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Spatial variation in groundwater quality and potential extent of contamination in Santa Ignacia, Tarlac, Philippines

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Abstract: The municipality of Santa Ignacia in the Province of Tarlac is highly dependent on groundwater; thus, its quality is significant to the community. This study presents the first assessment of groundwater quality and spatial variation of possible groundwater contamination in Santa Ignacia. A total of 274 groundwater samples were collected from 21 sampling sites in the municipality. Five groundwater quality parameters were measured, namely: pH, conductivity, nitrate, nitrite, and iron. Geographical coordinates of sampled wells and measurements of measured groundwater quality parameters were transformed and analyzed using Geographic Information System software, QGIS. Spatial variations of measured groundwater quality parameters were mapped using the Inverse Distance Weighted (IDW) interpolation technique. Constructed spatial variation maps revealed that groundwater quality parameters varied in the study area. All measured parameters, except nitrite content, were within the acceptable limits set by the DENR and WHO for groundwater quality. The nitrite content of groundwater in Padapada has exceeded the permissible limit which may cause long-term public health problems; hence, further evaluation and monitoring of groundwater quality in this area is highly recommended. The identification of the possible source of nitrite in Padapada is necessary to lessen the contamination risk; hence, protecting the groundwater sources in the municipality.

Key Words: groundwater; groundwater quality; groundwater contamination; spatial variation; Geographic Information System

1. INTRODUCTION

Groundwater comprises about 20% of freshwater resources worldwide and used for domestic and irrigation purposes (Usha et al., 2011). In terms of frequency and volume, it is the most extracted raw material worldwide and the Philippines has an extensive groundwater reservoir (Greenpeace, 2007; Margat and van der Gun, 2013). Though it is generally accepted that groundwater is a safe water source for human consumption, it is not ubiquitously free from chemical contaminants (Murphy et al., 2017).

Water quality is determined by its physical properties, chemical composition, and biological parameters (AlSuhaimi et al., 2019). The levels of parameters indicate whether the water is safe for consumption. Otherwise, the water is needed to be treated to acceptable standards by reducing them to levels determined by regulatory authorities. Furthermore, when raw water quality is fully understood, the most appropriate water purification method can be determined (Patella et al., 2017).

Understanding differences in groundwater quality using Geographic Information System (GIS) is necessary to effectively monitor groundwater (e.g., extent of groundwater contamination) (Korbel et al., 2016; Chaudhry et al., 2019). Hence, generating such information is useful in facilitating groundwater management.

The municipality of Santa Ignacia in the Province of Tarlac has a total number of 6,815 level 1 water supply according to the Field Health Service Information System (FHSIS) from the Municipal Health Office.

To date, studies on groundwater quality assessment using GIS technique are lacking in the Philippines. Thus, the present study measured selected groundwater quality parameters and produced spatial variation maps to determine possible groundwater contamination.

2. METHODOLOGY

2.1 Study site

The municipality of Santa Ignacia is a second-class municipality in Central Luzon, and is situated in the western side of Tarlac Province (15.5841°N and 120.4588°E; Fig. 1). The topography of the municipality is roughly rolling to hilly and mountainous.

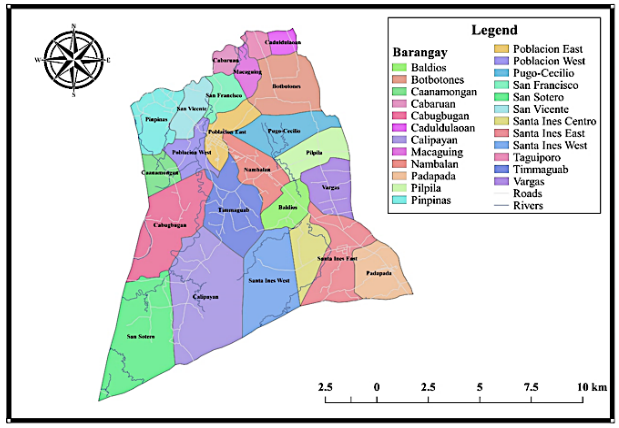

Fig. 1. Constructed map showing the entire land area of the study site, Santa Ignacia, Tarlac, Philippines.

2.2 Groundwater samples

From 21 sampling sites in the municipality (Fig. 2), a total of 274 groundwater samples were collected.

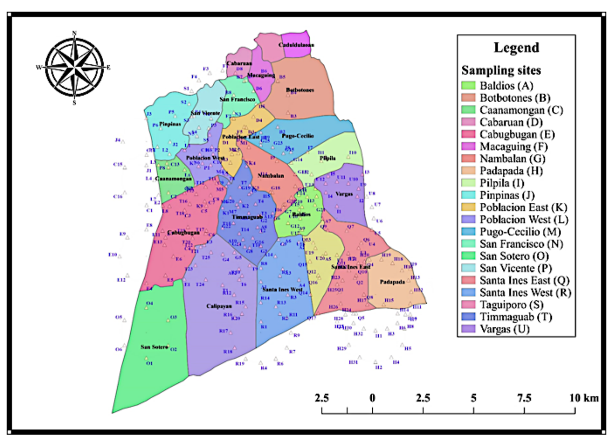

Fig. 2. Spatial distribution of sampled wells in Santa Ignacia, Tarlac, Philippines.

Wells used for drinking were randomly sampled. Water from wells was obtained using 1 L sterile, properly labeled, polyethylene bottles. Geographical coordinates of each sampled well were determined.

2.3 Groundwater quality parameters

Five groundwater quality parameters were measured using 1 L of water samples collected per well. These include pH, conductivity, nitrate, nitrite, and iron.

2.4 Data analysis

Geographical coordinates were transformed and measured groundwater quality parameters were analyzed using Inverse Distance Weighted (IDW) interpolation technique in Geographic Information System software, QGIS version 2.18.24, to construct spatial variation maps.

3. RESULTS AND DISCUSSION

Constructed maps of groundwater quality parameters in Santa Ignacia shows that it varies greatly across sites (Fig. 3). Slightly acidic pH values (< 6.5) of groundwater were observed in groundwater in Botbotones, Caanamongan, Cabaruan, Cabugbugan, Macaguing, Pilpila, Pinpinas, Poblacion East, Poblacion West, Pugo Cecilio, San Francisco, San Vicente, and Taguiporo, which were below the permissible limit for pH (6.5 to 8.5) set by the Department of Environment and Natural Resources (DENR, 2016) and the World Health Organization (WHO, 2008). Neutral pH values (6.5-8.5) were recorded in Baldios, Nambalan, Padapada, San Sotero, Santa Ines East, Santa Ines West , Timmaguab, and Vargas, which were within the permissible limit. High pH indicates a decrease in carbon dioxide concentration while low pH indicates an increase in carbonic acid (WHO, 2003). High conductivity (> 270 µmho/cm) was observed in groundwater in Cabugbugan, Pilpila, and Vargas; but within the permissible limit (WHO- 1,000 µmho/cm). This result indicates higher salt dissolution in groundwater (Shakerkhatibi et al., 2019). High nitrate concentration (> 3.55 mg/L) in groundwater was observed in Pilpila and Vargas but within the acceptable limits (DENR- 7 mg/L; WHO- 50 mg/L). The highest nitrite content in groundwater was in Padapada (> 14.6 mg/L) which has exceeded the permissible limit (WHO- 3 mg/L). A high value of nitrates and nitrites in groundwater indicates water pollution (Maglangit et al., 2014). The highest iron concentration (> 0.109 mg/L) in groundwater sources was in Nambalan and Vargas but also within the acceptable limit (DENR- 1 mg/L ; WHO- 0.3 mg/L). High iron concentration leads to the metallic taste of water (Du et al., 2017).

Results revealed that there is a significant variation in the measured groundwater quality parameters among the sampling sites in the study area. Diversity in topography causes variation in the physical and chemical composition of groundwater. Inputs from natural resources such as atmosphere, soil and water-rock weathering, and anthropogenic factors including mining, agriculture, and domestic and industrial wastes are reflected in groundwater quality parameters (Yuan et al., 2017; Shakerkhatibi et al., 2019).

All measured groundwater quality parameters, except the nitrite content, were found to be within the permissible limits set by the DENR and the WHO for groundwater quality. According to the Department of Health (DOH, 2007), the minimum frequency of sampling for level 1 water supply, for physical and chemical analysis, is once a year. However, the sanitation officer of the study area claimed that there is no regular monitoring of the physical and chemical quality of groundwater used for drinking in the area.

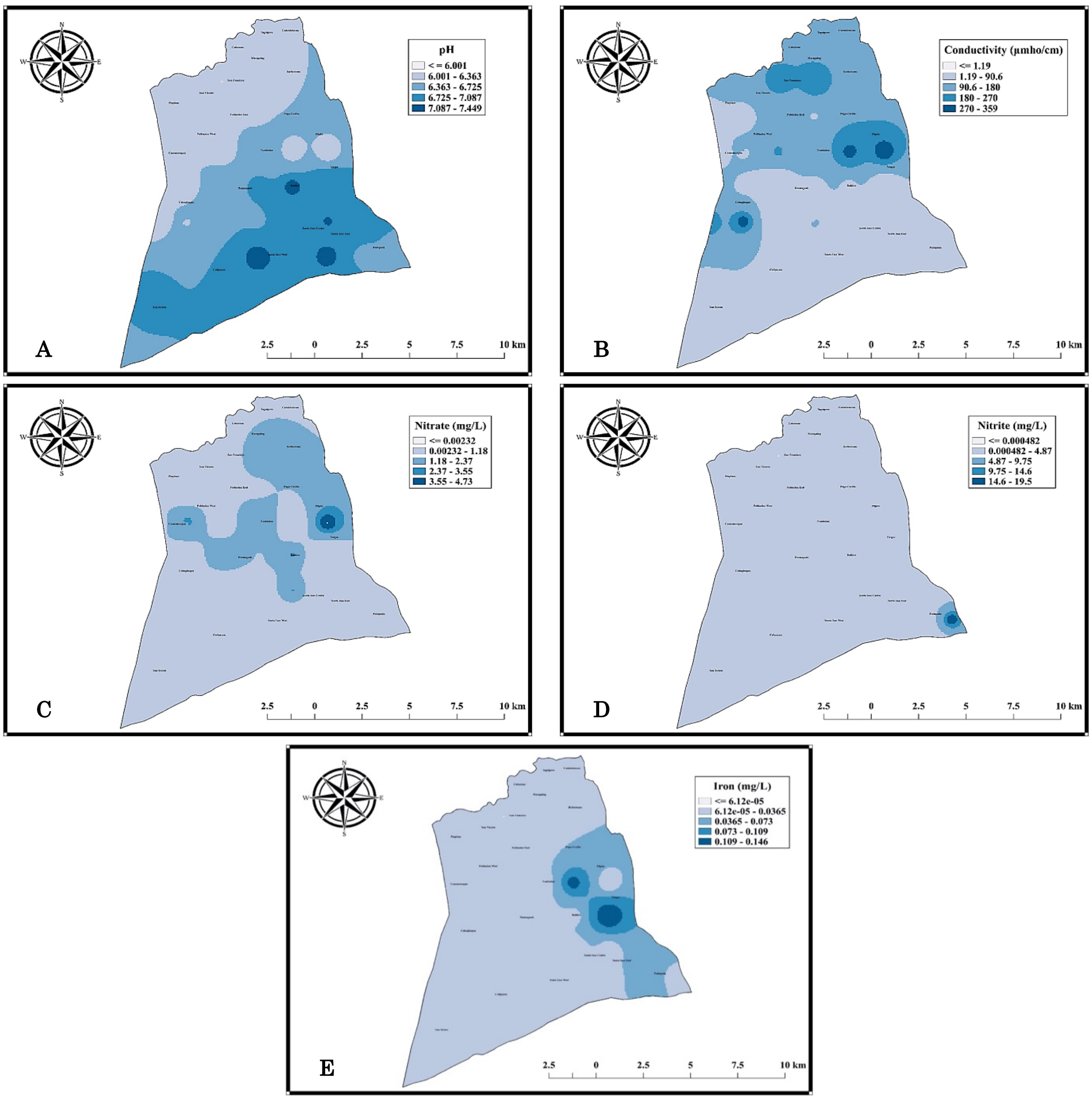

Fig. 3. Spatial variation maps of measured groundwater quality parameters in Santa Ignacia, Tarlac. A- pH, B- conductivity (µmho/cm), C-nitrate (mg/L), D- nitrite (mg/L), E- iron (mg/L).

4. CONCLUSION

Overall, the spatial variation maps of measured selected groundwater quality parameters have presented an overall understanding of the groundwater quality in the study area. The measured groundwater quality parameters in Santa Ignacia evidently varied. The nitrite content in groundwater in Padapada has exceeded the permissible limit which indicates drinking water contamination. Notably, future health problems may arise if there will be a continued lack of regular monitoring of the physical and chemical quality of groundwater in the municipality. It is recommended to conduct studies on the identification of topographical features and existing anthropogenic activities in Padapada to identify the possible source of nitrite in groundwater and to establish proper intervention to lessen contamination risk and to protect the groundwater sources in the municipality.

5. ACKNOWLEDGMENTS

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