Groundwater quality and people's awareness – A case study in Hoang Tay commune, Kim Bang district, Ha Nam province

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Abstract. In this study, groundwater quality in Hoang Tay commune, Kim Bang districts, Ha Nam province was investigated. The results show that the groundwater in this area was highly polluted by arsenic (As), iron (Fe), ammonium (NH_4^+), and coliform. Total As concentrations in the groundwater ranged from 0.06 to 0.178 mg/L. Although total As concentrations remarkably decreased after sand filtration (0.013–0.109 mg/L), As in the sand-filtered groundwater was still up to 10 times higher than the As safety limit (0.01 mg/L). In addition, the high concentration of Fe and the Fe/As ratio in Hoang Tay's groundwater play a critical function in effectively removing As from groundwater. NH_4^+ level in groundwater was also remarkably high (8.62–58.8 mg/L), which is roundly 28 to 196 times higher than the NH_4^+ safety standard in Vietnam's technical guideline on domestic water quality (QCVN 01:2018/BYT). The structured interview showed that most of interviewed people (69%) are aware of groundwater quality issues. However, due to the issues of tap water supply in the area, the majority of the households (78.3%) were still using groundwater for their drinking purposes and other daily activities. There is a high demand for safe water in this commune.

1. Introduction

The current world population is more than 8 billion. The number of people accessing safe drinking water and basic sanitation services, however, is only around 6 billion people and 1.5 billion people, respectively [1]. This means that one in three people globally does not have access to clean drinking water, or a majority of the world population is still lacking sanitation services. In many countries, such as South Africa, India, Bangladesh, Vietnam, Cambodia, etc., groundwater is considered an invaluable natural resource and one of the primary drinking water sources [2-4]. Globally, around 2.5 billion people are using groundwater sources for essential purposes in their lives [5]. However, the recent rapid decline and depletion of groundwater sources have increased global water security issues. Consumption of unsafe drinking water sources for a long time is related to the transmission of diseases as well as caused of harmful effects to human health.

Vietnam is a lower middle-income country located in Southeast Asia. Red River Delta is one of 2 major river deltas in Vietnam, with a population of more than 23 million and a population density of

1102 people/km^2 in 2019. In Red River Delta, groundwater is used as a principal source for domestic water supplies in many communities. The exploitation and consumption of groundwater sources in this area started approximately 100 years ago. Since 1982, the installation of private tube wells for households' domestic water supply has become popular in countryside areas in the Red River Delta [6]. However, arsenic (As), iron (Fe), ammonium (NH_4^+), and pathogens (bacteria and viruses) are also often found in the groundwater in this area. Since then, many studies on As, NH_4^+ contamination in groundwater in this delta have been conducted. According to Berg, Stengel [3], the total As level in groundwater in the Red River Delta varied between 1 and 3050 µg/L (average 159 µg/L). The concentrations of NH_4^+ in the groundwater in this Delta ranged from 51–99 mg/L, which are approximately 170 to 330 times higher than the NH_4^+ safety limit in the Vietnam technical guideline on domestic water quality (QCVN01-1:2018/BYT, 0.3 mg/L) [7]. Nearly ten million people in the Red River Delta have been reported to be potentially at risk because of their exposure to As-contaminated groundwater. In the Red River Delta, Hanoi, the capital of Vietnam and Hanam province are two provinces that are mostly affected by As and NH_4^+ pollution in groundwater [8-11]. The population living in these two provinces has used groundwater as the main water source for drinking purposes and daily activities for several decades. Several studies have investigated groundwater quality in these provinces. However, studies on people's awareness of groundwater quality and perceived risks to arsenic-contaminated water are still in their beginning stages. According to Singh and Taylor [12], the risk perception of groundwater quality is crucial for pollutant mitigation programs because it influences the adoption of efficient remediation equipment.

Hoang Tay commune in the Kim Bang district is located in the Northeast of Ha Nam province. According to results from the community census conducted in 2023, Hoang Tay's population was 5921, with 12.7% of the population under the age of five and 50.4% of the population being women. In this area, decentralized groundwater wells are still explored as the principal source of domestic water supply for the local residents, even after the installation of a commune water treatment facility in 2017. Therefore, it is crucial to evaluate the quality of groundwater in this area and link it to the people's awareness of the risks of using the groundwater for domestic and drinking purposes. Two main aims of this study are: (i) to evaluate the groundwater quality, focusing on main contaminants (As, Fe, NH_4^+, and coliform), and (ii) to understand the people's awareness about groundwater contamination. The results from this study could be used in the future to propose suitable solutions for safe water use in this area.

2. Materials and methods

2.1 Survey area and sample collection

In order to evaluate the groundwater quality in Hoang Tay commune, Kim Bang district, Hanam province, a variety of water samples were collected from five distinct villages. Similar to other communes in the Red River Delta, the majority of households in Hoang Tay commune have a conventional sand filtration system to treat groundwater before utilizing this water source. In addition, tap water from the commune water treatment plant and rainwater are also being used as other water sources in the households. However, many household owners are concerned about the quality of their tap water and sand-filtered groundwater. This prompted them to purchase commercial water filtration systems on the market to further treat these water sources. Thus, in this study, all 5 different types of water sources used in Hoang Tay commune were collected and analysed to evaluate the water quality. These types of samples included (i) untreated groundwater, (ii) filtered groundwater from household conventional sand filters, (iii) tap water from commune drinking water treatment plant, (iv) filtered tap water from commercial household water filters, and (v) rainwater. These water samples were collected at 34 locations, including 31 households, a healthcare center, a primary school, and a kindergarten (**Figure 1**). Overall, 34 samples of untreated groundwater, 34 samples of sand-filtered groundwater, 10 samples of tap water, 5 samples of commercial household water, and 5 samples of rainwater were collected. The design of sampling programs and sampling techniques of all water samples in this study

were conducted following the Vietnam national standards TCVN 6663-1:2011 (ISO 5667-1:2006). The untreated groundwater, the sand-filtered groundwater, tap water, commercial filtered tap water and rainwater were collected according to Vietnam national standards TCVN 6663-11:2011 (ISO 5667-11:2009), TCVN 5994:1995 (ISO 5667-4:1987), TCVN 5995:1995 (ISO 5667-5:1991), and TCVN 5997:1995 (ISO 5667-8:1993), respectively. All water samples were preserved according to the Vietnam national guideline TCVN 6663-3:2016 (ISO 5667-3:2012).

2.2 Water quality analyses

Total As, Fe, NH_4^+ concentrations and coliform number were measured according to SMEWW 3125:2012, TCVN 6177:1996, SMEWW 450-F:2012 (detection limit of 0.011 mg/L), and TCVN 6187-1:2009 methods, respectively. Atomic absorption spectroscopy (model AAS 280FS, Agilent) was used to analyse total As and Fe concentrations in water samples. Measurement of total As, Fe, NH_4^+ concentrations, and coliform number was conducted at the VNU Key Laboratory of Geoenvironment and Climate Change Response, University of Science, Vietnam National University, Hanoi. The values of pH were determined using the HQ40D Portable Meter.

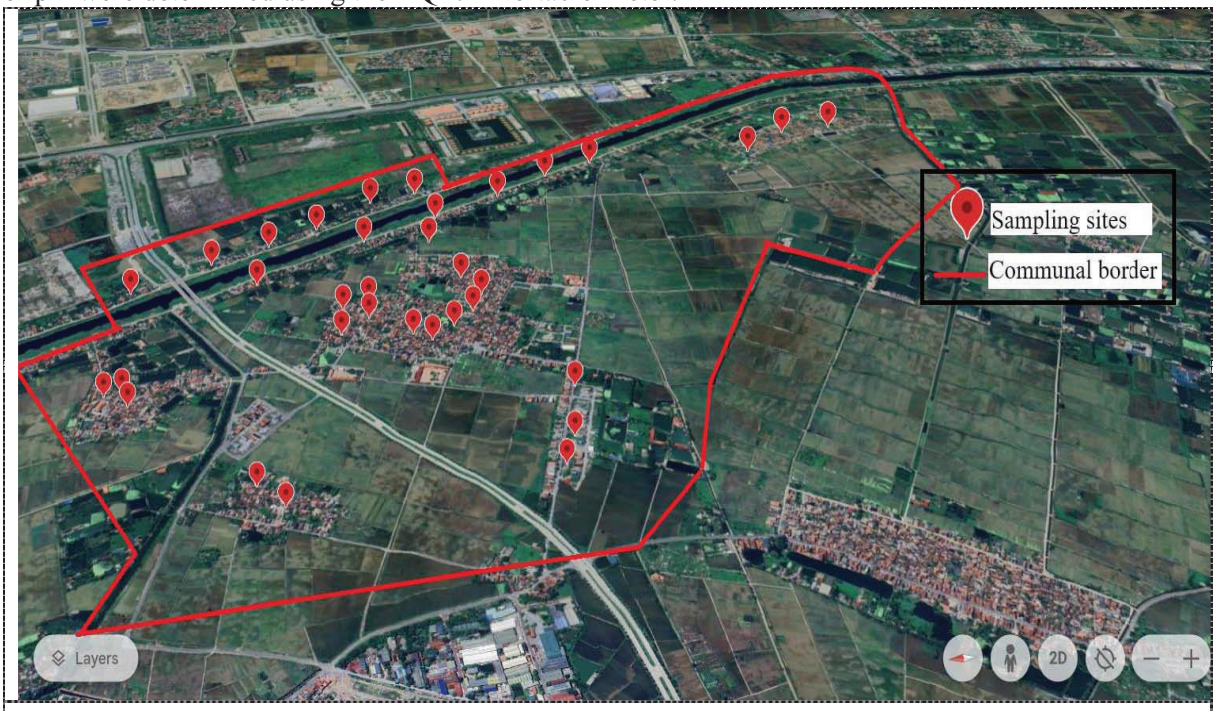

Figure 1. Sampling sites in Hoang Tay commune, Kim Bang district, Hanoi, Vietnam.

2.3 Social studies

In September 2023, a structured interview was conducted to thoroughly understand the current status of water source use and the perceptions about groundwater pollution of households in Hoang Tay commune, Kim Bang district, Hanam, Vietnam. 150 households were randomly selected based on the even distribution in 5 villages in the Hoang Tay commune. The questionnaire included general information (name, gender, address, phone, family size, and occupation), groundwater use, current treatment systems, and satisfaction with these water sources. In addition to understanding the status and perceptions of local communes, this social study could also provide useful information on noticeable groundwater problems and treatment, as well as increase knowledge for local people and suggest proper mitigation methods for the study area.

3. Results and discussions

3.1 Water quality results

The quality of groundwater in the Hoang Tay commune was assessed using a variety of indicators, including pH, total As, total Fe, NH_4^+, and coliform. The analysis results show that pH values of raw groundwater and sand-filtered groundwater samples ranged between 6.41–8.43 and 7.13–8.52, respectively. The pH of most water samples collected after the sand filtering system was found to be greater than 7, which is slightly higher than the pH of groundwater samples. The pH values of tap water, rainwater, and commercial filtered tap water were 6.89–8.43, 7.21–8.30, and 7.0–7.73, respectively. These results indicate that the pH values in all water samples were within the permissible limits for both national technical guidelines on the quality of groundwater (QCVN 09-MT:2015/BTNMT) and domestic water (QCVN 01-1:2018/BYT).

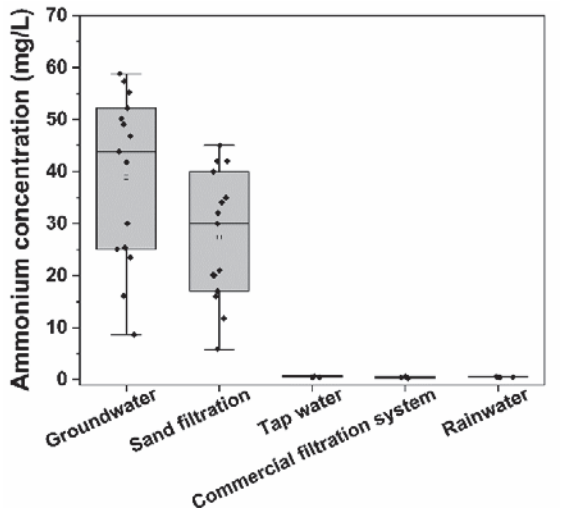

Figure 2. NH_4^+ concentrations in 5 different types of water samples in Hoang Tay commune.

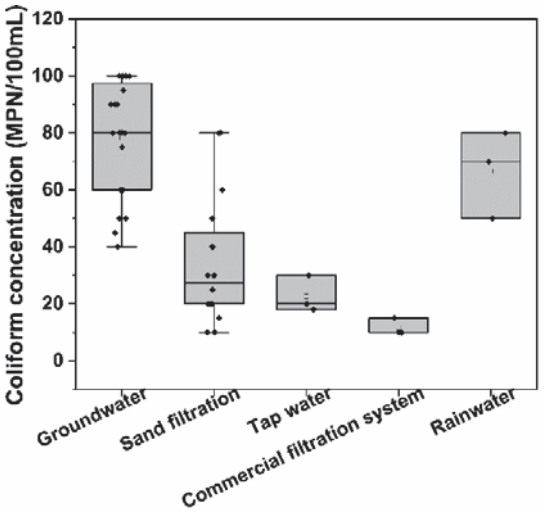

Figure 3. Coliform values in 5 different types of water samples in Hoang Tay commune.

The NH_4^+ concentrations in raw groundwater, sand-filtered groundwater, tap water, commercial filtered tap water, and rainwater samples were presented in **Figure 2**. The analysis results show that the water samples collected from tube wells (groundwater samples) had an unexpectedly high NH_4^+ concentration with their average concentration of 38.9 mg/L (varied from 8.62–58.8 mg/L). These concentrations are significantly greater than the allowable limit of NH_4^+ in the national technical regulations on domestic water quality (QCVN 01:2018/BYT) from 28 to196 times and groundwater quality (QCVN 09-MT:2015/BTNMT) from 9 to 59 times. In other words, the groundwater quality in Hoang Tay commune is identified to be contaminated by NH_4^+. After passing through the conventional sand filtration systems, the sand-filtered groundwater still had a high level of NH_4^+, ranging from 5.84 to 45 mg/L. These results illustrated that there was no discernible difference between NH_4^+ concentration in groundwater samples taken before and after treatment by conventional sand filtration. In other words, - traditional sand filtration is not effective in removing NH_4^+ in groundwater. On the contrary, most of the water samples collected from rainwater tanks, tap water, and commercial filtered tap water were found to have a lower NH_4^+ concentration. However, these NH_4^+ values of the 3 later water sources still have not met the NH_4^+ safety limit regulated in the Vietnam technical regulations for the quality of domestic water (QCVN 01-1:2018/BYT, 0.3 mg/L). Specifically, NH_4^+ concentrations of tap water, commercially filtered tap water, and rainwater ranged from 0.42–0.67 mg/L, 0.25–0.38 mg/L, and 0.45–0.59 mg/L, respectively.

The analysis results show that the coliform levels in groundwater, sand filtered groundwater, tap water, commercial filtered tap water, and rainwater ranged from 40–100, 10–80, 18–30, 10–15, and 50–80 MPN/100 mL, respectively (**Figure 3**). Although, the water samples obtained from commercial water systems (normally based on RO technology) had the lowest level of coliform, coliform values in this water type still have not met the requirement in Vietnam technical standard on the quality of domestic water (QCVN 01-1:2018/BYT, 0 MPN/100 mL).

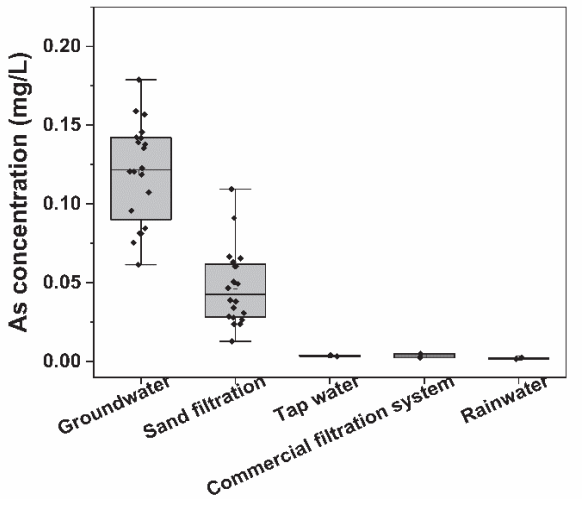

Figure 4. As concentration in 5 different types of water samples in Hoang Tay commune.

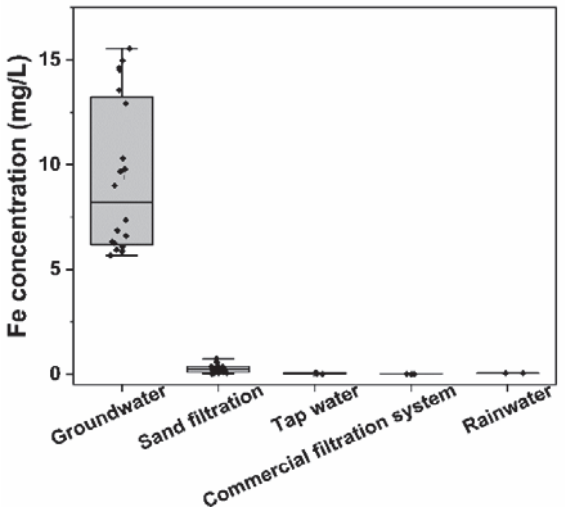

Figure 5. Fe concentration in 5 different types of water samples in Hoang Tay commune.

As concentrations in groundwater varied between 0.06 to 0.178 mg/L (average 0.12 mg/L), which was much higher (approximately 6–18 times) than Vietnam drinking water guidelines (0.01 mg/L)–QCVN 01:2009/BYT (**Figure 4**). Thus, the groundwater in this commune is identified as highly polluted by As. Obviously, As concentration in sand-filtered groundwater samples reduced significantly. As concentrations dropped dramatically to 0.013–0.109 mg/L (average 0.043 mg/L) (**Figure 4**). The results demonstrate the crucial function of sand filtration system in the investigated area in decreasing As concentrations in groundwater sources. It also highlights the requirement for further treatment of sand-filtered groundwater if this water source is used for drinking purposes. In contrast, results also showed that surface water and rainwater in the areas were not polluted by As. As concentrations in all tap water, commercial filtered tap water, and rainwater were lower than As limit in Vietnam domestic water quality standard (QCVN 01-1:2018/BYT).

Figure 5 shows the Fe concentrations in all collected water samples. The results showed that high Fe concentrations, a range of 5.67 to 15.5 mg/L (average 9.40 mg/L) were detected in groundwater water samples. These values corresponded to 9 to 37 times higher than the Vietnam domestic water quality requirement (QCVN 01-1:2018/BYT, 0.3 mg/L). Similar to As concentrations, Fe concentrations in sand filtered groundwater reduced considerably to 0.028–0.734 mg/L (average 0.26 mg/L). After sand filtration, only 20% of water samples was found to be contaminated by Fe. Fe concentration in three other water sources (tap water, commercial filtered tap water, and rainwater) could be able to meet the Fe safety limit recommended in QCVN 01-1:2018/BYT.

Table 1. Water quality in the investigated communes in Ha Nam province and Hanoi

Commune	Province	As (mg/L)					Fe (mg/L)					NH_4^+ (mg/L)					Coliform (MPN/100 mL)					Refs
		GW	SF	TW	CS	RW	GW	SF	TW	CS	RW	GW	SF	TW	CS	RW	GW	SF	TW	CS	RW	
Hoang Tay	**Ha Nam**																					
Schools		**0.10-0.16**	**0.030-0.034**	NS	NS	NA	**5.93-15.55**	0.06-**0.73**	NS	NS	NA	**8.62-50.16**	**5.84-42.0**	NS	NS	NA	**90-100**	**40-60**	NS	NS	NA	**This study**
Health care centre		**0.06**	**0.024**	NS	NS	NA	**14.62**	**0.36**	NS	NS	NA	**16.13**	**11.79**	NS	NS	NA	**100**	**80**	NS	NS	NA	
Households		**0.075-0.179**	**0.013-0.11**	0.003-0.004	0.002-0.005	0.002-0.003	**5.67-14.97**	0.03-**0.59**	0.01-0.07	0.002-0.005	0.045-0.058	**23.51-58.8**	**16.9-45.0**	**0.42-0.67**	0.25-**0.58**	**0.45-0.59**	**40-100**	**10-80**	**18-30**	**10-15**	**50-80**	
Dong Lo	**Hanoi**																					
Schools		NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	[18]
Health care centre		NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	
Households		**0.07-0.18**	0.01-**0.09**	NA	NS	NS	**1.98-14.2**	0.03-0.11	NA	NS	NS	**12.1-42.7**	**10.3-28.5**	NA	NS	NS	NS	NS	NA	NS	NS	
Tram Long	**Hanoi**																					
Schools		**0.17**	**0.013**	NS	NS	NS	**7.11**	0.588	NS	NS	NS	**43.70**	**43.4**	NS	NS	NS	NS	NS	NS	NS	NS	[19]
Health care centre		**0.31**	**0.030**	NS	NS	NS	**3.89**	0.054	NS	NS	NS	**42.33**	**27.4**	NS	NS	NS	NS	NS	NS	NS	NS	
Households		**0.05-0.34**	0.010-**0.046**	NS	0.003	0.005	**2.78-10.99**	0.053-1.282	NS	0.092	0.058	**22.92-43.94**	**14.74-41.45**	NS	**0.445**	0.265	NS	NS	NS	NS	NS	
Phuong Tu	**Hanoi**																					
Schools		NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	[18]
Health care centre		NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	NS	NS	NA	NS	NS	
Households		**0.04-0.14**	0.006-**0.032**	NA	NS	NS	0.05-**4.28**	0.02-0.06	NA	NS	NS	**3.05-21.0**	**1.86-19.8**	NA	NS	NS	NS	NS	NA	NS	NS	
Standard				**0.01**					**0.3**					**0.3**					**0**			

Note: GW (untreated groundwater), SF (groundwater after conventional sand filters), TW (tap water), CS (tap water after commercial filter systems), RW (rainwater), NS (Not survey), ND (Not detectable), NA (Not available), Values in bold is higher than current standard for domestic water, Standard (National technical regulation on domestic water quality QCVN 01-1:2018/BYT).

Figures 4 and **5** also show that all groundwater samples treated by conventional sand filtration exhibited a simultaneous decrease in total As and Fe concentrations. These findings suggest that sand filtration systems installed in households play an essential role in simultaneously removing As and Fe in groundwater. This phenomenon can be deciphered by the co-precipitation mechanism between Fe and As in water. Basically, pumping the water from tube wells through traditional sand filter systems leads to the exposure of iron existed in groundwater to natural air. As a result, the oxidation of Fe^{2+} into Fe^{3+} could proceed naturally (Equation 1). At the same time, As(III) was converted to As(V) through the oxidation process to form the As(V)'s species $HAsO_4^{2-}$ [15] (Equation 2). Then, the oxidized Fe^{3+} or un-oxidized Fe^{2+} interacted with oxidized As(V) to create the precipitates forms of $FeAsO_4 \cdot 2H_2O$ and $Fe_3(AsO_4)_2 \cdot 8H_2O$. These interactions were presented in Equations 3 and 4 [16]. On the other hand, neither the simultaneous precipitation between formed Fe^{3+} and As(V) nor the process between initial Fe^{2+} and As(V) was considered to be the primary mechanism in reducing both As and Fe in water. However, the ratio of Fe/As and oxidizing conditions (contact time and oxygen level) have a substantial influence on this co-precipitation process. According to Meng, Korfiatis [17], a Fe/As atomic ratio greater than 40 is anticipated to successfully remove As from groundwater via co-precipitation mechanism. The analysis results in groundwater in Hoang Tay show that the Fe/As ratio in groundwater in this area ranged between 75.2 and 83.7, which is much higher than the required Fe/As ratio. After coprecipitation, the Fe/As ratio in sand-filtered groundwater sharply decreased to 2.3–6.7.

$$Fe^{2+} \rightarrow Fe^{3+} + 1e^- \quad \textbf{(1)}$$

$$H_3AsO_3 + H_2O \rightarrow HAsO_4^{2-} + 4H^+ + 2e^- \quad \textbf{(2)}$$

$$Fe^{3+} + HAsO_4^{2-} \rightarrow FeAsO_4 + H^+ \quad \textbf{(3)}$$

$$3Fe^{2+} + 2HAsO_4^{2-} \rightarrow Fe_3(AsO_4)_2 + 2H^+ \quad \textbf{(4)}$$

Table 1 shows the comparison of the water quality in some investigated communes in Hanoi and Hanam provinces, such as Hoang Tay commune (this study), Dong Lo commune [18], Tram Long commune [19], Phuong Tu commune [18]. The results show that the groundwater in all investigated communes is polluted by As, Fe, and NH_4^+ (concentrations of As, Fe, and NH_4^+ were up to 0.34 mg/L, 15.55 mg/L, and 58.8 mg/L, respectively, corresponding to 34, 52, and 196 times higher than the current As, Fe, and NH_4^+ standards for Vietnam's drinking water). Although the total As and Fe concentrations in sand-filtered groundwater significantly decreased in all investigated communes, their concentrations still could not meet the safe levels. The tap water in Hoang Tay commune was also polluted by NH_4^+ and coliform (nearly 2 and 18 times higher than NH_4^+ and coliform standards, respectively). Coliform was even found in the tap water treated by the commercial RO system in Hoang Tay commune.

3.2 Water supply status and relevant socio-economic aspects

The main information in Hoang Tay commune, including water supply status and relevant socio-economic aspects are presented in **Table 2**. The income per capita of the Hoang Tay commune in Ha Nam province is 77.1 million Vietnam Dong (VND)/year (about 3212.5 USD/year). The number of poor households and near-poor households were 55 and 59 households, respectively, which corresponded to 3% and 3.2% of households in the whole commune (**Table 2**). In Hoang Tay area, centralised water treatment stations have been installed since 2017. Nearly 89.7% of households in Hoang Tay commune, Ha Nam province are using tap water from the commune's centralized system (**Table 2**). However, most houseowners using tap water are concerned about the tap water quality and a number of them further treat the tap water using commercial water filtration systems (mostly based on RO technology). Concerned about the water quality, the authorities in Hoang Tay communes have even advised local people not to use tap water for drinking purposes. While, approximately 189 households (10.3% households) in this commune do not use tap water as these households as they (i) are concerned about the water quality of centralised water systems (local people complain about the bad smell, fishy taste, effect on the skin, etc. when using the tap water) and/or (ii) cannot afford to the install tap water in their houses (6% local people has income less than 32 million VND/year (about 1333 USD/year)).

The noteworthy sociological study findings are displayed in **Figure 6**, including information on the local population's use of groundwater source in the surveyed area (**Figure 6a**), their awareness of the

issues surrounding groundwater sources (**Figure 6b**), and their degree of satisfaction with the quality of the groundwater (**Figure 6c**). Although a high percentage (nearly 90%) of households using tap water was recorded, most of households in Hoang Tay commune (up to 78%) are still using groundwater as the principal water source for their everyday activities (**Figure 6a**).

Table 2. Water supply status and selected relevant socio-economic parameters in Hoang Tay commune, Kim Bang district, Ha Nam province [20]

No	Parameters	Hoang Tay
I	***Socio – economic aspects***	
1.	Population	5921
2.	Number of households	1836
3.	Number of women	2984
4.	Number of children (under 6-year-olds)	750
5.	Income per capita (million VND/year)	77.1
6.	Number of poor households	56
7.	Number of near-poor *households*	59
8.	Number of childcare/number of students	1/405
9.	Number of primary schools/number of students	1/613
10.	Number of secondary schools/number of students	1/330
II	***Water supply status***	
1.	Drinking water access rate (%)	100
2.	Percentage of households using tap water from commune centralised systems (%)	89.7
3.	Tap water price (VND/m^3) [a]	8000
4.	Tap water consumption (m^3/month/household)	10
5.	Number of drilled wells	650
6.	Number of rainwater tanks	1388

[a] *Water price doesn't include the depreciation of the commune centralised treatment plants*

Generally, these characteristics such as age, level of education, income, and ethnicity are the principal social, economic, and demographic factors influencing people's awareness of groundwater pollution issues. Higher income and higher levels of education were found to be linked with higher levels of awareness. Among them, 69 % of interviewed households had a high awareness of the related problems of their groundwater sources, including the awareness of As, Fe, and NH_4^+ contamination in groundwater. The majority of them agreed that long-term exposure to polluted water would be harmful to their health (**Figure 6b**). The satisfaction level of local people in the surveyed area about groundwater quality is presented in **Figure 6c**. The results revealed that the satisfaction rates were as follows: dissatisfied (47.82%) > highly dissatisfied (34.43%) > average (13.93%) > satisfied attitude (3.83%).

The survey shows that no one in this area was very satisfied with groundwater quality and nearly half of the participants (47,82%) were dissatisfied with the quality of the groundwater.

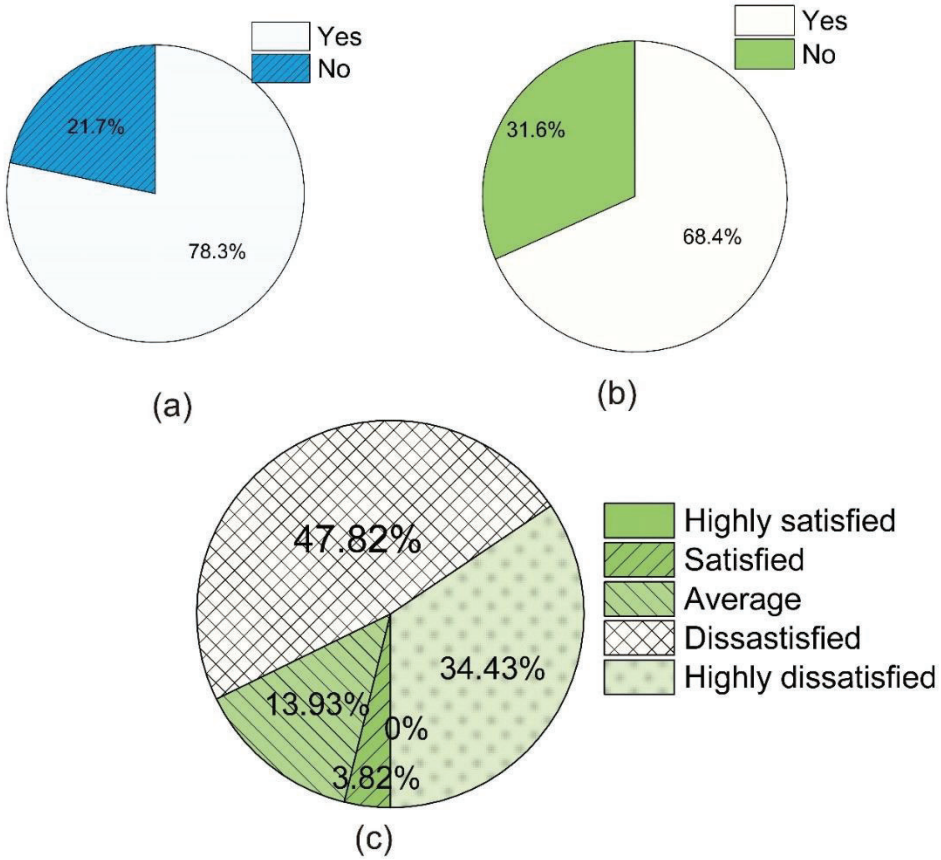

Figure 6. The status of: (a) using groundwater in living area; (b) understanding the related problems of their groundwater sources; (c) satisfaction level of local people in surveyed area about groundwater quality.

Figure 7 shows information on the main water sources used in this area for resident's daily activities. The results indicated that more than half (57%) of population is simultaneously using three water sources, including rainwater, tap water, and groundwater for their daily activities. About one-fifth of the participants is using two water sources: tap water and groundwater (20%), or rainwater and groundwater (19%) for their daily needs. No household only utilizes either bottled water or rainwater for their daily activities. The survey also found that residents were using rainwater as the main water source for drinking and eating purposes (**Figures 7** and **8**).

As shown in **Figure 8**, a majority (nearly 80%) of the respondents used rainwater as the main water source for their eating and drinking purposes. However, the shortage of rainwater in the dry season was reported to be a challenge in this area. To solve this problem, more than 10% of interviewed households have used groundwater and tap water along with rainwater in order to give them more choices and to reduce their reliance on rainwater sources in the dry season. As shown in **Figure 8**, the percentage of participants who chose to use only water sources such as groundwater or bottled water for their daily eating and drinking purposes was 0%. This reason could be the high price of the bottled water. For groundwater, this may be due to good participant awareness of As-contamination in the groundwater (68.4%, **Figure 6b**). This could lead to no option for using unique groundwater sources for eating and drinking purposes. Also, only a small percentage (about 20%) of local people was using this water source

with other sources such as tap water and rainwater. The interview results also show that although the commune decentralized water plant has been set up and operated in this area, the groundwater continues to be identified as the essential source for the local people's daily activities (**Figures 6 - 8**). These results illustrate the high necessity of groundwater treatment in this area to supply a safe domestic water source and even a drinking water source.

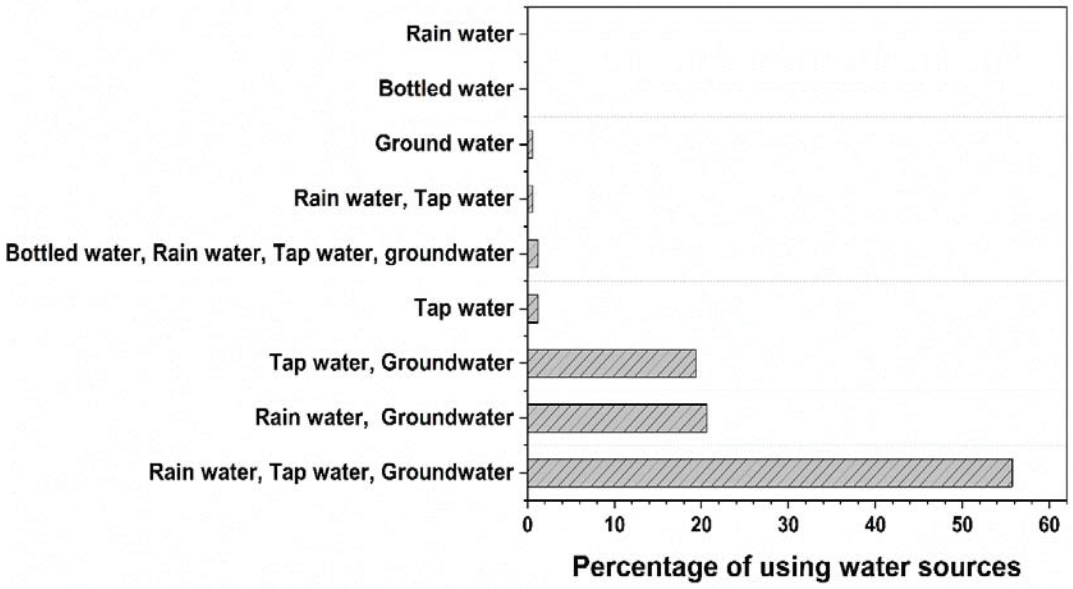

Figure 7. The main water sources used for residence's daily activities.

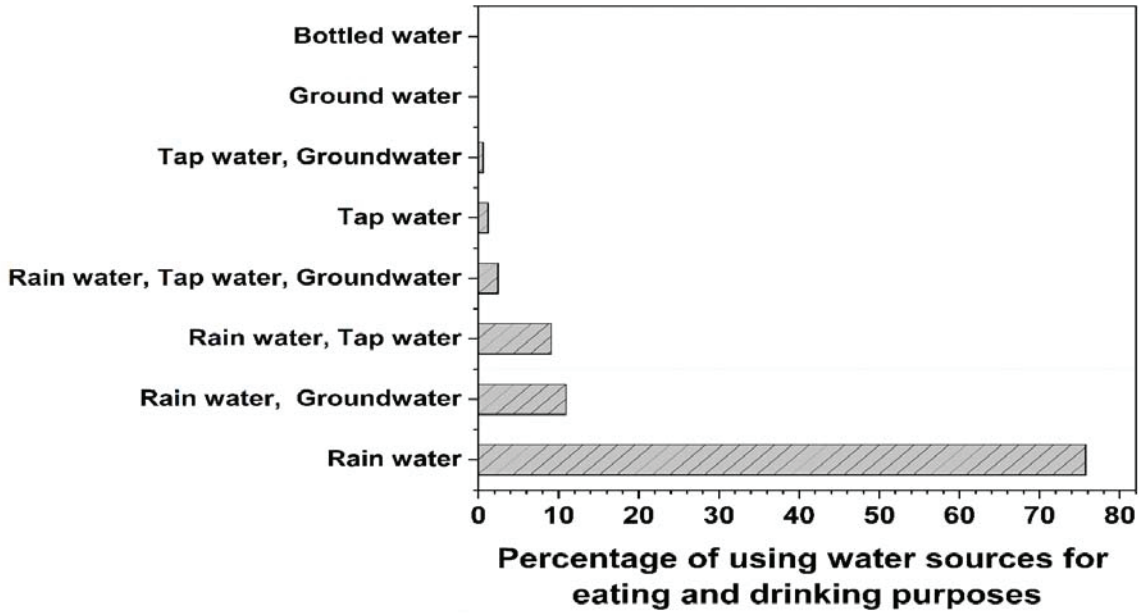

Figure 8. The main water sources used for residence's eating and drinking purposes.

4. Conclusions

The groundwater source in the Hoang Tay commune was highly contaminated by As, Fe, NH_4^+, and coliform. A high proportion of 78.3% of interviewed households was still using groundwater as the

primary water source for their daily life and most people (69%) were aware of groundwater quality issues. These sand filters could effectively remove some contaminants in the effluent. However, the quality of treated groundwater could not meet the Vietnam drinking and domestic water standards. The results indicate that local people should not directly use the untreated groundwater source as well as sand-filtered groundwater for their drinking and eating purposes. The tap water and rainwater qualities were better than the groundwater quality. However, they could also not be used for drinking directly and further coliform/pathogen treatment is needed. NH_4^+ is becoming an issue for drinking water supply. New safe, simple, and cost-effective treatment technologies should be developed to produce a safe drinking water source for local people.

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