<1 (MFT); <1.1 (MTFT)
Heterotropic plate count	<500

Source: Philippine National Standards for Drinking Water (PNSDW 2007)

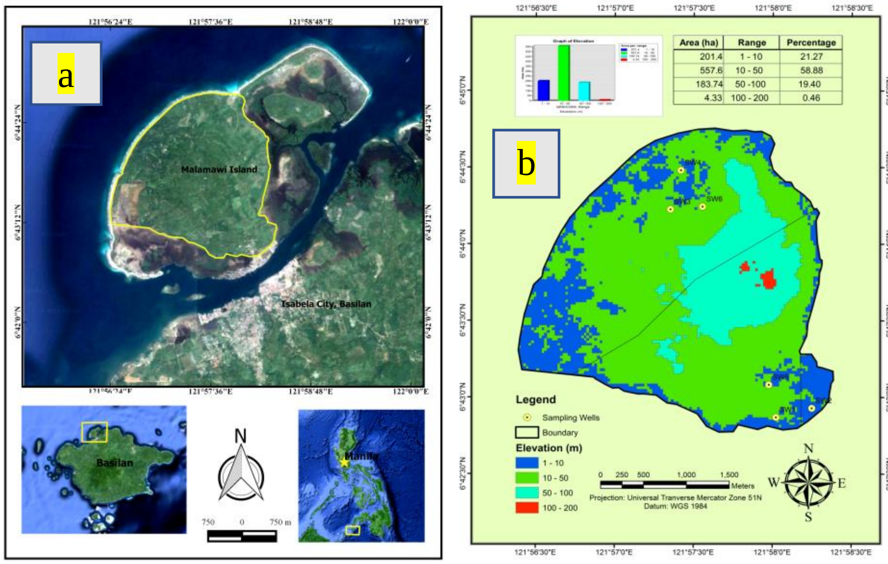

Figure 1. Location (a) and Eevation maps of Malamawi Island (b), Isabela City, Basilan, Zamboanga Peninsula, Philippines

Results

Temperature, pH, and total dissolved solids (TDS) of groundwater

The temperature, pH, and total dissolved solids (TDS) of all groundwater samples taken from six sampling wells are tabulated in table 2. The measured values ranged from 5.7 to 7.2 for pH, 23.7 ˚C to 25.2˚C for temperature, and 43.05 to 800.09 mg/L for TDS (Table 2). Furthermore, the highest values of pH and temperature were obtained from the corresponding sampling well (SW6) in Lukbuton, while the highest TDS value obtains from SW4 in the same village. On the contrary, the smallest value for the three parameters was obtained from the sampling well (SW5) in Santa Barbara. The mean groundwater pH in the study area was within the normal range of 6.5 having little variability similar to temperature. There was wide variability of TDS values as reflected in the higher SD value. The higher value of TDS in the northern part of the study area is ascribed to saltwater intrusion. Groundwater in the area is acidic to neutral based on Philippine National Standards for Drinking Water (PNSDW, 2007) which from 6.5 to 8.5. The spatial distribution of TDS in figure 2b showed that the groundwater surrounding sampling SW4 in northern Lukbuton with an area of 64.41 ha (6.80%) has concentrations of greater than 500 mg/L.

Nitrate-N concentrations of groundwater

Concentrations of nitrate-N from the six sampling wells in the study area ranged from 0.3 - 1.3 mg/L with a mean of 0.83 mg/L (Table 2). Spatial distribution of nitrate-N in the groundwater (Figure 2c) indicated most parts of Lukbuton have a concentration of nitrate-N within the range of 0.8 – 10 mg/L, while most parts of Santa Barbara have slightly lower concentrations of 0.6 – 0.8 mg/L. The concentration of nitrate-N is marginally small compared with the allowable amount of 50 mg/L based on PNSDW 2007 (Table 1).

Table 2. Values and concentration of some parameters of the groundwater samples of Malamawi Island, Isabela City, Basilan, March 2013

Sampling Wells	pH	Temperature (˚C)	TDS (mg/L)	NItrate-N (mg/L)	Chloride (mg/L)	Sodium (mg/L)
SW1	6.3	23.8	77.32	1	9.91	11.27
SW2	6.4	24.9	126.86	0.8	4.96	8.74
SW3	6.2	24.5	169.81	1.3	19.82	22.77
SW4	7.1	25.2	800.09	0.9	224.44	50.14
SW5	5.7	23.7	43.05	0.3	9.91	5.98
SW6	7.2	25.7	372.57	0.7	35.06	20.47
Mean	6.5	24.6	264.95	0.83	50.68	19.9
SD	0.6	0.8	286.54	0.33	78.32	14.81

Chloride concentration of the groundwater

Chloride concentrations ranged from 4.96 – 224.44 mg/L with the mean and standard deviation shown in Table 4. Based on PNSDW, 2007, chloride concentration from all sampling wells categorize as suitable for drinking. The spatial distribution of chloride (Figure 2d) showed a substantial increase in chloride concentrations in the groundwater towards the northern part of the island. More than 50% of the area situated between Lukbuton and Santa Barbara had chloride concentrations from 1 - 2 meq/L, and 4.43% of the area totaling 41.97 ha had higher chloride concentrations greater than 3.0 meq/L.

Sodium concentration of the groundwater

The concentrations of sodium groundwater took from each sampling well in the study area (Table 2). It showed that the highest concentrations of sodium were located in Lukbuton on sampling well SW4 while the lowest concentrations of sodium registered at well SW5 in Santa Barbara. The variations among the sampling wells for sodium were quite significant. Different concentration ranges of sodium. From figure 2a, 596 ha (63.04%) of the area had sodium concentrations within the range of 0.7 - 1.3 meq/L.

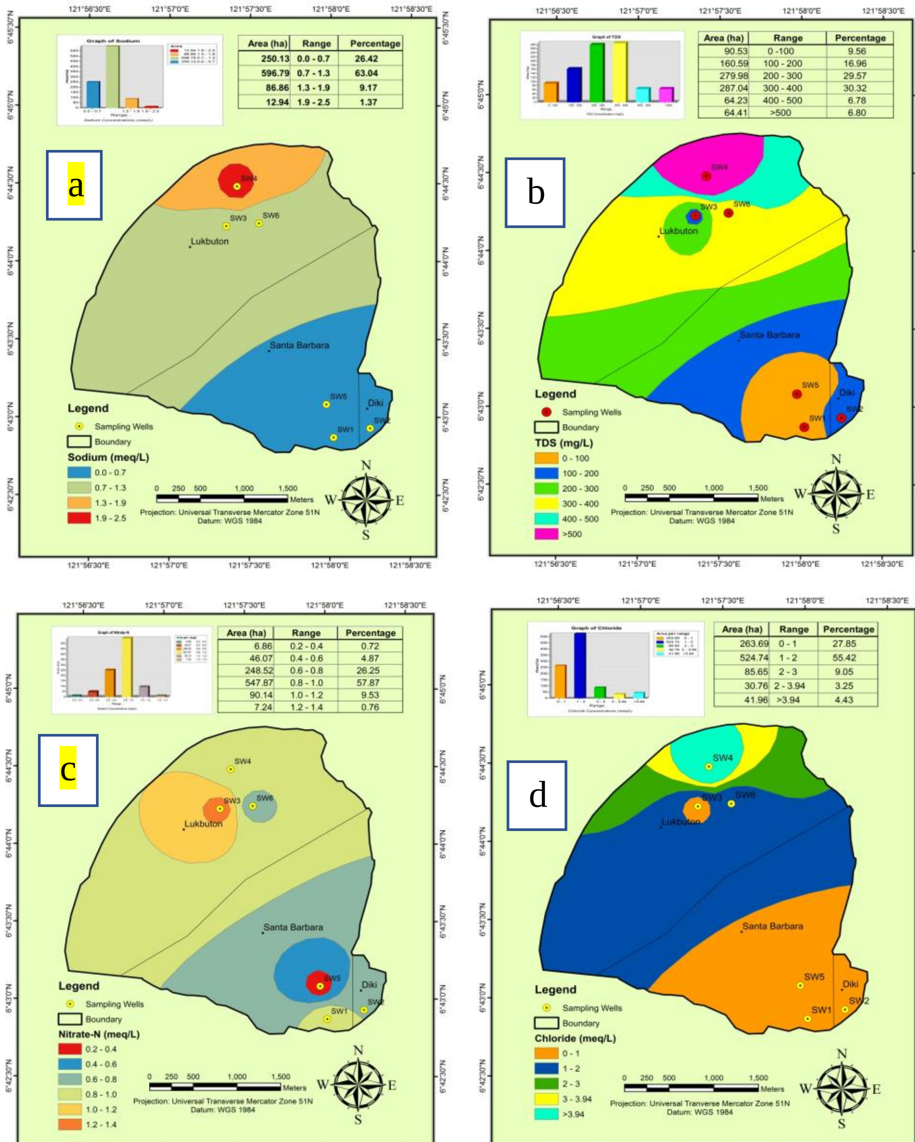

Figure 2. Spatial distribution of, a) Sodium, b) TDS, c) Nitrate-N, d) Chloride on the groundwater of Malamawi Island, Isabela City, Basilan, Zamboanga Peninsula, Philippines, March 2015

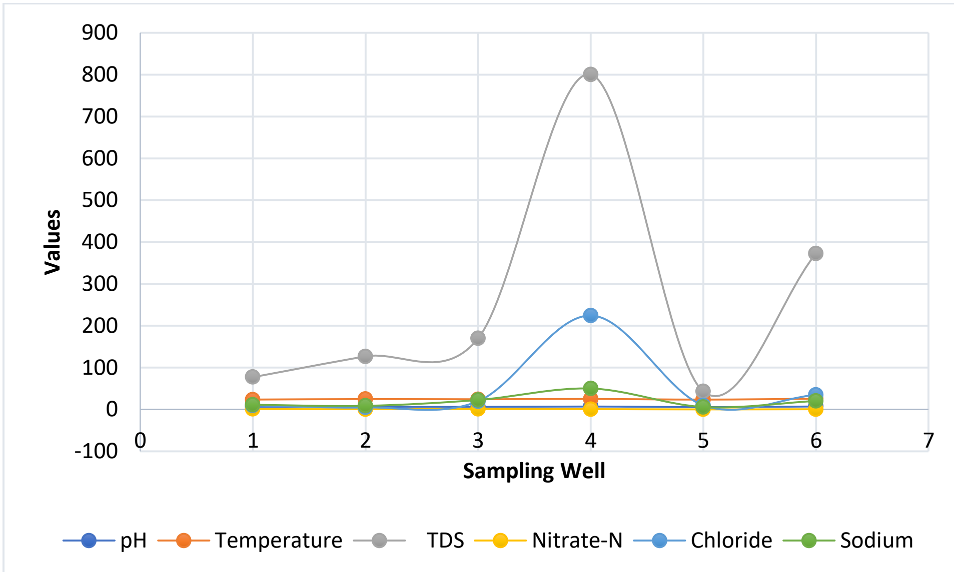

Figure 3. Graph of Concentration of Groundwater Parameters of Malamawi Island, Isabela City, Basilan, Zamboanga Peninsula, Philippines, March 2015

Table 3. Fecal and total coliform count of groundwater of Malamawi Island, Isabela City, Basilan, March 2015

Sampling Wells	Total Coliform Count (MPN/100ml)	Fecal Coliform Count (MPN/100ml)
SW1	<1.8	<1.8
SW2	2	<1.8
SW3	16,000	1,100
SW4	2	<1.8
SW5	<1.8	<1.8
SW6	79	4.5

Bacteriological examination of groundwater

The results of the bacteriological examination of the six existing sampling wells showed in Table3. Fecal coliform organisms are the main contributor to the total coliform organisms. Based on Table 3, none of the samplings well passed the limits set by (PNSDW, 2007) both for fecal and total coliforms. However, test results obtained from sampling wells SW1, SW2, SW4, and SW5 were only slightly higher than the standard.

Discussion

The pH of the groundwater of the study area was within the permissible limits (6.5–8.5) of PNSDW (2007). The pH of the groundwater samples was nearly neutral and has 100% of the pH of less than 8, which indicates the absence of carbonate in the water. The results of our study are in line with some other studies conducted by (Rasool *et al*., 2017; Ali *et al.*, 2017; Arshad and Imran, 2017; Khalid, 2019; Beyene *et al*., 2019). However, a study conducted by (Asghari *et al.,* 2018) has maximum pH of 9, which caused corrosion in the iron pipe. The temperature of the groundwater ranged from 23.7-25.7 ^{0}C with an average of 24.6 ^{0}C. The range values are too small compared to the study of (Abbasnia *et al*., 2019), which fluctuated and low temperature, which has only an average of 21.3 ^{0}C. The TDS embodies the total dissolved solids in water, demonstrating water salinity and the applicability of groundwater to human consumption (Adimalla *et al.,* 2020). The TDS values of the groundwater of the study area were within the permissible limit set by PNSDW (2007), except SW4 has 800.09 mg/L at the northern part of the Island. The higher TDS value of the groundwater is due to saltwater intrusion. It is also in line with the result of the study conducted by (Abbasnia *et al.,* 2019), where the maximum amount of TDS in the water is 1500 mg/L. The concentration of sodium (Na^+) was within the permissible limits set by PNSDW (2007). The results of the current study are the following (Rafique *et al*., 2009) and in contrast with the result conducted by (Youse *et al*., 2017), where many of the values exceeded the limit. The high amount of nitrate could have resulted in a blue baby syndrome in children, thyroid disease, hypertension, diabetes, and carcinogenicity effect due to nitrosamide and nitrosamine generated in the human body (Abbasnia *et al.,* 2019). The results showed that the nitrate concentration was in the range of 0.3-1.3 mg/L, which was within the permissible limit set by PNSDW (2007). The amount of nitrate in the groundwater was negligible and lower than the standard level (Abbasnia *et al.,* 2019). The amount of chloride concentration in the present study ranged from 4.96 to 224.44 mg/L which was within the limit of PNSDW (2007) of 250 mg/L. The result was in contrast with a study conducted by (Abbasnia *et al.,* 2019) which exceeded the limit. Bacteriological analysis indicated that the groundwater of the entire study area was contaminated with bacteria. The sources of contamination might be; pipe leaked, corroded manual pumps, and improvised filters made of recycled cloth. There were incidents of diarrhea or water-borne-related illnesses that were reported within the area of the sampling wells. Likewise, the groundwater taken from sampling wells SW3 and SW6 was highly contaminated with e-Coli bacteria. The contamination might be due to leaching from unlined septic tanks that are common in this particular area. The current study is in line with the result of (Asghari *et al.*, 2018). The groundwater in the study area generally requires disinfection from e-Coli bacteria, a northern portion may further require treatment due to exceeded concentration of TDS-based PNSDW (2007). Future researchers may consider a possible temporal variation of Physico-chemical concentration by re-sampling at different time intervals.

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