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Assessment of Groundwater Quality in Tha Xang Village, Pak Ngum district, Vientiane capital

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Abstract

Water resources are the main factor of livelihood and agricultural production, which is important for the Lao people as well as the study area. The study aimed to assess the quality of groundwater quality in Tha Xang village, Pak Ngum district, Vientiane capital and to assess the physical and chemical quality of groundwater. A total of 6 water samples were collected. The results of the study found that all 6 pH values were lower than the national environmental standard set by the Ministry of Natural Resources and Environment (Lao PDR), and the value of HCO_3^- at each point is equal to zero. The values of EC, TDS, Salinity, Turbidity, Total Hardness, SO_4^{2-}, Cl^-, F^-, NO_3^-, K^+), Na^+, Mg^{2+}, Ca^{2+}, Fe, As, Cd. The results of the analysis was considered to be good quality due to the addition of water to the aquifer during the dry season from the irrigation system, The water is pumped into the aquifer and percolates through the soil and increases the amount of groundwater stored in the aquifer in the dry season. With pesticides, the analysis showed that the average values of each groundwater well the same for all 6 wells, with the average values being Chlorpyrifos with a value of <1.79 µg/L and Bifenthrin with a value of <1.81 µg/L. This shows that the amount of pesticides that are present in the groundwater may be a challenge in the future because in the Thang Xang village area, there is a cluster of villages that grow organic vegetables, This indicates that there is a tendency for pesticides to be present in groundwater sources and these may increase in the future. In particular, the amount of Facal Coliform Bacteria (FCB) in wells PTX05 and PTX06, the results of laboratory analysis showed that they exceeded the national environmental standards.

Keywords: Groundwater, Groundwater Quality, Assessment, Agricultural production area

1. Introduction

The global water resources are estimated to be approximately 1.386 billion cubic kilometers (1.386 billion km^3) of which 97.5% is saltwater, with only 2.5% being freshwater (Balasubramanian, 2015 & Wikipedia, 2024). Groundwater is generally a usable source of water and some of it is of good quality, and modern drilling and pumping equipment now make it easy to access groundwater resources, and urban growth and development in many areas have reduced the global surface water abstraction (Villholth & Giordano, 2007). Groundwater plays an important role in supplying water to a large population around the world for consumption, agriculture, drinking water production and industry. Physical or economic water scarcity affects every continent with a population. In 2003, groundwater was estimated to contain about 50% of the world's potable water and water used for drinking water production, 40% of industrial water needs, and 20% of irrigation water needs (Al-sudani, 2018). As groundwater use increases, the composition or chemical composition of groundwater is an important study in both developing and developed countries to identify toxic chemicals present in groundwater that may result from the decomposition of minerals in the aquifer and the leaching of waste from human activities such as biological waste, chemical waste, as well as hazardous elements that cause excessive stress on groundwater.

The assessment of groundwater quality in each area has different characteristics and this study aims to present the importance of groundwater resources and to achieve the Sustainable Development Goals (SDGs), SDG6 (Clean Water and Sanitation) is the main goal of the development of this study on clean water and sanitation for all. In addition, threats to groundwater quality from anthropogenic contaminants and surface organisms, and challenges for groundwater management worldwide, aspects of groundwater quality assessment include management and management. Groundwater resources are of great importance, especially in a country with abundant surface water resources like the Lao PDR. The analysis of groundwater in the country is not yet clear and comprehensive. In addition, some studies have studied water quality in some areas and found that groundwater in the Lao PDR is mostly of good quality, but the overall quantity is limited compared to surface water. The quality of groundwater in Laos has not been comprehensively studied in each region. Each area has different quality and quantity of chemicals or minerals that affect the human body and living things. The use of groundwater in our country is used for industrial work, daily consumption, and agriculture.

The agriculture and forestry sector plays an important role in implementing the Party-State development guidelines and policies, as well as the socio-economic development plan IX, and the departments related to agriculture and forestry, water resources and the environment. The development of the agriculture sector is also an important sector for providing food to us, along with the development of agricultural infrastructure regarding the use of groundwater to help agriculture to provide water for production. Therefore, this study has challenges and opportunities in practical implementation in conducting a study on groundwater quality in the study area of Tha Xang Village, Pak Ngum District, Vientiane Capital (Figure 1). A study on water quality in community and agricultural areas focuses on assessing the quality of water for consumption. we will take samples of groundwater in the study area for qualitative and quantitative analysis.

This research area has been identified as the area of Tha Xang Village, Pak Ngum District, Vientiane Capital as a research area on assessment of groundwater quality. The area has a large amount of groundwater used for agricultural production and daily consumption. In the future, there is a tendency for groundwater use to increase because Tha Xang Village is a village that produces a large number of vegetables and economic crops, which makes the demand for water consumption tend to increase. Tha Xang Village is located in Pak Ngum District, which is about 60 kilometers from Vientiane Capital. There are more than 250 groundwater wells in the study area, covering an area of 435.50 hectares (Tha Xang Village Office, 2015). Most of the water sources used in this area are from groundwater, which is used for production and consumption activities. It is a village with a role and a model village in organic agriculture, which is outstanding in model agriculture (organic vegetables). This study selected this area as the study area for data collection, and water sampling. From the initial data collection and mapping using Google Earth Pro, the area is flat and located near the Ngum River. In agricultural production, water from irrigation and groundwater is used. In consumption, some Ngum River is used, but most of it is groundwater because it can be used for watering vegetables and in the household. Currently, the use of irrigation water obtained by pumping water from the Ngum River for production purposes is not readily available because the pump is broken and the Ngum River cannot be used to water vegetables directly. According to villagers, if water from the Ngum River is used directly, the vegetables that are watered will not pass the organic farming standards. The water must be pumped into an irrigation canal (soil canal) first to filter and soak into the ground before it can be used to water vegetables. This is because the Ngum River contains some contaminants that cause the water to be used to water vegetables, the time it takes to collect it, and the quality of the vegetables that are watered will not pass the organic farming standards

Therefore, this study aims to assess the quality of groundwater in Pak Ngum District, Vientiane Capital. To assess the physical and chemical quality of groundwater, since the surrounding area is mainly agricultural and banana plantations (Figure 4), there is a risk of associated chemicals in the surrounding area entering the groundwater aquifer. For this reason, it is necessary to study groundwater quality to determine the quality criteria of groundwater in this area.

2. Materials and Methods

2.1. Water Sampling and Determination Methods

Identify the target group for the survey on groundwater use for both target groups and determine the area to collect water samples within the designated area, taking 1km x 1km per well of water sample collection. In this interview, the target group household and agriculture were determined based on the initial target group. Groundwater measurements in the field were measured according to basic parameters and groundwater levels were measured based on groundwater data according to the 1km x 1km area that was designated for the survey as shown in Figure 1.

Water sampling and storage is an important task that requires special attention and strict procedures must be followed in collecting water samples to ensure that the water samples are transported to the laboratory without compromising the original water quality and to prevent other contaminants from mixing with the water samples collected from the main water source, as the water samples will be taken to analyze various minerals and chemicals in the laboratory according to the objectives of the study (Inthasone et al., 2024). In collecting water samples, there are steps and processes as follows:

1. Prepare a sample water bottle for the water and make sure the bottle is completely clean and free of odors or contaminants.
2. Prepare a container of ice of appropriate size for the water sample to maintain the temperature of the water sample collected from the well at the appropriate temperature.

3. Before collecting water samples at each point, the water level in the well must be measured first. A water level measuring instrument using a measuring stick will be used to help measure the distance from the water surface to the ground surface to record groundwater level data.

4. Collect water samples at each point. First, rinse the water bottle with the water to be collected 2-3 times, then gradually fill the bottle with water and seal it tightly without leaving air bubbles inside. For water samples, collect 1 liter.

5. Each water sample bottle must be labeled with the following details: date, month, and year the water sample was collected, and a code (the code section will include the abbreviation of the location and a number to indicate the point in the reservoir where the water sample was taken).

6. Create a data form for water collection, for example: the name of the well owner, village, city, province, date of data collection, coordinates, and other necessary details.

7. Water samples collected from the field at each point must be contained in containers prepared to maintain temperature.

Bring the collected water samples to the laboratory to analyze the various minerals that have been identified in the research. Preserving water samples collected from the field is very important because different temperatures in different areas can cause the loss of minerals in the water sample. Therefore, to preserve the water sample as much as possible before it reaches the laboratory, the following water sample preservation procedures must be followed:

1. After collecting the water sample, store it in a temperature-controlled container to maintain its original water quality.

2. Water samples must be kept away from hot sunlight to avoid mineral loss in the groundwater collected from the well.

3. After bringing water samples collected from the field to the laboratory for analysis, the test should be performed at an appropriate time because leaving the water samples for a long time may cause changes in the water quality.

4. During the experiment, the collected water samples after filtering before taking them for analysis should be stored in a cool place or stored in a refrigerator to keep the water quality from changing.

2.2. Determination of Parameters in Groundwater Quality Analysis

The determination of parameters for groundwater quality analysis in this study was based on methods and tools according to the research manual of the Center of Excellence of the National University of Laos, which defined water quality parameters according to the following characteristics:

1. Physical parameters include: Temperature, pH, Turbidity, Electrical Conductivity (EC).

2. Chemical parameters include: Salinity, Iron (Fe), Sulphate (SO_4^{2-}), Chloride (Cl^-), Fluoride (F^-), Nitrate (NO_3^-), Bicarbonate (HCO_3^-), Potassium (K^+), Sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Total Hardness, Total Dissolve Solid (TDS). And toxic Heavy Metals include: Arsenic (As), Cadmium (Cd).

3. Biological parameters include Facal Coliform Bacteria (FCB).

4. Some chemicals in pesticides belong to the chemical classification Organophosphorous compounds (OPCs) including Chlorpyrifos Pesticide and in the chemical classification Pyrethroid including Bifenthrin Pesticide.

2.3. Water quality analysis equipment

The tools and equipment used in this study were based on the methods and tools according to the pollutant analysis manual of the Department of Chemistry, Faculty of Natural Sciences, and water sample analysis in the laboratory at the Center for Environmental Excellence, National University of Laos (Vanhseng, 2018). Which describes the techniques and methods for analyzing water quality in detail. For equipment analyzed in the field includes Multifunction Model: 9909-SP and the tools used in the laboratory to analyze data include: Turbidity Meter, EDTA-Titrimetric, Potential Titration, Flame AAS Method, HG AAS Method, Petrifilm Plate Counting Method, SPE+LCMSMS and IC Chromatography. All types of analyzers are classified according to the parameters of each category as below:

Table 1. List of tools and equipment for water sample analysis

No.	Parameters	Units	Verification method
1	Temperature	°C	Multifunction Model: 9909-SP
2	Potential of Hydrogen (pH)	NA	
3	Electrical Conductivity (EC)	mS/cm	
4	Total Dissolve Solid (TDS)	ppm	
5	Salinity	ppt	
6	Turbidity	NTU	Turbidity Meter
7	Total Hardness	mg/L	EDTA-Titrimetric

8	Bicarbonate (HCO_3^-)	meq/L	Potential Titration
9	Sulphate SO_4^{2-}	mg/L	IC Chromatography
10	Chloride (Cl^-)	mg/L	
11	Fluoride (F^-)	mg/L	
12	Nitrate (NO_3^-)	mg/L	
13	Potassium (K^+)	mg/L	
14	Sodium (Na^+)	mg/L	
15	Magnesium (Mg^{2+})	mg/L	
16	Calcium (Ca^{2+})	mg/L	
17	Cadmium (Cd)	mg/L	Flame AAS Method
18	Iron (Fe)	mg/L	
19	Arsenic (As, inorganic)	mg/L	HG AAS Method
20	Fecal Coliform Bacteria (FCB)	CFU/100mL	Petrifilm Plate Counting Method
21	Chlorpyrifos	μg/L	SPE + LCMSMS
22	Bifenthrin	μg/L	

3. Results

3.1. Water use data interview analysis results

The results of the interviews with 122 target groups showed that most of the water use is groundwater, 20-liter bottled water, and Nam Ngum River, respectively. Groundwater use is mostly for household use and then for agricultural production, as shown in the survey results, which show many 197 wells used for household use and agricultural production, 159 wells are used, as shown in Figure 5. The survey results also show that the average number of groundwater wells per household is 2-3 wells. The survey in Tha Xang Village, Pak Ngum District, Vientiane Capital, shows that groundwater is used extensively, but it was not possible to collect data on the total number of wells in the village because we conducted a random survey as planned earlier.

3.2. Field water quality analysis results

From the results of water quality analysis in the field and in the laboratory, the results of a total of 6 analysis points have the following analysis results:

1. Potential of Hydrogen (pH) and Electrolytic Conductivity (EC): The results of water quality analysis showed that the pH values at points 1-6 were 4.69, 4.82, 4.40, 3.71, 4.13, and 4.11 respectively as shown in Figure 2 and the EC values at each point were found to have a maximum of 58 mS/cm and a minimum of 20 mS/cm as shown in Figure 2.

2. Salinity and Total Dissolved Solids (TDS) From the results of water quality measurements, it is seen that the salinity values measured in the study area have a minimum value of 10 ppt and a maximum value of 35 ppt as shown in Figure 3, and the TDS values at 6 points do not exceed the national and WHO (WHO, 2022) environmental standards have a minimum value of 11 ppt and a maximum value of 32 ppt, as shown in Figure 3.

3.3. Results of water quality analysis in the laboratory

Laboratory water quality test results in this study, a total of 6 groundwater wells were studied. A total of 17 parameters were determined for this analysis, including turbidity, total hardness, iron, potassium, sodium, magnesium, calcium, bicarbonate, sulfate, chloride, fluoride, nitrate, arsenic, cadmium, Fecal Coliform Bacteria and the pesticides Chlorpyrifos and Bifenthrin. Previously, 5 parameters were measured in the field, including pH, T, EC, TDS, and Salinity, as described earlier in Section 3.1. From the laboratory analysis results, the detailed results are as follows:

1. Turbidity: From the analysis results at 6 points, it was found that the lowest value was <0.1 NTU and the highest value was 1.18 NTU.

2. Total Hardness and Bicarbonate (HCO_3^-): From the results of water quality analysis at all 6 points, it was found that the lowest value was 0.13 mg/L and the highest was 3.84 mg/L, which compared to the national environmental standard value, it was found that it did not exceed the specified value, which was set at 500 mg/L. The value of bicarbonate was not found in the water source analyzed in the laboratory, with the result of the analysis being zero in every well.

3. Sulphate (SO_4^{2-}) and chloride (Cl^-): From the results of water quality analysis of all 6 points, it was found that sulphate had the same value in all the points, which was equal to <0.38 mg/L and the result of chloride had the lowest value equal to <1.66 mg/L and the highest value equal to 4.17 mg/L. According to the national environmental standard value, it is not exceeded in the threshold of less than 250 mg/L of sulphate (SO_4^{2-}) and the standard value of chloride (Cl^-) should not exceed 600 mg/L.

4. Fluoride (F^-) and Nitrate (NO_3^-): From the results of water quality analysis at all 6 points, it was found that fluoride (F^-) had the same value at all points, with a value of <0.29 mg/L, and nitrate (NO_3^-) had a minimum

value of 1.83 mg/L and a maximum of 5.72 mg/L, which are within the national environmental standard values.

5. Potassium (K^+) and Sodium (Na^+): From the results of water quality analysis at all 6 points, it was found that the lowest value was <0.03 mg/L and the highest was 0.31 mg/L, and the lowest value of sodium was 1.91 mg/L and the highest was 4.81 mg/L, which is within the national environmental standard.

6. Magnesium (Mg^+) and Calcium (Ca^+): From the results of water quality analysis at all 6 points, it was found that the lowest value was <0.14 mg/L and the highest was <0.44 mg/L, and the highest calcium value was <0.05 mg/L and the lowest was 1.17 mg/L, which is within the national environmental standard.

7. Iron (Fe), Cadmium (Cd) and Arsenic (As): From the results of water quality analysis of all 6 points, it was found that the value of Iron (Fe) was <0.12 mg/L in all 6 wells, while the value of Cadmium (Cd) was also <0.003 mg/L in all 6 wells, and the value of Arsenic (As) was <0.0005 mg/L in all wells. Which is within the national environmental standard value.

8. Fecal Coliform Bacteria (FCB): From the results of the water quality analysis of all 6 points, it was found that only wells PTX05 and PTX06 showed the analysis results. Well PTX05 had a value of 2 CFU/100mL and well PTX06 had a value of 9 CFU/100mL, while the other wells had zero values. It can be seen that the wells with a zero-analysis result do not have Fecal Coliform Bacteria, which according to the national environmental standard is reliable because the standard value is not allowed to exceed 2.2 CFU/100mL. Therefore, the well with an analysis value exceeding the standard is not only well PTX06 with a value of 9 CFU/100mL.

9. In the group of pesticides Chlorpyrifos and Bifenthrin: From the results of water quality analysis of all 6 points, it was found that the average values were the same in all of them, with Chlorpyrifos having a value of <1.79 µg/L and Bifenthrin having a value of <1.81 µg/L. Compared to the standard value, it is still considered low, but there may be a tendency for the future to increase in quantity because there are banana plantations or banana plantations owned by investors in the surrounding area of the village, which may have an impact in the future.

4. Discussion

This research found that the data measured in the field and water quality analysis in the laboratory obtained the results of this study. A total of 6 water sampling points were identified and 5 water quality parameters were measured in the field and 17 parameters in the laboratory. In the field, the following indicators were measured: pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and salinity. The results of field measurements show that the acidity-alkalinity value is lower than the national environmental standard but does not exceed the national standard value that has been determined. This indicates that in general, the pH value of groundwater is 7, but if the pH is lower than 7, it is considered acidic pH. If the pH is higher than 7, it is considered alkaline pH, because it is lower than the national environmental standard value set between 6.5 - 9.0. Therefore, the pH value is acidic pH (Figure 2). (Ministry of Natural Resources and Environmental, 2017) and corresponds to the research results of (Chansamone, 2021), and (Nika, 2018). Because the village is engaged in farming and animal husbandry (growing organic vegetables) and there are banana plantations in the surrounding area, which results in a pH value that is averaged at each point between 3.71 - 4.82, and the electrical conductivity (EC) is also considered low which are lower than the national environmental standards and the standards of the World Health Organization (WHO, 2022). The EC values at each point were found to be the highest at 58 mS/cm and the lowest at 20 mS/cm (Figure 2). his indicates that there are very few minerals dissolved in the water source, and the quality is at a good level. The results of this study correspond to the research results of (Phromjuti, 2013). And the average value of total dissolved solids (TDS) is between 11 ppm – 32. ppm (Figure 3) and the salinity is low with an average value between 10 ppt and 35 ppt (Figure 3).

In the laboratory analysis section, the analysis results show the details of the analysis in each element category: chemical characteristics including Major Ions (Table 3) and heavy metal types, biological characteristics, physical characteristics, and chemical characteristics from pesticides. In particular, the results of groundwater analysis in the laboratory showed that the amount of groundwater analyzed in the dry season had good water quality, which was reflected in the average turbidity value of <0.1 NTU to 0.18 NTU. which is below the national environmental standard value of not exceeding 20 NTU and consistent with the research results of (Piyarut, 2018). In addition, the analysis results did not find a value of carbonate (HCO_3^-) with a rate equal to zero, but there were also some elements with average values lower than the national environmental standards. The Major Ions group includes chloride (Cl^-), fluoride (F^-), nitrate (NO_3^-), bicarbonate (HCO_3^-), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}) as shown in the analysis results in (Table 3) and consistent with the research results of (Mmasabata et al., 2019), (Inthasone et al., 2024), and (Osei et al., 2022). The results of the analysis are considered to be of good quality and do not exceed the national environmental standards and the World Health Organization (WHO, 2022) standards, due to the constant replenishment of water in the groundwater aquifer during the dry season. It can be seen from the field survey and interviews that there is an irrigation canal system that is a soil canal, allowing water to seep into the ground easily, and water is pumped up to replace groundwater use throughout the village's water release schedule. This makes the amount of groundwater quality during this period good because water is pumped into the soil canal to seep through the soil layer and filter down to the groundwater aquifer to increase the amount of groundwater during the dry season. Because Tha Xang village has a large demand for water, since most people in the village are engaged in agriculture, there is a need to use water. As a result, the addition of this water has resulted in the groundwater quality in this area having indicator values from analysis that do not exceed the national environmental standards.

In the section of some chemical groups of pesticides of Organophosphorus compounds (OPCs), through analysis, it was found that in the 2 parameters determined in this study, the average value of each groundwater well was the same for a total of 6 wells, with the average value of each type being: Chlorpyrifos with a value of <1.79 µg/L and Bifenthrin with a value of <1.81 µg/L, which showed that the amount of contaminants resulting from pesticides exceeded the standard. However, even though the national environmental standards do not specify groundwater quality standards for consumption, if we refer to the surface water quality standards (Ministry of Natural Resources and Environment, 2017), the values exceed the national environmental standards, which have a threshold value of 1.0 µg/L. This could be a challenge in the future for the village because Tha Xang is a cluster of villages that grow organic vegetables, indicating that there is a potential for increased pesticide contamination in groundwater in the future. The contamination may come from multiple sources and may be caused by the banana plantations that have sprung up around Tha Xang, both on the banks of Tha Xang and the other side of the Ngum River, opposite Tha Xang, where banana plantations have begun to spread, causing the leaching of these chemicals into the groundwater.

As expected, we identified a range of pollutants, but what surprised us is that Chlorpyrifos and Bifenthrin was clearly causing more ecological damage than the rest. Chlorpyrifos and Bifenthrin is a synthetic insecticide. It is found in many common household surface sprays that are advertised as providing safe, long-term protection against infestation from insects. It is cheap and effective. It is toxic to insects, spiders, mites, and fish, but believed to be relatively safe to humans and other mammals. Because of its purpose as a persistent insect barrier, Chlorpyrifos and Bifenthrin lingers in the environment, water, so if it ends up in aquifer in groundwater in village, it will stick around and cause long-term damage.

In the section of biological parameters, Facal Coliform Bacteria (FCB), the analysis results showed that there were only 2 bacteria that exceeded the national environmental standards with an average value of 2 CFU/100mL - 9 CFU/100mL (Table 1). The rest had zero values and were consistent with the results of many researchers such as: (Phromjuti, 2013), (Wannarat, 2014), (Banjong, 2012), (Parin, 2016), (Edward, 2005), (Oluwayemi et al, 2022), and (Marina, 1997). From the random water sampling in the area around Tha Xang Village, the groundwater quality does not exceed the national environmental standards and the World Health Organization (WHO) standards for most of the time, with only a few chemicals exceeding the standards mentioned earlier. Due to the use of a large number of groundwater sources, 356 wells (Figure 5) and the risk of chemical contamination as shown by the results of the sample analysis, Tha Xang Village is at risk in the future and is another challenge in terms of growing organic vegetables because the contaminants in the water do not meet the organic vegetable standards, as most of the income of the people in the village comes from selling organic vegetables.

5. Conclusion

The results of this groundwater quality assessment evaluated the water quality in the field at a total of 6 points and assessed the chemical impurities in the water, including 5 elements: pH, T, EC, TDS, and Salinity. In particular, the pH at all points was below the national environmental standard and the EC at all points was lower than the environmental standard and WHO standard (WHO, 2022), which also resulted in low values for other types of chemicals in the water source. For water quality analysis in the laboratory, there are 17 elements: turbidity, total hardness, iron, potassium, sodium, magnesium, calcium, bicarbonate, sulfate, chlorine, fluoride, nitrate, arsenic, cadmium, fecal coliform bacteria, and the pesticides Chlorpyrifos and Bifenthrin. Of these, the amount of fecal coliform bacteria in wells PTX05 and PTX06. The results of the laboratory analysis showed that it exceeded the national environmental standards. The pesticides Chlorpyrifos and Bifenthrin in the 6 points analyzed had high values. Although the national environmental standards for groundwater quality standards are not specified, if referring to surface water quality standards, the values exceed the national environmental standards. Understanding what ultimately happens to Chlorpyrifos and Bifenthrin treatments will allow us to make recommendations on reduce the use of such substances causing undue ecological damage. Therefore, it is recommended Collaboration with pesticides regulators, on Tha Xang village, villages surrounding and Part of the government sector, including the Other relevant agencies will also be necessary to adequately manage insecticide pollution in groundwater resources in the long term.

6. Conflict of Interest

As a scientific researcher, I certify declare that all information contained in this academic article does not have any conflict of interest with any party and does not benefit any party. If any violation occurs, I am willing to take sole responsibility.

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Table 2. The Field and laboratory analysis results

Parameters	**Units**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**
Temperature	ºC	28.5	28.5	29.4	30.0	29.5	29.9
pH	NA	4.69	4.82	4.40	3.71	4.13	4.11
EC	mS/cm	30	58	20	22	48	46
TDS	ppm	29	32	11	13	20	24
Salinity	ppt	32	35	10	12	20	25
Turbidity	NTU	<0.1	<0.1	1.18	0.18	1.07	<0.1
Total Hardness	mg/L	0.27	3.77	3.84	0.63	0.13	1.94
Bicarbonate (HCO_3^-)	meq/L	0.00	0.00	0.00	0.00	0.00	0.00
Sulphate SO_4^{2-}	mg/L	<0.38	<0.38	<0.38	<0.38	<0.38	<0.38
Chloride (Cl^-)	mg/L	<1.66	2.31	<1.66	<1.66	4.17	2.31
Fluoride (F^-)	mg/L	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29
Nitrate (NO_3^-)	mg/L	3.29	5.72	3.06	2.79	1.83	5.02
Potassium (K^+)	mg/L	<0.03	0.18	<0.09	<0.03	<0.03	0.31
Sodium (Na^+)	mg/L	2.22	4.81	1.91	1.92	3.95	3.70
Magnesium (Mg^{2+})	mg/L	<0.14	<0.44	<0.44	<0.14	<0.14	<0.44
Calcium (Ca^{2+})	mg/L	<0.05	1.11	1.17	0.12	<0.02	0.42
Iron (Fe)	mg/L	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Arsenic (As, inorganic)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium (Cd)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Fecal Coliform Bacteria (FCB)	CFU/100mL	0	0	0	0	2	9
Chlorpyrifos	µg/L	<1.79	<1.79	<1.79	<1.79	<1.79	<1.79
Bifenthrin	µg/L	<1.81	<1.81	<1.81	<1.81	<1.81	<1.81

Table 3. Results of analysis of major ions in groundwater at 6 points

2024	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**Cl^-**	F^-	**SO_4^{2-}**	**HCO_3^-**	**NO_3^-**
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	mg/L
Min	0.02	0.14	1.91	0.03	1.66	0.29	0.38	0.00	1.83
Mean	0.48	0.29	3.09	0.11	2.30	0.29	0.38	0.00	3.62
Max	1.17	0.44	4.81	0.31	4.17	0.29	0.38	0.00	5.72

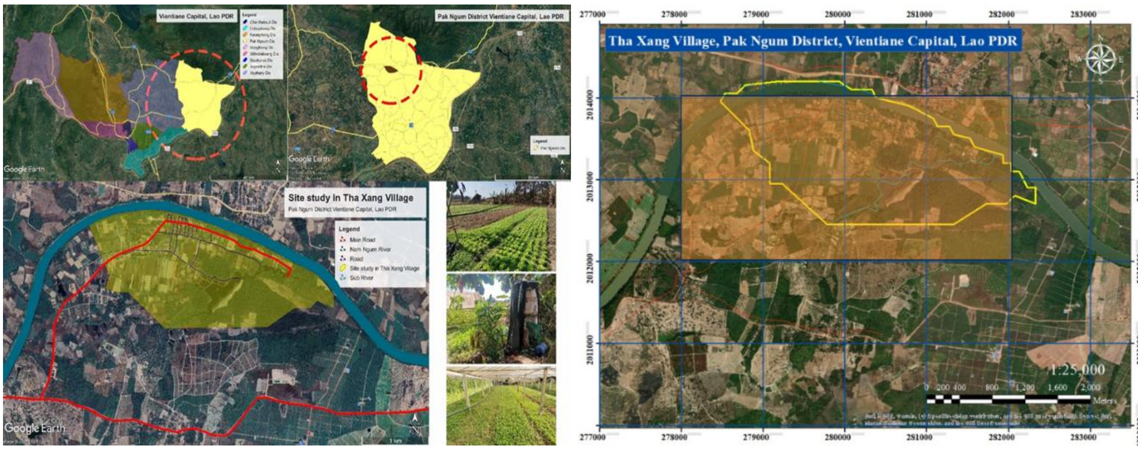

Figure 1. Location and map of the sample water collection area size 1km x 1km of the study area

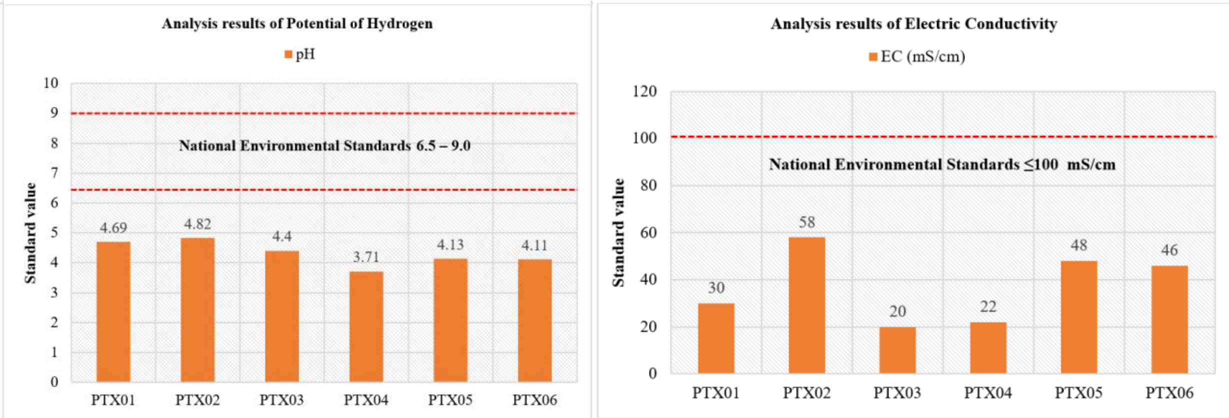

Figure 2. Results of pH and EC analysis of groundwater at 6 points

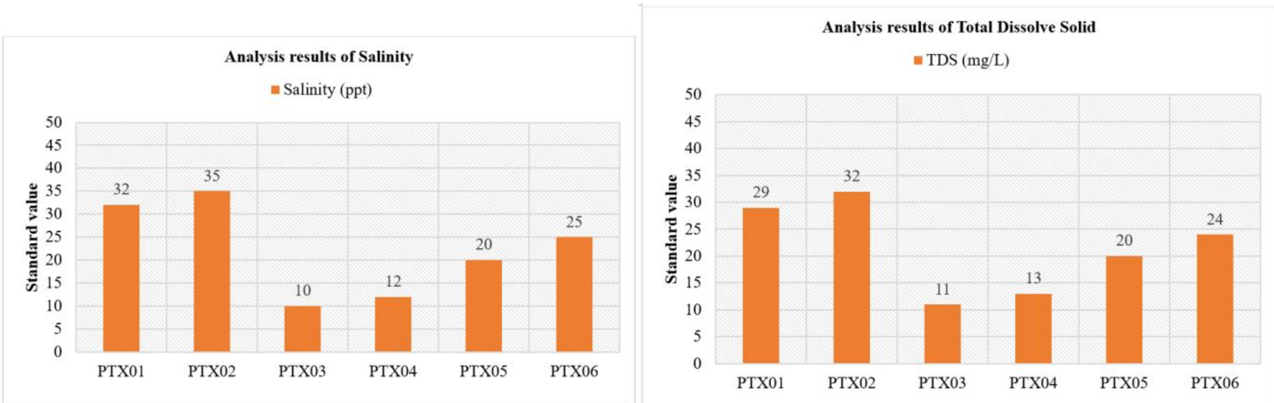

Figure 3. Results of Salinity and TDS analysis of groundwater at 6 points

Figure 4. The study area and surrounding area

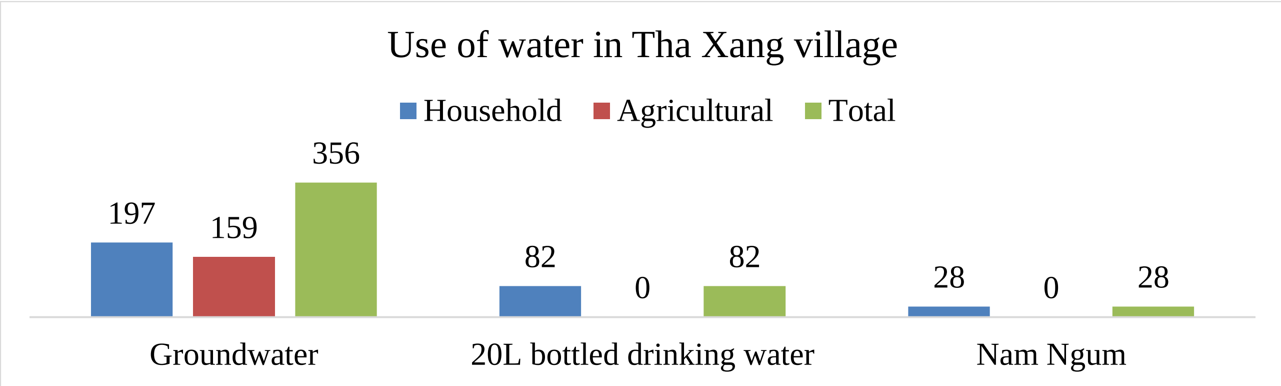

Figure 5. The Use of water in Tha Xang village

Figure 6. The Conducting field surveys and collecting water samples