A Survey of Household Water Use and Groundwater Quality Index Assessment in a Rural Community of Cambodia

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Abstract: To propose an efficient system for addressing water scarcity in a rural area through groundwater use, the information on water consumption and interpretation of groundwater quality are essential for estimating the optimal preparation of the comprehensive water system. Hence, this study aimed to estimate the current household domestic water consumption and groundwater quality index of currently accessed wells in a small rural community of Preyveng province, Cambodia as a practical and beneficial as well as a model for the water resource sector in rural areas. The questionnaire survey was designed as the main instrument for collecting the household water use as face-to-face interviews. The result showed that the average daily water consumption in the Preal commune is about 71 L per capita, which is almost two times lower than the minimum water quantity recommended by the World Health Organization (WHO), 150 L/day per capita. Moreover, 100% of the households in this commune heavily rely on groundwater wells for domestic water use and more than 50% confirmed that they used raw groundwater as drinking water without a proposer treatment system. Approximately 70% of the people in Preal wishes to have a clean water supply and more than 80% of the household had a positive willingness to pay for clean water supply. In terms of groundwater quality in the Preal commune, it is mainly contaminated by iron, arsenic, fluoride, and manganese, which are mainly associated with human health effects from daily consumption. About 75% of groundwater wells are presented in poor conditions and were unsuitable for drinking purposes. Lastly, the suitable water treatment and supply should be considered in order to reduce the effects on people’s health as well as to improve living conditions.

Keywords: household water use; rural community of Cambodia; groundwater quality; questionnaires survey; water quality index

1. Introduction

Over the past few decades, water scarcity has been experienced as a serious problem than ever on a local and global scale and relevant issues are now well defined by the Sustainable Development Goals (SDGs). On a worldwide scale, about 900 million people are estimated to not be access a qualified drinking water supply and 84% of them live in the
rural areas [1]. Many other studies also have also proved that this water shortage (target 6.4) will increase significantly over the coming decades [2,3]. It has been concerned as a serious problem in many developing countries since the contaminated water and unhealthy sanitation practices (targets 6.1–6.3, targets 3.2 and 3.9) cause more than 10,000 deaths per day which 5000 children are under the age of five. In Southeast Asia, about 20% of the total population lives in the poverty. In 2007, sanitation prompted the deaths of about 11,000 in Cambodia, 9000 in Vietnam, and 50,000 in Indonesia. A water pollution study in Thailand has prompted 30 to 60 times more pathogens, heavy metals, and poisons from industry than the limitation of the standards. Moreover, only 51% of the population can access to qualified water in Laos, while the waterborne diseases are the main warning in the Philippines and only 7% of the population is linked with the sewerage system that may causes the threat risk [4]. Water pollution troubles many countries in Southeast Asia.

Given this widespread problem, increasing attention has been paid to address the water scarcity in many parts of the world and it has become an interesting research topic in this century. Since this water crisis constitutes a serious threat as aforesaid, the other water sources have been considered. Groundwater can be considered as a suitable alternative water source due to its quantity and quality and the accessibility at the community level, which faces high water scarcity. It advances as the key resource of drinking water. Withdrawal of groundwater has been estimated at about 982 km$^3$ annually as the most extracted raw material in the world [5]. More than half has been used for domestic water supply in many counties and generally provides more than 45% of drinking water in the world, especially in the small towns and rural communities that rely on domestic supply [6,7]. Groundwater is an optional resource in urban, semi urban, and rural areas where piped water supply is not accessible. It is almost households, farms, and industries that have the individual wells. Clean and well protected from the contaminants, its availability is associated with surface water is the reason why this source type is in growing demand. In Cambodia, groundwater serves as the main source of drinking water supply, which used up to 53% of Cambodian households in the dry season [8]. It is estimated that about 270,000 tube-wells (hand pumps) are currently used for drinking water purposes, especially in Cambodia’s rural areas. It is currently used for a small community water supply and is expected to be used more for industrial and agricultural irrigation use. The main issues and challenges are that the groundwater contains high levels of arsenic, iron, manganese, fluorides, and salt in the Mekong and Tonle Sap River basin, particularly along the river and some areas [9]. Not only Cambodia, but also neighboring countries including Laos, Thailand, and Vietnam have reported about the serious arsenic, iron, fluoride, etc. pollution in water sources such as groundwater.

To propose an efficient system for addressing the water scarcity, the information on water consumption and groundwater pollution related to the water quantity and quality is essential for estimating the optimal preparation of the comprehensive water system including groundwater treatment processes design and supply system. Such type of investigation assumes importance for satisfying the growing needs of the people in the community. Various studies have been investigated different tools for evaluating groundwater quality and its suitability [10]. Geographic information system-based groundwater quality index (GIS-based GQI) was considered as a synthetic index proposed by Babiker et al. (2007) [11]. Moreover, the GIS tool has been successfully applied with advanced statistical or geostatistical methods for producing the high interpretation capacity for assessing the spatial analysis of water quality [12]. This study aimed to estimate the current household domestic water consumption and groundwater quality index assessment in a small rural community of Preyveng province, Cambodia, in order to propose a quantitative information for designing groundwater treatment processes and supply systems as well as to address water scarcity through groundwater use in the study area. The questionnaire survey on household water use was conducted for collecting the data, while the water quality index (WQI) method with spatial analysis of GIS was used for groundwater quality estimation. Moreover, the results and findings of the present study with respect to Preal commune in the Kanhchriech
district of Preyveng province would be practical, beneficial, and meaningful and will act as a model for the rural sector water resource managers in rural or semi-urban areas of Cambodia as well as in other parts of the globe.

2. Materials and Methods

2.1. Study Area

This study has been carried out in a small area of Preyveng province in Preal commune of Kanhchriech district (see Figure 1). Preal is one of the communes among eight in the Kanhchriech district, where is located at the south of the Phnom Penh capital about 45 km, along the coordinate 11°39' N latitude and 105°37' E longitude. The coverage area of Preal commune is about 66.5 km² to group 16 villages including Trapeang tuem, Trapeang seh, Pou thmei, Andoung sala, Trapeang thlan tboung, Trapeang thlan cheaung, Thmei, Tuol tnaot, Kouk roka, Prey ta prum, Trapeang kranh, Lhaeuy, Pouthi proeks, Tuol trach, Trapeang kakaoh, and Svay. Based on the commune database online (CDB) of the national committee for sub-national democratic development (NCDD) [13], every family in this Preal commune has used groundwater from a type of pump, mixed well, ring well, and opened dug well as the household potable water source. Therefore, groundwater in this study area serves as a very important source for both domestic and irrigation water use. Almost all of the families depended on groundwater for daily living while other sources such as water from purified system equipment, pond, rain water storage, and rivers, lakes, natural ponds/reservoirs are not accessible due to their quantity and quality along space and time. All of the wet rice land area is about 4067 ha. There are only two types of soil in the study area, alumisol and cultural hydromorphic soil. However, alumisol soil has almost coved all of the area. Almost all of the area is used as a paddy field which others are abandoned filed covered by grass and shrub, shrubland, and village garden crop. Moreover, there is no surface water and water supply available in this study area.

Figure 1. Study area of Preal commune, Kanhchriech district, Preyveng province, Cambodia.

2.2. Data Collection and Analysis on Water Use

For water demand analysis, the detail of actual water use such as drinking, washing of utensils, toilet flushing, bathing and clothes washing on a household level is important [14]. However, in most developing countries including Cambodia, it is very difficult to obtain...
such information. Hence, the data used in this study is mainly from primary data sources. The questionnaire survey approach, one of the indirect estimation methods, was used in this study as it is more convenient and reliable for community data collection, compared to direct estimation, and input-output tables and materials flow analysis methods. The surveying was conducted at the individual household level in the study area. In the surveying study, the basic information of sample size selection for data collection is of crucial importance related to resource and time consuming as well as result accuracy. Determining the sample size is mainly dependent on three parameters including the level of precision (e), level of confidence or risk, and the degree of variability in attribute [15]. There are different methods for determining the sample size including census for small population populations, imitating a sample size of similar studies, published tables, and calculation of formulas [16]. Using the published table is a simple and fast approach to obtain the sample size for a given set of criteria. In this study, the sample size of the respondents was determined from the amount of family need to conduct interview with prepared questionnaires. The 95% of confidence level (CL), 50% of variability degree, and 10% of precision level were selected to estimate the sample size. The maximum sample size for infinite population is 100. Hence, 100 samples of questionnaire respondents were collected for conducting the response analysis.

Since the data of this part was collected by a survey study as the primary data source, the methodology of water use analysis is based on an interdisciplinary, descriptive, intergraded, and cross-sectional analysis approaches. The survey on water use was conducted between mid and the end of June 2018 using a structured questionnaire as the main research instrument. It was conducted within the early of rainy season in Cambodia, the seasonal impact on water consumption may not be significant. Moreover, there is no linguistic issue even though the questionnaire was designed in English and the field survey was conducted in Khmer (Cambodia language) because it was interviewed face-to-face directly by the researcher. Volumes of various types and sizes of vessels used in each household were measured. The amount of household domestic and drinking water use was asked in terms of usage duration per each vessel in which is convenient for the respondent and data accuracy. It was therefore used to determine the daily water consumption for overall household and drinking only. Quantity assessment of water use in various activities cannot be conducted since there is no estimable information in the study area, only overall household and drinking water use could be estimated.

2.3. Socio-Economic Classification

Various variables can be selected for socio-economic classification such as household assets score, education, occupation, size of land holding, and household annual income. Annual household income was selected for socio-economic classification in this study since it is easy to operate and understand, as indicated by Singh and Turkiya (2013) [14]. In addition, annual income analysis-based is more practical for understanding the collected data. A collected annual income data from each surveyed household was classified into five socio-economic groups based on their income in Preal commune. These five groups are Group 1 (<KHR 2,000,000 equivalent to <USD 500), Group 2 (KHR 2,000,000–4,000,000 equivalent to USD 500–1000), Group 3 (KHR 4,000,000–8,000,000 equivalent to USD 1000–2000), Group 4 (KHR 8,000,000–16,000,000 equivalent to USD 2000–4000), and Group 5 (>KHR 16,000,000 equivalent to >USD 4000). It should be noted that various statistics used in this analysis, e.g., frequency, percentage, means, standard deviation, were analyzed by Microsoft Excel computer software.

2.4. Groundwater Quality Assessment

Groundwater quality assessment in this study was mainly based on the secondary data source. Available groundwater quality data of a total of 21 accessible wells (see Figure 2) sampled and analyzed between 2007 and 2008 was collected for this study. It was obtained from The National Well Database of the Ministry of Rural Development of Cambodia [17].
Based on the National Well database, groundwater quality data in Preal commune was originally assessed by Resource Development International (RDI) and UNICEF database. The parameters recorded in the source are pH, conductivity, total dissolved solids (TDS), arsenic, chloride, manganese, iron, nitrate, turbidity, hardness, zinc, sulfate, ammonium, nitrite, fluoride, salinity, E. coli, and total coliform. The analytical methods and instruments of each parameter can be found in the databases of RDI-Cambodia and UNICEF [18].

Figure 2. Available groundwater quality data in the study area.

2.5. Water Quality Index Method

Water quality index (WQI) is the method for investigating the influence of individual water quality parameters on the overall water quality. Standard water quality for drinking purposes recommended by WHO was used for WQI calculation. The procedure for WQI calculation, it was mainly divided into three steps. First, all nine parameters were assigned as weight based on their perceived effects on primary health. The assigned weight of each parameter in this study was referred to the previous studies [19,20], as shown in Table 1.

Secondly, a relative weight \( W_i \) of each parameter was therefore determined by using Equation (1), where \( w_i \) is the weight of each parameter, \( n \) is the number of parameters investigated, \( W_i \) is the relative weight. The WHO standard level, weight \( (w_i) \), and relative weight \( (W_i) \) of each parameter were provided in Table 1. For the last step, a quality rating scale \( q_i \) was determined for each parameter by using Equation (2), where \( q_i \) is quality ranking, \( C_i \) is concentration of each parameter in each water sample presented in milligrams per liter, and \( S_i \) is the WHO standard level of each parameter in each water sample presented in milligrams per liter. The value of \( q_i \) was used for determining the sub-index \( S_i \) of each water quality parameter before calculating WQI for all water quality parameters by using Equations (3) and (4), respectively. WQI calculation steps used in this study follow various existed works [21–25]. Estimated values of WQI were classified into five levels described water condition including excellent, good, poor, very poor, and
unsuitable water for drinking purposes (see Table 2), as suggested and applied in previous studies [20,26].

Table 1. Weight (\(w_i\)) and relative weight (\(W_i\)) of each water quality parameter.

| Parameter | Unit             | WHO Standard | Weight (\(w_i\)) | Relative Weight (\(W_i\)) |
|-----------|------------------|--------------|------------------|---------------------------|
| pH        | -                | 6.5–8.5      | 4                | 0.125                     |
| Iron      | mg/L             | 0.3          | 4                | 0.125                     |
| Arsenic   | µg/L             | 10           | 5                | 0.156                     |
| Fluoride  | mg/L             | 1.5          | 4                | 0.125                     |
| Hardness  | mg/L-CaCO\(_3\) | 100          | 2                | 0.063                     |
| Chloride  | mg/L             | 250          | 3                | 0.094                     |
| Manganese | mg/L             | 0.05         | 4                | 0.125                     |
| Nitrate   | mg/L             | 50           | 5                | 0.156                     |
| Turbidity | NTU              | 1            | 1                | 0.031                     |

\[
W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}, \quad (1)
\]

\[
q_i = \frac{C_i}{S_i} \times 100, \quad (2)
\]

\[
S_{li} = W_i \times q_i, \quad (3)
\]

\[
WQI = \sum S_{li}, \quad (4)
\]

Table 2. Water quality classification based on WQI.

| WQI Range | Water Quality             |
|-----------|---------------------------|
| <50       | Excellent water           |
| 50–100    | Good water                |
| 100–200   | Poor water                |
| 200–300   | Very poor water           |
| >300      | Unsuitable water for drinking purpose |

2.6. Mapping by ArcGIS Software

Geographic information system (GIS) is a tool for storing, analyzing, and displaying spatial data and it is also popular applying for several area including engineering as well as environmental fields. The topo to raster interpolation method of spatial analyst tool was used in this study for spatial interpolation of water quality distribution of the Preal commune. It shows the interpolation value to a whole study area map, which can fully discuss the groundwater quality in the study area. A spatial distribution map of water quality in terms of main associated contaminants on WQI was constructed for determining the spatial variations in Preal commune using ArcMap from the ArcGIS computer software.

3. Results and Discussion

3.1. A Survey of Household Water Use

3.1.1. Demographic of Participants

One hundred respondents (60 are female) representing 100 different households in the study area, were selected for responding to the field survey questionnaire. Respondents were randomly selected in Preal commune which 34%, 22%, 18%, and 16% were collected from Prey ta prum, Por prik sa, Kouk roka, and Trapeang khanh villages, respectively. Others were from Lhaeuy, Trapeang chambok, and Tuol tnaot villages. The majority of respondents were aged between 20 and 70 years old. More than 80% of the respondents
have not entered high school education level while 17% had. Only two among 100 samples were educated up to bachelor’s degree.

3.1.2. Daily Water Consumption

Daily total domestic water consumption by the residents of Preal commune across five socio-economic groups of 100 households was estimated at about 31,303 L. The maximum domestic water in the commune was taken by Group 4 households followed by Group 5 and 3 households. These three socio-economic groups constituted of more than 70% of the total water consumption of Preal commune. For maximum water consumption by Group 4 represented the socio-economic group with an annual income between USD 2000 and 4000 which is in a good agreement with the previous findings [14]; maximum water consumption was observed at a socio-economic class with annual income Rs. 100,001–200,000 equivalents to USD 2000–4000.

Table 3 presents the total daily domestic water consumption per household and per capita in Preal commune. The average daily water consumption per household in the study area is 313.0 L whereas per capita is about 70.7 L. Group 1 households consume about 376.2 L of water while only 285.8 L were consumed by Group 3. Per capita, the highest water consumption was observed from Group 1 while the minimum was Group 2. It is quite low, almost two times compared to the minimum water quantity (150 L/day per capita) recommended by the WHO. Table 4 reports water consumption in rural areas of different regions in the world. It demonstrated that water consumption is highly based on behavioral and cultural conditions of a household as well as the living lifestyle of the people [27]. In addition, water consumption in the rural community of Cambodia from this study also presents in the range among other rural communities around the world. Moreover, the WHO categorized the water accessibility in terms of service level to meet requirements for sustaining good health and interventions required for ensuring health gains. This is shown in Table 5 including category 1—no access (quantity collected often below 5 L/day per capita), category 2—basic access (average quantity unlikely to exceed 20 L/day per capita), category 3—intermediate access (average quantity about 50 L/day per capita), and category 4—optimum access (average quantity 100 L/day per capita).

Table 3. Number of households and their daily domestic water consumption in unit of liter across socio-economic groups in Preal commune (SD: standard deviation).

| Socio-Economic | Number of Households | Per Household | Per Capita |
|----------------|---------------------|---------------|------------|
|                | Mean | SD  | Mean | SD  |
| Group 1        | 13   | 376.2 | 509.2 | 76.8 | 69.0 |
| Group 2        | 14   | 313.8 | 229.6 | 65.8 | 45.2 |
| Group 3        | 25   | 285.8 | 154.4 | 68.6 | 46.4 |
| Group 4        | 25   | 300.4 | 263.5 | 76.0 | 64.1 |
| Group 5        | 23   | 320.2 | 200.3 | 66.2 | 44.3 |
| Total          | 100  | 313.0 | 271.4 | 70.7 | 53.8 |

Table 5 also describes the needs met for different water consumption categories as well as health concern levels. Therefore, the percentage of households in different water consumption categories was determined across socio-economic groups, as shown in Table 6. The daily water consumption for each category was assumed based on its description. It indicated that all socio-economic groups passed out from category 1 while about 8–21% was in category 2 considered as the average quantity accessibility with a high level of health concern.
Table 4. Water consumption in rural area of different regions in the world.

| Rural Communities                  | Average Water Consumption [L/Day per Capita] |
|------------------------------------|---------------------------------------------|
| East African                       | 5–23                                        |
| Kyenjojo, Uganda                   | 11–23                                       |
| South India                        | 14–42                                       |
| Sahel region                       | 26–45                                       |
| Sri Lankans                        | 36–54                                       |
| Wei river basin, China             | 56.2                                        |
| South-east Cambodia (this study)   | 65.8–76.8                                   |
| China                              | 89                                          |
| North-west India                   | 117                                         |
| Ramjerd area, Iran                 | 121.7                                       |
| Fars Province, Iran                | 250                                         |

Table 5. Summary of requirement for water service level to promote health.

| Category | Needs Met                                      | Level of Health Concern |
|----------|-----------------------------------------------|-------------------------|
| 1        | ■ Cannot be assured a consumption              | Very high               |
|          | ■ Not possible for hygiene                     |                         |
| 2        | ■ Should be assured a consumption              | High                    |
|          | ■ Handwashing and basic food hygiene possible  |                         |
|          | ■ Laundry/bathing difficult to assure          |                         |
| 3        | ■ Assured a consumption                        | Low                     |
|          | ■ All basic personal and food hygiene assured  |                         |
|          | ■ Laundry/bathing should be assured            |                         |
| 4        | ■ All consumption needs met                    | Very low                |
|          | ■ All hygiene needs should be met              |                         |

Table 6. Percent of households in different water consumptions across socio-economic groups in Preal commune.

| L/Day per Capita | Socio-Economic Group |
|------------------|----------------------|
|                  | 1 2 3 4 5            |
| <5               | - - - - -            |
| 5–20             | - 21% (3) 8% (2) 9% (2) |
| 20–100           | 85% (11) 57% (8) 72% (18) 84% (21) 65% (15) |
| >100             | 15% (2) 21% (3) 20% (5) 16% (4) 26% (6) |

Note: figures in parenthesis indicate number of households.

The majority of households in Preal commune were classed in category 3, about 57–85% of the total households investigated. About 15% to 26% could access to the optimum amount of water consumption. In terms of quantity, total water consumption among 100 households investigated for categories 2, 3, and 4 are 528, 17,825, and 12,950 L/day equivalent to 75.4, 244.2, and 647.5 L/day per household, respectively. If water consumption 100 L/day per capita was selected as the criterion for defining water deficient, 80% of the households in Preal commune remain water deficient. The proportion of deficient households is the highest in Group 1 (85%) and Group 4 (84%), followed by Group 3 (80%) and Group 2 (79%). Among all socio-economic groups, the least percentage of domestic water-deficient households is found in Group 5 (74%).

Daily drinking water consumption by the residents of Preal commune across five socio-economic groups of 100 households was estimated at about 1063 L (see Table 7). The maximum drinking water in the commune was taken by Group 3 households followed by
Group 4 and 5 households. These three socio-economic groups constituted more than 70% of the total water consumption of Preal commune as the total domestic water consumption as well. Compared to total domestic water consumption, drinking water fraction is about $3.4 \pm 0.6\%$ across all socio-economic groups. Per household daily consumption of drinking water was found at a similar value, about $10.6 \pm 0.6$ L across all socio-economic groups. Per capita daily consumption of drinking water was found to be $2.4$ L in mean value across all socio-economic groups. Among all groups, Group 4 households consumed the highest amount of drinking water ($2.8$ L), followed by Group 3 ($2.6$ L) and Group 1 ($2.5$ L). The least per capita daily drinking water consumption is Group 5 and Group 2.

Table 7. Drinking water consumption in unit of litter across socio-economic groups in Preal commune.

| Socio-Economic Group | Per Household | Per Capita |
|----------------------|---------------|------------|
|                      | Mean  | SD     | Mean  | SD     |
| Group 1              | 10.5  | 5.8    | 2.5   | 1.1    |
| Group 2              | 10.2  | 5.8    | 2.1   | 1.1    |
| Group 3              | 11.2  | 5.1    | 2.6   | 1.5    |
| Group 4              | 10.9  | 4.9    | 2.8   | 1.1    |
| Group 5              | 10.9  | 8.1    | 2.0   | 0.8    |
| **Total**            | 10.6  | 6.0    | 2.4   | 1.1    |

In conclusion, regarding daily water consumption, the average water consumption in Preal commune is 313 L per household and about 71 L per capita. The values found are almost two times lower than the minimum water quantity recommended by the WHO, 150 L/day per capita. Using this minimum water consumption criterion, more than 80% of the households in Preal commune are facing the water scarcity in terms of water quantity. The value found is such as a serious concern for health promoting in the study area which instantly requires a suitable and sustainable solution.

3.1.3. Sources of Water Use

Information on water sources for domestic water was also investigated during the field survey. The results are summarized and directly showed in Table 8. All households in Preal commune depend on groundwater wells and a few households have an additional source of rainwater storage or surface water. It was summarized that 93% of the households in commune rely heavily on groundwater wells only, while another 6% are using both groundwater wells and rainwater storage. There is only 1% of the households depend on groundwater wells with surface water.

Table 8. Sources of domestic water use in Preal commune.

| Domestic Water Source                                             | Percentage of Households |
|-------------------------------------------------------------------|--------------------------|
| Rain water storage only                                           | 0%                       |
| Surface water only (e.g., pond, river, etc.)                     | 0%                       |
| Groundwater only                                                  | 93%                      |
| Rain water storage and surface water                             | 0%                       |
| Rain water storage and groundwater                               | 6%                       |
| Surface water and groundwater                                     | 1%                       |
| Rain water storage, surface water, and groundwater                | 0%                       |
| **Total**                                                        | 100%                     |

Moreover, the question during the field survey regarding groundwater accessibility was also conducted in order to understand the current groundwater use. All residents also confirmed that 91% of the households have their own groundwater well at home while another 9% are using groundwater wells within 150 m away. Moreover, groundwater use
was accessed in both seasons, rainy and dry seasons, even a few households complained about the seasonal effect on the water level in the wells. In the dry season, few groundwater wells cannot be used due to too low a water level to withdraw. Figure 3 shows different types of groundwater withdrawal commonly used in Preal commune including simple ring wells constructed by concrete, cast iron hand pump, PVC suction pump operated manually by pull/push, and machinery pump.

Since the household portable water use was directly supplied by groundwater for all residents in Preal commune, it may serve as the main source of drinking water in the community as well. The field survey study also investigated the source of drinking water with any additional treatment processes before consumption. The result is summarized in Figure 4, which is classified into four types of drinking water, i.e., directly drink raw groundwater without additional treatment processes (called raw groundwater), drinking groundwater after boiling (called boiled groundwater), drinking groundwater after passing through the household filtration unit (called filtrated groundwater), and drinking the purchased bottled water (called bottled water). Some households used two or three types between the mentioned drinking waters.

Based on the result, 49% of households in Preal commune drank raw groundwater directly without any treatment processes and another 37% used groundwater as the source for drinking water with the additional processes including boiling, water filter unit, and both. In addition, using mixed types between raw and boiled groundwater was found in about 5% of households. Moreover, only 1% of residents were found using only bottled water as the drinking water while other 8% used bottled water with boiled groundwater (5%), with raw groundwater (1%), with filtrated groundwater (1%), and with raw and boiled groundwater (1%). It indicated that a majority of households in Preal commune consumed raw groundwater directly without treatment processes (49%), followed by

![Figure 3](image-url)
filtered groundwater using household filtration unit (27%), and mixed four types of drinking water (13%). Boiled groundwater (5%) and bottled water (1%) were found in low consumption possibly due to the higher cost required. In summary, the household used raw groundwater as drinking water was counted up to 56% without a proposer treatment system. Therefore, the groundwater quality assessment is crucial for the health concerns of residents in the study area.

Figure 4. Number of households in different types of drinking water.

3.1.4. Perception of Water Quality

The perception of water users on current water use quality is another important information should be acknowledged even there is a water quality standard set, especially, for a rural community of a developing country. Sheat (1992) [28] emphasized that planners have to acknowledge the importance of water quality perception among the water users as it represented their indigenous knowledge and culturally constructed concepts and definitions. Based on the result of the previous part, 100% of households in Preal commune used groundwater for their domestic water use in daily life without any treatment. More seriously, approximately 56% of them directly drank raw groundwater as drinking water without any treatment or processing as well as concerning on water quality. In this study, perceived water quality was evaluated from the field survey questionnaire. First, the participants were asked if they are ever concerned about their current water use quality. Responses were rated as ‘yes’, ‘no’, and ‘I don’t know’. The results are summarized in Figure 5a, whereas 56% of households have concerns on water quality of their current water use. Surprisingly, up to 40% responded that they are never concerned or care about their water use quality. In order to clarify the people in the study area on the quality of current water use perception, a second question was directly asked on whether their current water use is safe or not. The result is illustrated in Figure 5b, whereas more than half of the households indicated that their current water use is safe and the other remaining considered it is not safe. Among 47% of the households acknowledged their current water use is not safe, 40% of them still access to groundwater without any proper treatment in a reason they have no choice while other 60% considered to use other types of water, i.e., filtrated, boiled, and bottled water. Based on this result, 40% of the respondents do not concern themselves about their current water use quality as they believe that it is safe for their daily use. A similar finding was also found in two communities in Kandal province of Cambodia by Orgill et al. (2013) [29], nearly all respondents think that their drinking water is 100% safe.
Across socio-economic group analysis, the majority of Group 3 households, followed by Group 4 demonstrated that their current water use is safe (see Table 9). However, the households indicated ‘their water is not safe but no choice’ are mostly distributed in similar percentage from all socio-economic groups, except Group 3. Moreover, a large portion of Group 5 households (34.5%) used other types of water than raw groundwater as they considered ‘it is not safe’. This finding might be related to the economics of the families in Group 5 as the households of this group has the highest annual income. Hence, they can support the other water sources. It was also indicated in a recent study in north-west Ethiopia that modern treatment measures are not common and accessible for low-income households [30]. Moreover, it might be related to the lowest daily water consumption of drinking water of Group 5 households as their drinking water was from various types, for example, boiling or filtration or bottled water.

Table 9. Perception of households about water use quality across socio-economic group in Preal commune.

| Water Perception          | Socio-Economic Group |
|---------------------------|----------------------|
|                           | 1  | 2  | 3  | 4  | 5  |
| It is safe                | 7.3% | 12.7% | 36.4% | 29.1% | 14.5% |
| Not safe, but no choice   | 21.1% | 26.3% | 5.3%  | 21.1% | 26.3% |
| Not safe, then use other waters | 17.2% | 6.9%  | 24.1% | 17.2% | 34.5% |

In conclusion, approximately 40% of households in Preal commune responded that they did not concern about their current water use quality. Moreover, it was noticed during the field survey that few people simplified that their water was traditionally used a long time ago without any serious problems observed, while other few people mentioned that raw groundwater is more favorable and tastier compared to boiled or filtrated or bottled waters. From a personal point-of-view, it was attributed by lack of knowledge about the quality of water and health effect. Consequently, more than half of the households in Preal commune believe that their current water use is safe while another 19% considered not safe still directly accessed to that raw water. From this result, the water quality assessment becomes more and more important in order to clarify the safety level of their current water use. Moreover, the information or knowledge about the quality of water and health effects is highly recommended to delivery to the water users in rural community.

3.1.5. Estimated Current Price of Water Use

The price of current water used in Preal commune was estimated for both total domestic water and drinking water across socio-economic groups. It should be noted that the price of water was determined from the cost of the related payment for water supply, for example, the cost of petroleum or electric city used for pump, the maintenance cost of
the pump, cost of the heating energy for boiling water, the maintenance cost of household filtration unit, cost of bottled water, etc.

Summary and calculation were carried out for this price of water estimation and the result is illustrated in Figure 6 across socio-economic groups. For total domestic water use, it was found that Group 1, Group 2, Group 3, and Group 4 paid at similar costs, about 0.240 ± 0.007 USD/m³ while the lowest one is Group 5 (0.181 USD/m³). In comparing the results, the price of drinking water across socio-economic groups presented in similar amount between Group 1 (0.262 USD/m³), Group 2 (0.247 USD/m³), Group 3 (0.253 USD/m³), and Group 4 (0.260 USD/m³). However, the highest value was found to be Group 5 (0.410 USD/m³). It indicated that the price of drinking water was found higher than the price of domestic water about 6.2% in average for low economic income households (Group 1, Group 2, Group 3, and Group 4). However, a big gap of the price (more than two times) between domestic and drinking water was observed in high-income households.

![Figure 6. Estimated price of water of domestic and drinking water use.](image)

The socio-economic Group 5 paid the highest price for drinking water might be due to the type of drinking water used in this household group. Based on Figure 7, more than 60% of households in Group 5 did not use raw groundwater directly as drinking water. Bottled water and additional processes (i.e., boiling and filtration unit) may require more payment. On average, the results demonstrated that the price of domestic water use in Preal commune is about 0.228 USD/m³ (~931 KHR/m³), whereas drinking water is about 0.286 USD/m³ (~1168 KHR/m³). This result is very important for future estimation on water use development as well as water economic analysis in the study area. Assuming that a single household monthly consumed about 10 m³ of water (estimated based on Table 3), the price of water use in Preal commune (0.228 USD/m³) is more expensive than that of clean water supply of Phnom Penh Water Supply Authority (see Table 10). It likely seems the people in rural area have to pay more for unqualified and hard-to-access water. This term was also mentioned by editor-in-chief Rich Connor of UNESCO, poor homes in slums often had to pay 10 to 20 times more for water, while rich with piped water tended to pay far less per liter [31]. It is expected the people’s living conditions, as well as local Gross Domestic Product (GDP), should be better after a qualified water is supplied with a reasonable price due to the payment on the water sector, consequently resulting in health concerns as well as human productivity, etc.
a single household monthly consumed about 10 m³ of water (estimated based on Table 3), use development as well as water economic analysis in the study area. Assuming that Preal commune is about 0.228 USD/m³ (~931 KHR/m³), whereas drinking water is about payment. On average, the results demonstrated that the price of domestic water use in Bottled water and additional processes (i.e., boiling and filtration unit) may require more 60% of households of Group 5 did not use raw groundwater directly as drinking water. Based on Figure 7, more than domestic water supply.

3.1.6. Awareness about Safe Water Supply

Before investigating the awareness about safe water supply, an opinion of the households on water sectors should be developed in order to improve their water use challenging. Options of different water sectors including provide water supply by connecting the water pipe, constructing a central water treatment for a community, providing a household filtration unit, and constructing new groundwater wells. The result (see Figure 8a) showed that a majority of ‘Government water supply’ selection was obtained up to 70% of household in Preal commune, followed by ‘Provide household filtration unit’ (18%). It indicated that the awareness about water supply in Preal commune is adequate in order to addressing the water scarcity issue. However, willingness to pay for a safe water supply and adequate water price are other challenges to overcome. Willingness to pay for a safe water supply got a positive response of up to 82% of households in Preal commune, as illustrated in Figure 8b. Only 2% of the households did not reply while another 16% did not show willingness to pay for a safe water supply. The result even indicated the awareness on safe water supply, the other challenges should be considered in the adequate water price proposed by the household opinion. A survey on water price willing to pay for safe domestic and drinking water was conducted by requesting them to evaluate the maximum price of water they can accept or suitable for their current living condition.

The result in average value among the household of each socio-economic groups for both domestic and drinking water proposed by the opinion of the households and current water price was shown in Table 11. For domestic water, Group 2 and Group 5 households could effort the highest water price up to about 0.58 USD/m³, followed by Group 1 (0.476 USD/m³) and Group 4 (0.412 USD/m³). In higher value, Group 5 and Group 4 showed a majority on proposed water price for drinking water, up to 1.031 and 0.939 USD/m³, respectively. About 0.740 and 0.706 USD/m³ could be paid for drinking water by Group 2 and Group 3, respectively, followed by Group 4 (0.593 USD/m³). This adequate water price is about higher than the current water price (see Table 10) of clean water supplied by PPWSA. This result indicated the potential development of the water sector in Preal commune in order to develop the living standard as well as reducing the degree of health concern caused by unqualified water use. This quantitative information

Figure 7. Number of Group 5 households in different types of drinking water.

Table 10. Current price of water supplied by Phnom Penh Water Supply Authority (PPWSA) for domestic water supply.

| Quantity [m³] | Fee per Cubic Meter |
|--------------|---------------------|
| 0–3          | KHR 400–USD 0.098   |
| 4–7          | KHR 500–USD 0.12    |
| 8–15         | KHR 770–USD 0.19    |
| 16–50        | KHR 1010–USD 0.25   |
| >50          | KHR 1270–USD 0.31   |

| Raw groundwater 35% |
|--------------------|
| Boiled groundwater, 31% |
| Raw and boiled groundwater, 4% |
| Boiled and filtrated groundwater, 4% |
| Boiled groundwater and bottled water, 9% |
| Filtrated groundwater and bottled water, 9% |
| Raw, boiled GW and bottled water, 4% |
| Other 65% |

Figure 6. Estimated price of water of domestic and drinking water use.
is also important for future water investment in the study area as well as other similar rural communities.

![Figure 8.](image)

**Figure 8.** (a) Opinion of households towards better water use, and (b) willingness to pay for safe water supply of households in Preal commune.

**Table 11.** Opinion of households on proposed water price as willingness to pay condition across socio-economic groups in Preal commune.

| Socio-Economic Group | Domestic Water [USD/m³] | Drinking Water [USD/m³] |
|----------------------|-------------------------|------------------------|
|                      | Current Water Price     | Proposed Water Price   | Current Water Price | Proposed Water Price |
| Group 1              | 0.248                   | 0.476                  | 0.262              | 0.939               |
| Group 2              | 0.243                   | 0.583                  | 0.247              | 0.740               |
| Group 3              | 0.234                   | 0.302                  | 0.253              | 0.706               |
| Group 4              | 0.237                   | 0.412                  | 0.260              | 0.593               |
| Group 5              | 0.181                   | 0.578                  | 0.410              | 1.031               |

Note: the price presented as average value among household of each socio-economic groups.

### 3.2. Groundwater Quality Assessment

The objective of this part is to assess the quality of groundwater in Preal commune mainly based on the secondary data source. Based on the result from the previous part, 100% of households in Preal commune mainly rely on groundwater wells for their domestic activities, and more than half of households directly consumed raw groundwater as drinking water without any treatments. Therefore, this groundwater quality assessment is very important in order to clarify the potential effect of contaminants in groundwater as well as on human health. The result of this part was divided into three parts including the water quality collection of groundwater well, determining the water quality index, and spatial variation of main associated contaminants.
3.2.1. Statistical Analysis of Groundwater Quality

In this section, the nine groundwater quality parameters including pH, iron, arsenic, fluoride, hardness, chloride, manganese, nitrate, and turbidity, were collected from secondary data sources and determined their statistical analysis such as minimum, mean, maximum, and standard deviation. The statistical analysis results were presented in Table 12 and value distributions in Figure 9.

Table 12. Statistical analysis of groundwater quality parameters in Preal commune.

| Parameters | Unit       | Min  | Mean  | Max   | SD  |
|------------|------------|------|-------|-------|-----|
| pH         | -          | 5.30 | 6.80  | 7.42  | 0.47|
| Iron       | mg/L       | 0.00 | 2.70  | 9.00  | 3.01|
| Arsenic    | mg/L       | 0.00 | 6.00  | 25.00 | 8.00|
| Fluoride   | mg/L       | 0.35 | 2.46  | 5.33  | 2.23|
| Hardness   | mg/L-CaCO₃ | 18.00| 131.00| 198.00| 54.00|
| Chloride   | mg/L       | 0.29 | 4.32  | 14.00 | 3.68|
| Manganese  | mg/L       | 0.01 | 0.10  | 0.15  | 0.03|
| Nitrate    | mg/L-NO₃  | 0.00 | 1.38  | 10.54 | 2.87|
| Turbidity  | NTU        | 0.42 | 10.82 | 106.00| 23.84|

In this study area, pH values varied between 5.30 and 7.42 with a mean value of 6.80 ± 0.47 (see Table 12). From the pH values distributed across Preal commune (see Figure 9), four groundwater wells, i.e., WDB ID 5395, 5397, 5401, and 5402, exceeds the permissible range (<6.5). For iron in water, its presence results in an unpleasantness of taste in the mouth and anesthetize red or brown stains on clothes and sanitary facilities or even foods. This parameter varied between 0.0 and 9.0 mg/L with mean value of 2.7 mg/L. From the investigated groundwater wells (see Figure 9), all samples are desirable limit (<0.3 mg/L), except for WDB ID 5391, 5393, and 5397. The mean value of 6.0 mg/L of arsenic in groundwater of Preal commune was assessed between the range of 0 and 25 mg/L, whereas almost half of groundwater wells exceeds standard level (0.01 mg/L) (see Figure 9).

For fluoride in groundwater sample, its concentration varied between 0.35 and 5.33 mg/L with a mean value of 2.46 mg/L and almost half of samples (see Figure 9) presented in higher amount compared to standard limitation (1.5 mg/L). Water hardness can be divided in to various conditions including soft water (<150 mg/L), moderately hard water (150–300 mg/L), hard water (300–450 mg/L), and extremely hard water (>450 mg/L). Total hardness varied between 18 and 198 mg/L as CaCO₃ with a mean value of 131 mg/L (see Figure 9). More than half of groundwater samples can be considered as soft water while the other remains are slightly hard water (<200 mg/L). Compared to the WHO standard, about 70% of groundwater wells in the study area is higher than standard level while all wells can pass the drinking water standard of Cambodia (<300 mg/L). For chlorine and nitrate levels in groundwater of Preal commune, these parameters are 0.29–14.00 mg/L (4.32 mg/L in mean) and 0.00–10.54 mg/L (1.38 mg/L in mean), respectively (see Figure 9). Compared to the drinking water standard, these two parameters are in allowable condition. For manganese, it distributed between 0.01 and 0.15 mg/L with a mean value of 0.10 ± 0.03 mg/L. Based on the distribution of its concentration across the map of Preal commune (see Figure 9), 95% of groundwater wells demonstrated a higher level than the standard condition (>0.05 mg/L). Last, turbidity varied between 0.42 and 106 NTU with a mean value of 10.82 NTU. If the standard limitation set 1 NTU, about 75% of groundwater wells are over permission condition, however, only 20% exceeded if 5 NTU was considered as the standard condition of turbidity in drinking water (see Figure 9).
Figure 9. Values distribution of groundwater quality parameters in Preal.

Hardness = 90.11 (pH) − 481.77 \((R^2=0.62)\), \(5\)
Iron = 0.09 (Turbidity) + 1.70 \((R^2=0.54)\), \(6\)
Arsenic = 2.33 (Fluoride) + 0.03 \((R^2=0.41)\), \(7\)
Chloride = −4.63 (pH) + 35.77 \((R^2=0.35)\), \(8\)
In addition, the correlation between any parameters is another important investigation in order to understand their relationships. It can be conducted through various methods, e.g., genetic programming (GP) [32], linear regression [33], correlation coefficient matrix [19,20], etc. In this study, the correlation between various parameters of Preal commune aquifer was calculated which is presented in Table 13. The correlation coefficient between water quality variables and regression analysis indicates indirect means for water quality [34]. A greater value of coefficient demonstrated the better and more useful of variables [35]. From Table 13, it revealed the highest correlations between hardness and pH (R~0.789), iron and turbidity (R~0.732), arsenic and fluoride (R~0.638), and chloride and pH (R~0.590). The linear regression analysis has been carried out for groundwater quality parameters in a high level of significance in their correlation (R > 0.500) [36]. In terms of statistical analysis, four pairs of water quality parameters were found as very significant (p-value < 0.01) while other three were significant at the 0.05 level. Four correlations between very significant variables including hardness vs. pH, iron vs. turbidity, arsenic vs. fluoride, and chloride vs. pH, were constructed as expressed with R squared in Equations (5)–(8), respectively. Based on the results, it indicated that groundwater in Preal commune is mainly contaminated by iron, arsenic, fluoride, and manganese, which are mainly associated with human health effects from daily consumption. Additionally, the water quality index should be estimated in order to understand the water condition of each groundwater wells in the study area as well as to find out the main associated contaminants on the water quality index.

| pH    | Iron    | Arsenic | Fluoride | Hardness | Chloride | Manganese | Nitrate | Turbidity |
|-------|---------|---------|----------|----------|----------|-----------|---------|-----------|
| pH    | 1       | 0.233   | −0.011   | −0.005   | −0.005   | 0.235     | 0.256   | −0.314    |
| Iron  | 1       | 0.517   | 0.161    | −0.057   | −0.038   | 0.037     | 0.037   | −0.267    |
| Arsenic | −0.201 | 1       | 0.138    | −0.138   | −0.195   | −0.118    | 0.054   | −0.276    |
| Fluoride | −0.230 | 1       | 0.638 *  | 1        | −0.439   | 0.115     | −0.061  | 0.162     |
| Hardness | 0.789 * | 0.161   | 1        | 1        | −0.497   | 0.115     | 0.098   | −0.197    |
| Chloride | 0.138 | −0.057  | 1        | 1        | −0.35    | 0.115     | 0.098   | −0.197    |
| Manganese | 0.235 | 0.161   | 0.638 *  | 1        | 0.466 *  | 0.115     | 0.098   | −0.197    |
| Nitrate | 0.256   | −0.061  | 0.132    | 0.466 *  | 0.162    | 0.115     | 0.098   | −0.197    |
| Turbidity | −0.314 | −0.276  | −0.035   | −0.35    | −0.061   | 0.115     | 0.098   | −0.197    |

Cell content: Pearson correlation coefficient [18]. Value with (*): significant at 95% CL. Value in bold with (*): significant at 99% CL.

3.2.2. Water Quality Index

Water quality index was determined in order to check if groundwaters in Preal commune is suitable for drinking purpose or not. The water quality index of each groundwater well is shown in Table 14. There is no groundwater that can be categorized as ‘Excellent water’ while only five wells are classed in ‘Good water’ and the rest fall below this range. It means that 75% of the groundwater wells in the study area presents in poor conditions and unsuitable for drinking purposes. This percentage is higher than the finding in An Giang, a province in southern Vietnam sharing a border with Cambodia, 50% of the investigated wells was found as ‘poor water’ condition to ‘unsuitable water for drinking purpose’ during wet season of 2009 [37]. Moreover, the water quality index was mainly distributed by four contaminants including arsenic, iron, fluoride, and manganese. It indicated that the presence of these contaminants is the barer for accessing to the qualified water use in the daily life of the people in Preal commune and may distribute the nearby communities as well. Comparing the water condition to the groundwater drill depth, the results showed that the groundwater wells classified as ‘Good water’ are attributed mostly to the shallow groundwater depth (data not shown).
### Table 14. Groundwater classification based on WQI with main contaminants.

| WDB ID | Top Three Contaminants Associated on WQI (High → Low) | Condition of Water                      |
|-------|-------------------------------------------------------|-----------------------------------------|
| 5383  | Arsenic, iron, fluoride                               | Water unsuitable for drinking purpose  |
| 5384  | Arsenic, fluoride, iron                               | Water unsuitable for drinking purpose  |
| 5385  | Arsenic, iron, manganese                              | Water unsuitable for drinking purpose  |
| 5386  | Iron, manganese, fluoride                             | Poor water                              |
| 5387  | Iron, manganese, fluoride                             | Good water                              |
| 5388  | Manganese, iron, fluoride                             | Good water                              |
| 5389  | Iron, manganese, fluoride                             | Poor water                              |
| 5390  | Iron, manganese, fluoride                             | Poor water                              |
| 5391  | Manganese, fluoride, iron                             | Good water                              |
| 5392  | Manganese, iron, fluoride                             | Good water                              |
| 5393  | Fluoride, manganese, iron                             | Good water                              |
| 5394  | Arsenic, iron, fluoride                               | Water unsuitable for drinking purpose  |
| 5395  | Iron, manganese, fluoride                             | Water unsuitable for drinking purpose  |
| 5396  | Arsenic, iron, fluoride                               | Water unsuitable for drinking purpose  |
| 5397  | Arsenic, fluoride, manganese                          | Water unsuitable for drinking purpose  |
| 5398  | Arsenic, iron, fluoride                               | Water unsuitable for drinking purpose  |
| 5399  | Arsenic, iron, fluoride                               | Water unsuitable for drinking purpose  |
| 5400  | Iron, manganese, fluoride                             | Water unsuitable for drinking purpose  |
| 5401  | Iron, manganese, fluoride                             | Water unsuitable for drinking purpose  |
| 5402  | Iron, manganese, fluoride                             | Water unsuitable for drinking purpose  |

#### 3.2.3. Spatial Variation of Main Associated Contaminants

Even the most associated contaminants on the water quality index were defined in the previous part, it was counted from each groundwater well in percentage of sub-index compared to water quality index value. Another multiple correlation analysis between groundwater quality parameters and a score of water quality index was determined in terms of Pearson correlation coefficient \([34]\) and \(p\)-value. The result indicates that two contaminants, i.e., arsenic and fluoride, are statically significant \((p\)-value < 0.01\) in contribution to water quality index (data not shown). However, the top five contaminants including arsenic, fluoride, turbidity, chloride, and iron were found as the main associated contaminants in terms of Pearson correlation coefficient \((|R| > 0.18)\).

Considering both results, it can be concluded that arsenic, fluoride, and iron are the main associated contaminants in groundwater on the water quality index. These three contaminants, arsenic, fluoride, and iron, in groundwater were mapped their spatial variation in Preal commune using spatial analyst tool of ArcMap of ArcGIS computer software. Spatial variation of arsenic, iron, and fluoride concentration in Preal commune were mapped in Figure 10. For arsenic, it can be observed that the contribution of its concentration was high at the west and lower contributions to the east of the study area. In the opposite pattern, iron concentration highly distributes at the east and lower to the west side. In a similar pattern to arsenic, fluoride is highly presented at the west and lower to the east of the study area.
Figure 10. Mapping of arsenic, iron, and fluoride concentration in Preal commune.

4. Conclusions and Future Perspective

This study aimed to estimate the household domestic water consumption and assess the groundwater quality in a small rural community of Preyveng province, Cambodia, in order to propose a quantitative information for designing groundwater treatment processes as well as water supply systems for addressing water scarcity in the study area. Therefore, this work was mainly divided into two main parts including the study of household water consumption.
use by conducting a field survey questionnaire and assessment of groundwater quality by collecting secondary data for estimating water quality index and spatial variation map. About household water use, 100 respondents which 60 are female represented 100 different households in Preal commune were randomly selected as the participants for the field survey questionnaire. On average, daily water consumption in Preal commune is about 71 L per capita. Moreover, it can be estimated that more than 80% of the households in Preal commune are facing the water scarcity in terms of water quantity, which may result on the health effect in the study area. Related to daily water use, all residents in this community heavily rely only on groundwater wells for household domestic water use and the household used raw groundwater as drinking water was found up to 56% without treatment process. Due to the importance of groundwater used in Preal commune and their accessibility without treatment, the assessment of its water quality is very necessary for a protection and solution preparation. Available groundwater quality data in a total of 20 wells in Preal commune was used in this study. Based on the water quality index method, about 75% of groundwater wells in Preal commune presented in poor conditions and unsuitable for drinking purposes. Arsenic, fluoride, and iron were defined as the main associated contaminants in groundwater on water quality index. Consequently, the presence of these three contaminants has been considered as one of the major challenges associating with water scarcity in Preal commune as well as many rural communities of Southeast Asia countries.

It is recommended future studied should focus on another recent household water use estimation and groundwater quality assessment in the study area. Moreover, a health risk assessment of the main associated pollutants should be investigated. Finally, a suggestion of comprehensive study of iron, arsenic, and fluoride and the removal from water is very necessary for overcoming water accessibility in the rural commune as well as for addressing water scarcity through groundwater use. The finding of efficient and sustainable treatment technology to improve groundwater quality through the removal of iron, arsenic, and fluoride before consuming may not only be beneficially in respect to Preal commune, but it would be practical, beneficial and meaningful for other rural or semi-urban areas of Cambodia as well as in other parts of the globe.

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