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Geographic Mapping of Tube Wells and Assessment of Saltwater Intrusion in the Coastal Areas of La Union

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A large number of coastal aquifers are threatened by saltwater intrusion. Over-abstraction due to high demands for domestic water supply is the main cause of saltwater intrusion. This can also be accelerated by the rise in sea level due to climate change and global warming. This reduces the fresh groundwater resources. With the impact of sea level rise and over-pumping combined together, the problem becomes even more serious.
A large part of the province of La Union in the Ilocos Region, Northern Philippines is lying along the coastline, with its community stakeholders depending on wells for their source of water. Considering the safety of users, the study aimed to determine the incidence of saltwater intrusion in the coastal communities of La Union. In this study, the descriptive-qualitative research design was used. A questionnaire was formulated to determine the perceptions of the community stakeholders on the quality of water they are using but their responses were verified by the use of salinity meter to test the actual water salinity from the tube wells. Through the use of handheld Global Positioning System (GPS), the geographical coordinates depicting the location of the wells included in the study were identified. There was a total of 42 barangays selected as study sites. Using quota sampling, a total of 420 tube wells were subjected to analysis. A geographical map of tube wells showing the affected areas served as an output of the study.
The research revealed that salt intrusion already exists into tube wells along coastal areas of La Union. Community stakeholders had already resorted to other sources/means for their water consumption.

1. Introduction

Water is unequally distributed across earth's surface. Throughout the world, particularly in areas of arid and semi-arid climate communities are suffering from water shortage problem. This is triggered by the increasing population growth and continuous development which require larger quantities of water, especially in the coastal regions where about 70 % of the world population dwell. Groundwater is usually replenished or recharged by rain and seepage from rivers. With almost 90% of the surface water being saline, desalination is one of the most sustainable alternative source of fresh water (Sowgath, 2017). In the Philippines, groundwater contributes about 14 % of the total water resource potential, where Region I and Region VII have the highest potential (Ancheta et al., 2003). The country is faced with one of its major cities plagued by water problems (McGlynn, 2011). Due to seasonal variations and geographic distribution, water shortages often occur in highly populated areas, especially during the dry season. Another problem is saline water intrusion, which is caused by over-exploitation or excessive withdrawal of groundwater. This reduces water availability for domestic usage, including drinking and agricultural usage.
Saltwater intrusion is the movement of saline water into fresh water aquifers, which can lead to contamination of drinking water sources and other consequences. It has become a major problem all over the world particularly in coastal aquifers. The rising of sea water level caused by global warming resulting in the quantity of salt water putting pressure on fresh water aquifer. Change in precipitation, and climatic changes are global causes while locally, it could be attributed to increasing consumption of water (both groundwater and surface water), and over-pumping which may result in inversion of the groundwater flow from the sea towards the inland causing saltwater intrusion.

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Saltwater intrusion into freshwater aquifers is also influenced by factors such as tidal fluctuations, fractures in coastal rock formations and seasonal changes in evaporation and recharge rates. Recharge rates can also be lowered in areas with increasing urbanisation and thus impervious surfaces. Intrusion has also occurred in areas because of water levels being lowered by the construction of drainage canals (Barlow, 2003).
Low levels of salts are found naturally in waterways and are important for plants and animals to grow. When salts reach high levels in freshwater it can cause problems for aquatic ecosystems and complicated human uses. The presence of excessive salt in the drinking water is posing multiple health risks. High concentrations of chloride can make water unfit for human consumption and for many industrial uses. It also has bad effects on the environment as well: it can produce leaf burn and even defoliation in sensitive crops.
Most incidents of saltwater intrusion occur in coastal regions, as has been the focus of discussion thus far, but inland areas can also be affected (Doremus and Lewis, 2008).
La Union is located in the Ilocos Region, Philippines (Figure 1) wherein twelve among the nineteen municipalities and one city of La Union were located along its coastline. With the premise that most of the community stakeholders are already relying on other sources (i.e. water district, water refilling stations) for their water use, saltwater may have already intruded into the wells. Some wells in the coastal areas are already abandoned and some are used only for agricultural and some domestic purposes. Considering the safety of users, the study aimed to determine the incidence of saltwater intrusion in the coastal communities of La Union.

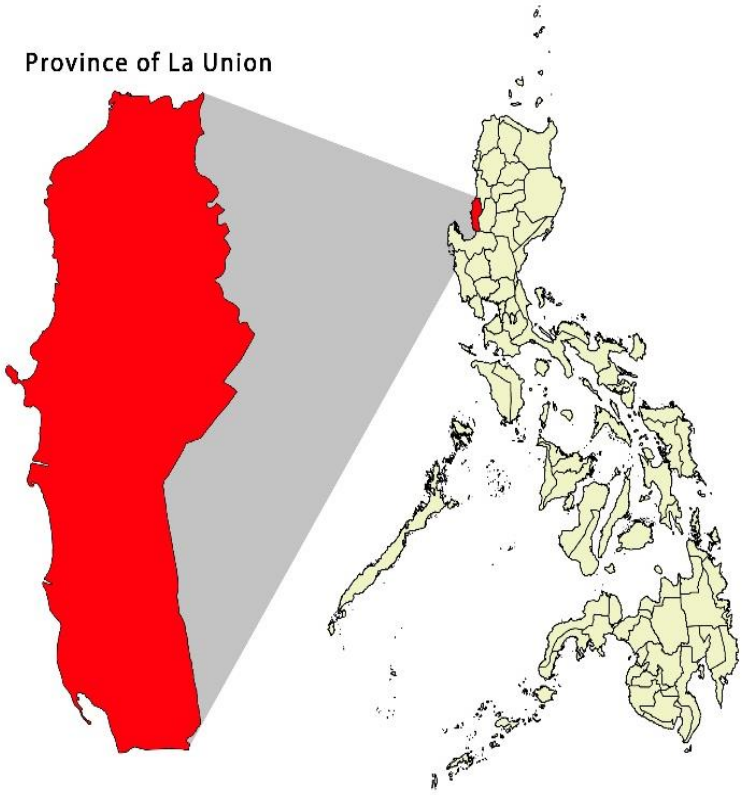

Figure 1: Map showing the province of La Union (generated using QuantumGIS 2.18).

2. Methodology

The descriptive-qualitative type of research was used in the study. A questionnaire was formulated to determine the perceptions of the community stakeholders on the quality of water they are using. A numerical rating scale of 5 was used to determine the degree of agreement with the given criteria with 1 denoting disagree and 5 denoting very strongly agree. Their responses were verified by the use of digital salinity meter to test the actual water salinity from the tube wells. Sampling stations for salinity are shown in Figure 2. Samples from the wells were collected through grab method and coordinates depicting the location of the wells included in the study were identified.

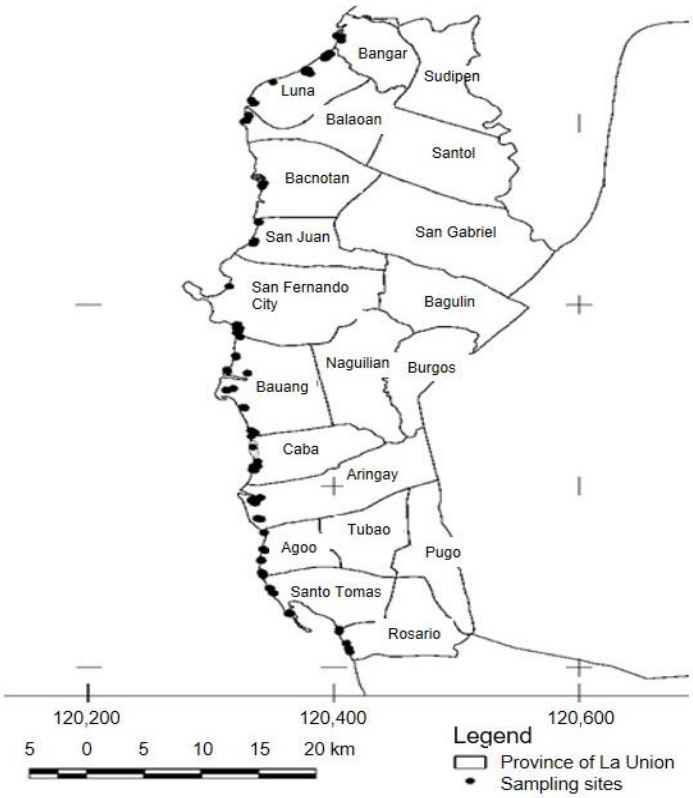

Figure 2: Geographic map of the tube wells in the coastal areas of La Union (generated using ArcGIS Desktop 10.1 (ArcGIS Desktop 10.1, 2012)).

There was a total of 42 barangays selected as study sites. Using quota sampling, a total of 420 tube wells were subjected to analysis. This was used to obtain the current salinity of water in tube wells and the perceptions of the respondents on water quality of these wells which the community stakeholders are using. These wells were taken within the 500 m distance from the shoreline.

3. Results and Discussion

Table 1 shows the salinity values obtained from each municipality of La Union. With an average mean of 2.61 parts per thousand (ppt), the salinity value manifested the incidence of saltwater intrusion in the coastal areas of La Union. The standard salinity value for groundwater ranges from 0 - 0.5 ppt. As shown in the results, Aringay posted the highest salinity value with a mean salinity value of 6.53 ppt followed by Sto. Tomas with a mean salinity value of 5.30 ppt and Agoo with 4.12 ppt. However, there are tube wells in the areas which were not yet affected as observed in the minimum values which ranged from 0.1 - 0.3 ppt.

Aringay posted the highest salinity value of 19.6 ppt followed by Bangar with 14.5 ppt and followed by Luna with 13.5 ppt salinity values. Sto. Tomas was not far behind with 13.2 ppt salinity values. These values are high enough to make groundwater in tube wells unsuitable for human consumption. While small quantities of salt are essential for regulating the fluid balance of the human body, consumption of salt higher than the recommended levels is associated with adverse health effects (Vineis et al., 2011). As divulged by the respondents during the interview, Aringay, Luna and Bangar are flood-prone areas and often experienced coastal flooding affecting the water in the wells. Most of the respondents are already relying on water providers in their area. The water samples analysed in tube wells in the municipalities of Sto. Tomas, Agoo and Balaoan showed also high salinity values.

Among the municipalities and city, only three municipalities posted a salinity value below 0.5 ppt, which is the standard salinity for freshwaters. No salinity values were obtained from the wells in Bauang and Rosario; in Caba only one well was measured with salinity (0.3 ppt). The nine other municipalities and city showed salinity value above 0.5 ppt, indicating the incidence of saltwater intrusion. Salinity of surface and groundwater is determined by a combination of factors, including river flow, tidal surges, rainfall and groundwater extraction,

as well as the influence of sea-level rise and other climatic variables (Vineis et al., 2011). This limits the use of the wells from these areas to some domestic and agricultural purposes.

Table 1: Salinity values in coastal areas of La Union

Municipality/City	Salinity Values (ppt)		Mean
	Minimum	Maximum	(ppt)
Agoo	0.30	10.4	4.12
Aringay	0.70	19.6	6.53
Bacnotan	0.10	3.20	0.93
Balaoan	0.60	8.20	1.90
Bangar	0.10	14.5	3.33
Bauang	-	-	-
Caba	-	-	0.3
Luna	0.20	13.5	1.54
Rosario	-	-	-
San Fernando City	0.30	1.70	0.90
San Juan	0.60	3.40	1.25
Sto. Tomas	0.60	13.2	5.30

As shown in Table 2, there is already an evidence of saltwater intrusion in the coastal communities in La Union. Among the coastal municipalities/city, only three has no saltwater intrusion as indicated in the zero percentage of sampled wells with salinity values higher than 0.5 ppt. These municipalities are located in the second district of the province where it was noted that wells are located far from the coastline but still within the 500 m distance used in sampling. More percentage of intrusion was noted in the northern part of the province particularly in the municipalities of Bangar, Balaoan, Luna, San Juan and the city of San Fernando as indicated by above 50 % of saltwater intrusion among the sampled wells. The province has an intrusion of 51 % which is very alarming for this indicates the reduction of the usability of the water resources in the coastal communities. Based on interviews conducted, there were still wells that were used for drinking purposes. The high amount of salt in drinking water may bring about negative health impacts. As cited by Vineis et al. (2011), dietary salt intake has an association with high blood pressure. An epidemiological study reported that a sodium intake of higher than 1.8 g/d caused a rise in systolic and diastolic blood pressure of approximately 3 – 6 / 0 – 3 mm Hg.

Table 2: Percentage of tube wells with saltwater intrusion

Municipality/City	Percentage (%)
Agoo	32
Aringay	70
Bacnotan	40
Balaoan	100
Bangar	90
Bauang	0
Caba	0
Luna	60
Rosario	0
San Fernando City	90
San Juan	100
Sto. Tomas	32
Mean	51

Table 3 shows the perceptions of the respondents on the quality of water obtained from the tube wells. Results revealed that the respondents agreed very strongly on the criteria indicated. They agreed that the plants do not show stunted growth and development when the water extracted from the tube wells are used for watering (4.67), reacts well with detergents (4.62), does not form scum with soaps (4.58). They too agreed that the water obtained from the ground does not have a characteristic odour (4.35), and it is clear (4.34).
Though the clarity of water obtained from most of the wells is evident, there were wells that show discoloration, especially in the municipalities of Aringay and Agoo. Some of the tube wells in Luna also

showed discoloration. These were the three municipalities where the highest salinity values were obtained. The municipalities of Rosario and Caba yielded the two lowest rating pertaining odour from the wells (Table 3). In fact, there were wells in these municipalities inhabited by frogs which may have contributed in the characteristic odour of water. Respondents in Agoo and Aringay gave the two lowest mean rating on the ability of water to react well with detergents. Most of the wells were found not used for washing laundry and bathing because of the salt content of water. According to the respondents, the water hardly reacts with the soaps and detergents. They are also experiencing itching of skin when they use the water for bathing. Most of the respondents were drawing their water from other sources. The World Health Organization recognised health impacts of consumption of highly saline waters. Observational studies and clinical trials performed in general populations provide overwhelming evidence that higher salt intake is also associated with raised blood pressure (Khan et al., 2011).

The waters from the wells which are highly saline are not used in watering the plants. The combination of flooding and salinity causes foliage damage and substantial reductions in carbon assimilation. The morphological response and reductions in gas exchange rates are closely associated with increases in salt levels. Exposure to salt concentrations greater than 50 mol m^{-3} (3 ppt) causes some leaf burning and decline in carbon assimilation rates of up to 84 % in seedlings of some species (Pezeshki et al., 1990).

Table 3: Percentage of tube wells with saltwater intrusion

Criteria	Municipality/City												Mean	DE
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
1. Water obtained from the ground is clear.	3.56	3.15	5.00	4.10	4.80	4.89	4.10	3.95	4.80	5.00	4.90	3.84	4.34	VSA
2. It does not have a characteristic odour.	3.96	4.05	4.90	4.50	4.78	4.86	3.60	4.15	3.40	5.00	4.30	4.68	4.35	VSA
3. It reacts well with detergents.	3.68	3.85	4.80	4.90	4.94	5.00	4.80	4.70	5.00	5.00	4.70	4.12	4.62	VSA
4. It is free from any suspended materials or dirt.	2.72	4.30	4.80	4.70	4.78	3.90	3.90	4.00	3.50	4.50	4.60	3.46	4.10	SA
5. It is tasteless.	2.88	3.40	4.60	4.90	4.88	4.90	3.90	4.55	3.70	4.80	4.00	3.88	4.20	VSA
6. Plants do not show stunted growth and development when used for watering.	3.72	3.90	4.90	5.00	4.98	5.00	5.00	4.90	5.00	4.60	4.80	4.24	4.67	VSA
7. It does not form scum with soaps.	3.68	3.85	4.90	4.85	4.82	5.00	4.60	4.70	5.00	4.60	4.80	4.10	4.58	VSA
8. No solid particles that settle at the bottom of the container when stored	2.64	3.30	4.90	4.15	4.72	3.76	4.40	3.90	3.40	4.50	3.30	3.38	3.86	SA
Mean	3.36	3.73	4.85	4.64	4.84	4.66	4.28	4.36	4.23	4.75	4.43	3.96	4.34	VSA

Legend: DE - Descriptive Equivalent VSA - Very Strongly Agree SA - Strongly Agree

I - Agoo	IV - Balaoan	VII - Caba	X - San Fernando City
II - Aringay	V - Bangar	VIII - Luna	XI - San Juan
III - Bacnotan	VI - Bauang	IX - Rosario	XII - Sto. Tomas

Results show that respondents, who were the direct users of the water from the sampled wells, perceived that the characteristics of the water from the wells were still acceptable. The respondents were using the water from wells for so many years that they are used to it already and may not have noticed the deviation of its characteristics from the desirable quality. Some of the wells sampled were only the source of water of the community for various water uses. Unaware of the presence of high salinity values of the water used, people

continue to use the water from wells and the extraction even increases as the demand for water increases because of increased population in the coastal communities.

4. Conclusions

The water drawn out from the wells has exceeded the maximum salinity value for freshwaters, reaching as high as 19.6 ppt. Saltwater intrusion has already manifested in most of the coastal areas of La Union. The high values of salinity imply that wells are no longer safe for human consumption. Most of these wells were only used for domestic and agricultural purposes only. There are some who experienced itchiness after using water from wells for bathing. Water for drinking were not drawn from these wells but bought instead, for their safety. Respondents have already opted into other water sources or means, especially for their domestic use. Measures to solve the problem on salt intrusion must be done, especially by the local government to include water treatment and/or establishment of connection with the water district. Information dissemination on the issue of salt intrusion must be strengthened to safeguard the lives of the community stakeholders, particularly on water usage or consumption.

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