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Private Sector Involvement in Sustainable Piped Water Supply Service: The Case Study of Sustainable Piped Water Supply in Cambodia's Mountainous Area

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Abstract

In Cambodia, 70 percent of the population has no access to piped water, despite 245 private operators licensed to provide this public service. Of the remaining 30 percent that does have access to piped water, Cambodia's mountainous area to the North East has the least coverage and lowest access capability. There is a lack of research that focuses on the factors associated with the piped water sustainability function especially that of private service providers in Cambodia and its mountainous area. To obtain an evaluation of the current performances of piped water supply and its movement towards or away from sustainability, four criteria, adopted from the SWARD guidebook framework, will be employed. Through utilizing this lens, the effectiveness of the piped water supply delivered by private sector in Cambodia's mountainous area can be analyzed. This paper shows that, due to the poor performance of four determinants; economic, environmental, social and technical dimension, piped water services in Cambodia's mountainous region are not operating at optimal levels and fall short of sustainability.

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List of Abbreviations

BOO ..... Build, Own and Operate model
BOT ..... Build Own and Transfer model
DBL ..... Design, Build and Lease model
IDB ..... The Inter-American Development Bank
MIH ..... Ministry of Industry and Handicraft
MIME ..... Ministry of Mine and Energy
NIS ..... National Institution of Statistics of Cambodia
OBA ..... Operate-based Contracts
OECD ..... The Organization for Economic Co-operation and Development
SDD ..... Sustainable Development Goals
SWARD ..... Sustainable Water industry Asset Resource Decision Guidebook
UNDP ..... United Nations Development Program
UNICEF ..... The United Nations International Children's Emergency Fund
WHO ..... World Health Organization

Glossary of Terminology

Private piped water Operators: The private firms who have a license in providing piped water service recognized by Ministry of Industry and handicraft.

Sustainable/sustainability Function of piped water supply: The piped water supply service which operates to ensure demand is sufficiently met in both the present and the future, and satisfies the four key sustainability factors: economic, environment, social, and technical.

I. Introduction

1.1 Overview

Cambodia is one of many countries to have committed to the United Nation's Sustainable Development Goals (SDG), of which goal number 6, focuses it to "ensure availability and sustainable management of water and sanitation for all" (UN, 2017). Globally, three in ten people lack access to safe drinking water (UN, 2018), but when piped water meets the standards set out by World Health Organization (WHO), it is the most responsive intervention to those water-related diseases, thus increasing its implementation should be prioritized. In addition to concerns of global water quality, the sources that the rural population depend on for daily use does not prevent water scarcity during the dry season. In nearly all developing and developed countries, water governance practices rank poor to very poor, and risk causing a water crisis (Asit & Cecilia, 2010).

Ensuring the provision of safe water continues to be problematic across rural Cambodia. The risk of two-fold crises of public health in Cambodia is (1) high reliance on untreated surface water associated with the risks of bacterial contamination, diarrheal diseases, and infant mortality, and (2) significant contamination of shallow groundwater with arsenic associating the risks of arsenicosis and cancer (UNICEF, 2009). The quality of piped water can be more reliable due to its higher microbiological quality over the other sources (Shaheed, et al., 2014). More than 12 million people in Cambodia (70 percent of the population) in 2015 did not have access to piped water (UNICEF, 2018), and to scrutinize the progress of coverage since then, access remains at a low 30 percent. The lowest concentration of licensed piped water operators is in the north-east of the country; the area is categorized as the mountainous region (NIS, 2014). The main challenges of expanding and maintaining clean water supply across Cambodia by the private sector participation are characterized by unfair competition, financial limitation, and lack of technical assistance (Shaheed et al., 2014). In addition to these challenges, there is a lack of access to credit, high investment risk, poor business skills development, and a weak regulatory system (MRD, 2012). Water investment is also required to insure sustainability in investment (IDB, 2016). The key task for water service providers is incorporating sustainability assessment into decision making process (Foxton, et al., 2010).

To achieve this, the mechanisms that lead investment towards, or away from, sustainability must be understood. However, there is little research focusing on the factors associated with the piped water sustainability function, especially in relation to private service providers in Cambodia's mountainous region. Thus, this study will focus on one main research question:

> *To what extent can piped water service delivered by the private sector ensure the sustainable piped water service in Cambodia mountainous region?*

In addition to answering this question, this study will (1) provide information that can assist in expanding piped water services; (2) incentivize piped water supply operators to enlarge their coverage of service; and (3) contribute to available literature on the current operation methods for piped water supply practices associated with the sustainable water supply function. The scope of this research is limited to the private model only, for two main reasons. First, based on the following literature review, it is apparent that the private model is one of the main tools for accelerating the piped water service delivering and second, there is a large presence of private organisations in this public service, yet a severe lack of specific, regional research on the matter.

1.2 Methodology

Multiple methods of data collection are used throughout this study, and include (1) desk review, (2) in-depth interviews, and (3) household interviews.

1. A **desk-review** of relevant reports, journals, and government and non-government publications are the primary source of information used for the literature review. This process

provides insight and understanding of the general overview of piped water services across the globe and in Cambodia.

2. **In-depth interviews** with relevant key stakeholders provide further insight to the information obtained in the desk review, allowing specific questions to be asked. Such interviews were conducted with (1) a representative from the Ministry of Industry and Handicraft (MIH), (2) Village Heads, and (3) Private Operators (two total).

a. **Ministry of Industry and Handicraft:** An interview was conducted to obtain clarity on the role between MIH and MRD; to receive the most updated number of private sector providers in each province; and to gain an overview of the piped water service in Cambodia.

b. **Village Head:** Interviews with the village heads of both sites provided up-to-date information including: total village population; current sources of water; the opinions of the village header regarding piped water service; their relationship with the private providers; public participation in piped water projects; the relationship between provider and client; the degree of villager header involvement and authority; and their opinion on what makes investment sustainable.

c. **Private Operators:** This interview was conducted to further understanding regarding: the way piped water is being operated; the difficulty in investment from the beginning; difficulty in providing service; water tariff and water connection fee; and what makes investment sustainable.

3. Household interviews with 10 households from each site (20 total) provided greater insight into public awareness and opinion of piped water, as well as water tariffs and connection fees. Households chosen for interview were not random, rather, two considerations were made: (1) connected and non-connected households in each village should be interviewed, and (2) distance from the operating site – households close to, and far away from, the operating site were selected.

II. Literature Review

2.1 Brief Overview of Piped Water Service Delivery Governance in Cambodia

Water governance in Cambodia is divided into water management and clean water service provision (Sithirith, 2017). To achieve the coverage of a safe drinking water service, two Ministries – the Ministry of Industry and Handicraft and the Ministry of Rural development – have been tasked with meeting universal clean water coverage as was committed to under the sixth SDG. The Ministry of Industry and Handicraft (MIH) is responsible for water provisioning in urban areas, management of water supply licenses with the purpose of gaining income, and management of water tariffs, water quality and service quality, while the Ministry of rural development (MRD) is responsible for water provision by well in rural areas, but such wells are managed by the community. As identified from data gathered from the key stakeholder interview, piped water utilities are owned by both the public and the private sector. Piped water utility has three models: public ownership, private ownership, and mixed public/private ownership. The private sector model is also divided into four types of business models: (1) Build, Own and Operate (BOO), (2) Build Own and Transfer (BOT), (3) Operate-based Contracts (OBA), (4) Design, Build and Lease (DBL). There are 256 privately-owned piped water providers in Cambodia, 11 of which are in urban areas, with the remaining 245 providing for the rural areas. Additionally, there are 12 and two public-owned operators located in urban and rural areas respectively, and only two with mixed ownership, one each located in Phnom Penh and Siem Reap. As mentioned, total piped water coverage across the country is

approximately 30 percent, with the remaining 70 percent continuing to require pipe-line water supply.

Piped water service failure can be traced to the degree of good governance. Achieving good water governance cannot follow a 'one-size fits all policy', instead, the varying differences form one location to another must be considered, and thus good governance must be shaped on local conditions (Charles, 2006; Neil, 2011).

Study of previous literature suggests water provided by the private sector is often more expensive than if provided by the public sector. This is the situation particularly in developing countries, including Cambodia, (Ciro, 2016). Piped water supplies are less efficient when under public control, as it lacks the necessary competition to ensure efficiency. Additionally, the lack of accountability of the public sector, and community involvement in planning, implementation and management of water supply projects; poor management and sustainability; low quality service and limited service alternatives are also issues with water service provision (ECOSO, 2005).

The Cambodian government began providing water, identified as an economic and social good in the 1990s, under the guise that consumers have to pay directly, or through tax, for receiving a 24 hours, uninterrupted and reliable water service; and the public monopolies operating in water supply were replaced after a decentralize model in delivery service was introduced (Asit & Cecilia, 2010; Clement et al., 2013).

Publicly-owned water, or water under the control of the government is one cause of the unsustainable function. To overcome the flaws and inefficiencies of public water provision, private provision was introduced into the water-provision model. Privatization – a responsive mechanism to the perceived, or actual, poor performance of the state-owned public services – was widely considered when it was realized the private sector could better provide, and better handle, the required resources, particularly finance, expertise, safety, and sustainably (Colin, 2003; Aziza & Céline , 2013; House, 2014). After arriving at this realization, Cambodia's water service delivery was transferred to private ownership to become more effective and efficient.

2.2 Cambodia's privately piped water supply operators

The Cambodian government has acknowledged the importance of private sector participation in providing this public service (Baker, 2009). Some features of the privately-owned piped water service include ownership of hard infrastructure and operation of said infrastructures. The piped water operators can be classified into two levels, beginners, and advance (The World Bank, 2016). "Beginners" are typically family businesses, with weak technical and business capacity and non-specialized staff. Those classified as "advanced" are often semi-professional and have adequate business skills, where many will have specialized staff to manage the technical and business functions.

In 2012, the private sector was estimated to be providing 1.4 million Cambodians with piped water services, and with additional hard infrastructure already in place, had the immediate potential for expansion of existing schemes to provide piped water to another two to three million Cambodian's, (The World Bank, 2016). However, based on key stakeholder interviews, Cambodia still only provides piped water to 30% of the population, suggesting no such expansion has successfully been implemented. The main challenges of expanding and maintaining a clean water supply facilitated through private sector participation are characterized the unfair competition, financial limitations, and a lack of technical assistance (Shaheed et al., 2014). In addition, there is a lack of access to credit, high investment risk, low business skills development, unfair competition, and a weak regulatory system (MRD, 2014). Previous studies emphasize the challenges faced by the private sector in piped water service delivery and urge the public sector to incentivize opportunities to overcome such challenges. However, no research to date has focused on the factors associated with the piped water sustainably function particularly in reference to private service providers in Cambodia's mountainous region. The sustainable water supply business is crucial to be considered in water

supply service since it can threaten the sustainability of existing systems (OECD, 2016). The key task for water service providers is incorporating sustainability assessment into their decision-making process (Foxton, et al., 2010).

III. Methodology, Conceptualization and Operationalization

3.1 Methodology and site selection

This research paper uses a qualitative method, and details findings in the format of a single case study with an embedded units' approach. It considers the influence of the private operators' practices on associated attributes of the piped water supply service's current levels of sustainability and focuses specifically on the sustainability of the piped water service delivered by the private sectors in Cambodia's mountainous area. This research identifies four factors (see framework) that are key to achieving sustainability. These are then employed to Cambodia's mountainous region to determine current sustainability levels.

First hand data is collected through five in-depth interviews with five different stakeholders: two private operators in two of Cambodia's mountainous region villages (Preak Prosob Ler in Kratie provence, and Oam village in Mondulkiri); two village heads; and one representative of Ministry of Industry and Handicraft. The in-depth interview method was used for its ability to facilitate personalized interaction between the interviewer and respondent, allowing for a direct and detailed probing of information, and to allow critical insights to emerge.

In addition to these stakeholder interviews, 20 household interviews were conducted in total, 10 in each of the two villages. Households identified for interview were chosen through purposive sampling. Both connected households and non-connected households were identified for interview: To identify such households, first the water supply operators were asked to specify areas of connected, and non-connected households, and then households were asked to confirm connectivity status. Additionally, consideration was given to the distance of households from the operation site to determine level of service provided: households closer to the operation site require less hard infrastructure to connect to piped water, and water pressure is typically greater the closer to the site the household is.

Site Selection

To determine what locations had access to piped water, an interview was held with a representative from the MIH. This information was then inputted to ArcGIS software to create a map of coverage areas (Figure 1). It is clear from this map that the coverage of piped water service is lowest in northeast region. Two regions were then chosen based on a projection of the coverage area, and presence of piped water operators, thus Kratie and Mondulkiri were the regions chosen for this research.

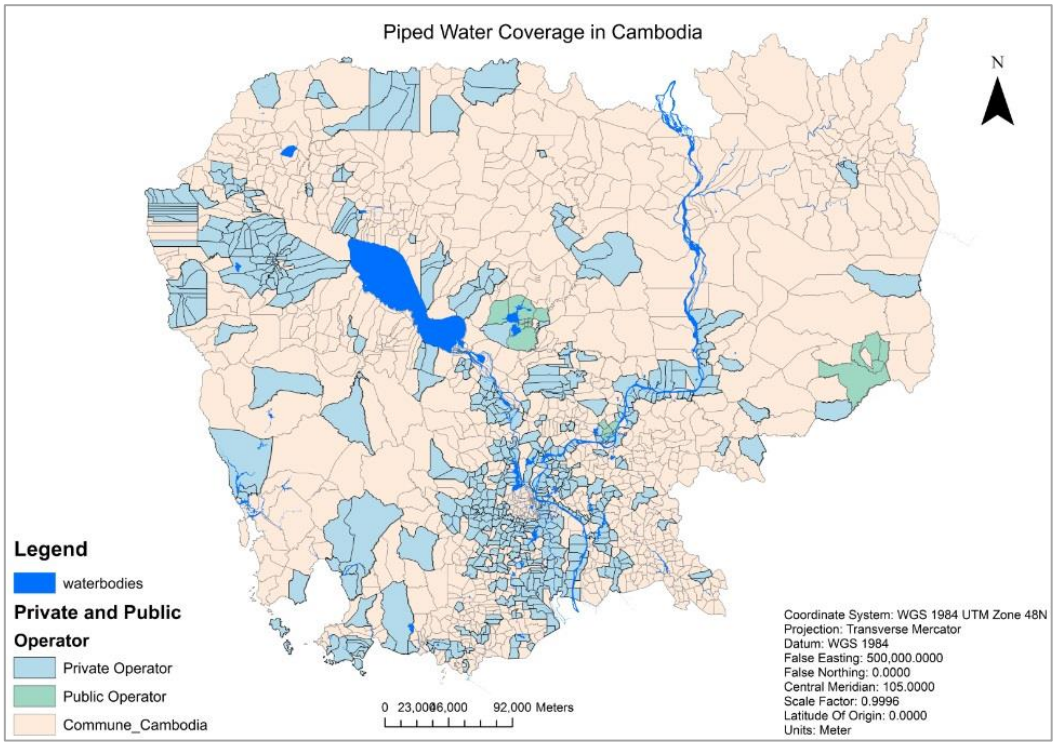
Kratie and Mondulkiri provinces, located in the northeast region, were selected as the key research locations (Figure 2), and from that, two villages chosen, Preak Prosob Ler village and OAm village. These two sites were focused on for three reasons: time in operation, village population similarity, and ability to contact operators.

1. As identified from an interview with the MIH, piped water service providers have been operating in Kratie and Mondulkiri for different periods of time. This allows for an insight of both old and new operators and their move towards or away from sustainability. The provider in Kratie province have been operating this service for longer than the provider in Mondulkiri province.
2. There are 16 private operators in Kratie, and only one operator in Mondulkiri. To identify the operator in Kratie for study, first the population of each village within Kratie was considered. A village similar in size to OAm village in Mondulkiri was identified.

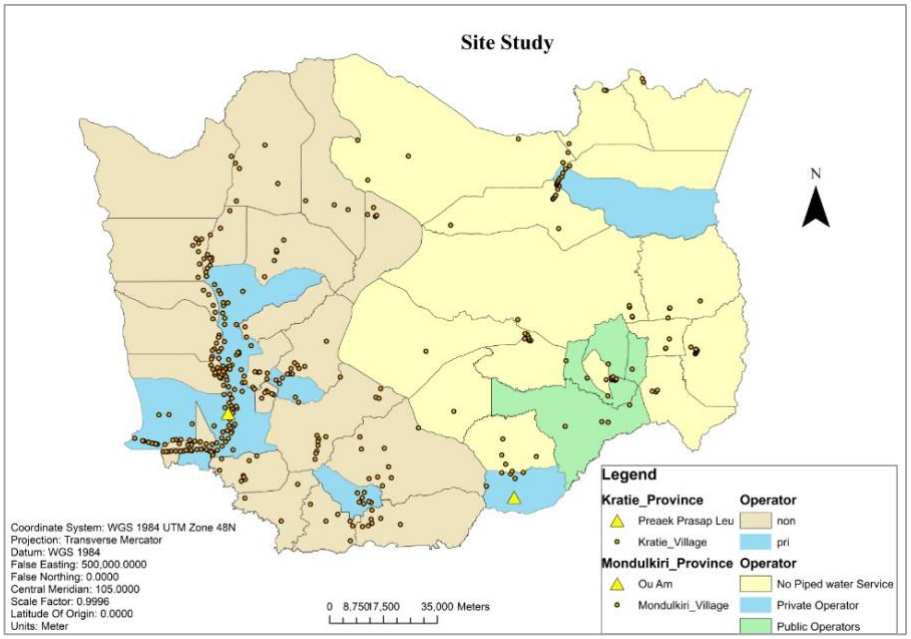
3. Then, of the contactable operators, only one was willing to be interviewed, thus Preak Prosob Ler was chosen for study.

When interviewing both operators, it was realized that the history of their business differed. Particularly, the operator in Preak Prosob Ler transformed their business form water vendor to piped water operator, whereas in OAm, the operator began their business as a piped water operator. This provides insight into the social factor identified in the sustainability framework (referred to in the empirical study).

Map 1: Piped water coverage in Cambodia



Map 2: Kratie and Mondulkiri piped water access by type (none, public, private)



3.2 Conceptualization and Operationalization

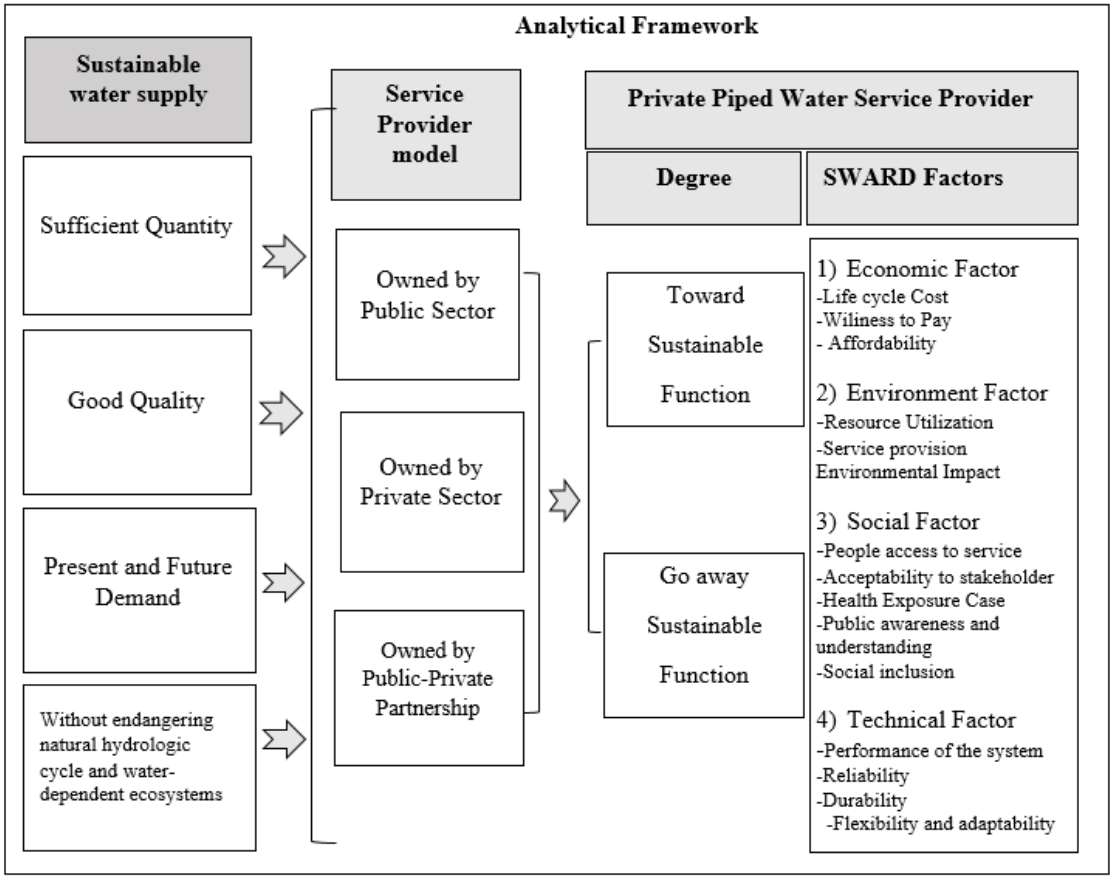
Water governance is defined by United Nations Development Program (UNDP) and Global Water Partnership as a "range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services directly and indirectly at different levels of society" (UNDP, 2011). It concerns the decision-making processes that ensure effective allocation of resources. (Sithirith, 2017). Through these concepts, water governance is divided into two parts: water resource management, and water service delivery, where different players (i.e. public and private sector, communities, local governance) have different responsibilities towards achieving the same goal. The following research focuses only on water service delivery, thus piped water, located inside the user's dwelling, plot or yard. Piped water is a water supply operation system that consists of a set of structured facilities and services that produce and distribute water to consumers; the distributed water must be compatible with the needs associated with domestic consumption, utilities and industrial consumption on both water quality and quantity.

Private sector participation is one model used as a response to the piped water accessibility. According to Ministry of Mine and Energy (MIME), private enterprises operating in the piped water service are classified into four categories, depending on the number of employees and the amount of start-up capital. Those four categories are: micro, small, medium and large.

Involvement of the private sector will accelerate the water delivery service only if the sustainability function of the water supply system is considered. Many definitions of sustainability in broader context exist, but for the purpose of this research sustainability will refer to "the long-term stability of the economy and environment only achievable through the integration and acknowledgement of economics, environmental, and social concerns throughout the decision-making process" (Emas, 2015). Furthering this definition, sustainable water supply refers to the water supply meeting present and future demand to ensure sufficient quantities and is good-quality (drinkable) water without endangering the natural hydrologic cycle and water-dependent ecosystems (Halkijević, 2012).

To operationalize the sustainable water supply service delivery, the SWARD (Sustainable Water industry Asset Resource Decision) guidebook will be used as a framework to evaluate the degree of private piped water supply service toward the sustainable function. This framework consists of four main criteria – economic, environmental, social, and technical – and is used to evaluate the current performance of piped water supply moving towards, or away from, sustainable functioning (Richard et al., 2004). All four factors must be considered to ensure an accurate evaluation.

Figure 1: Analytical Framework



This analytical framework provides a clear lens and direction for an empirical analysis, which is based on both literature and data in order to answer the research stated question. The four SWARD factors are analyzed in the following section using an explanatory approach to empirically examine the sustainability of the piped water service in Cambodia's mountainous area as delivered by private sector.

IV. Empirical Analysis

Primary data will come predominantly from two villages in Cambodia's northeast provinces of Kratie and Mondulkiri. Preak Prosob Ler village in Kratie and OAm village in Mondulkiri were identified for this study (for methods of identification, refer to methodology) Prior to analysis using the SWARD framework to determine the piped water sustainability in each village, village demographics are discussed to provide a clearer background understanding.

4.1 Demographic Information

Water demand will differ on a household basis depending on the number of occupants within each household. The maximum occupancy rate in the sample size is 13 persons; the minimum is 1 person, and average is 5 persons.

Income is another important factor when determining water demand. Household income has been determined by aggregating all occupants' earnings within one household. In Preak Prosob Ler Village, the maximum household income recorded is 14,550 USD; the minimum is 1,200 USD; and the average is 275USD. In OAm Village, the maximum is 19,000 USD, the minimum is 1,800 USD and the average is 7,580USD. To compare the households'

income based on water user group (e.g. well, river, mix sources), the households using piped water as main water source do not have the highest income, despite previous literature suggesting only wealthy families choose to access piped water.

Figure 2: Total income per year and by village

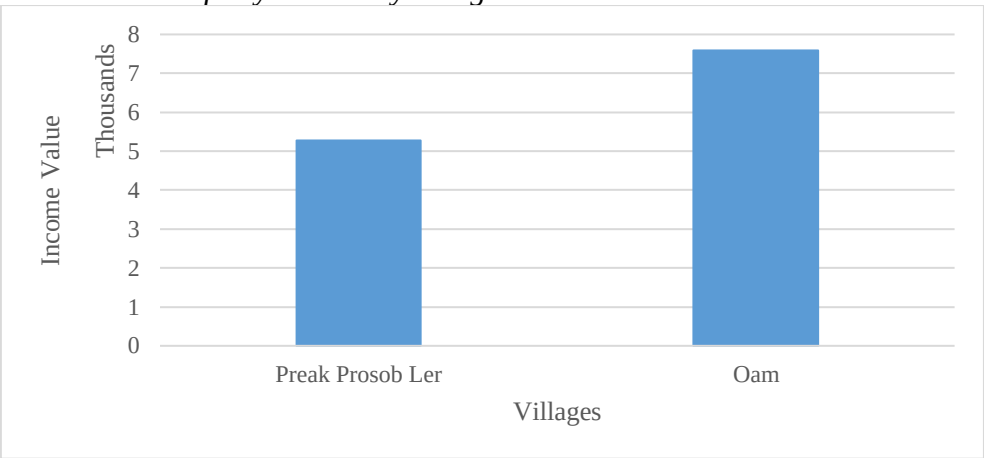
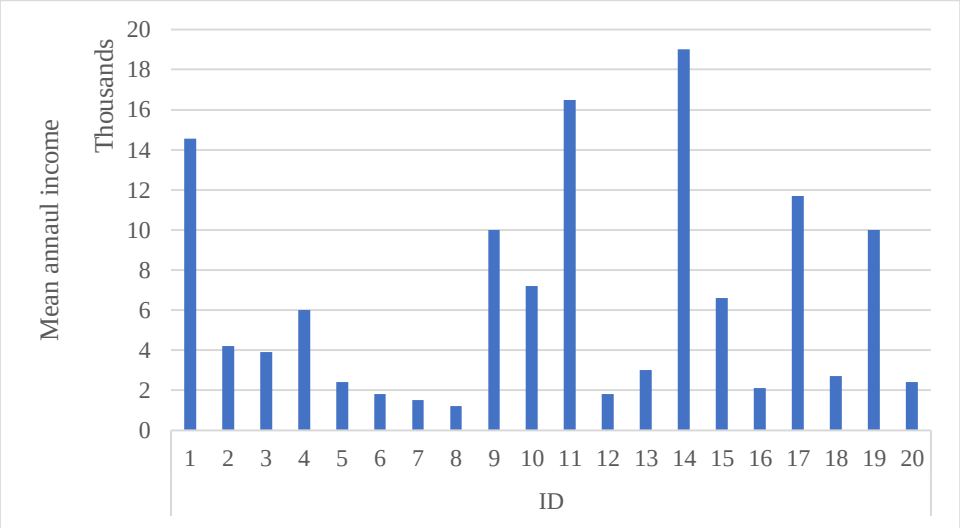


Figure 3: Mean income for total sample



Education is a key factor in the perception of piped water. Based on the literature, those with a higher education typically prefer piped water, due to the understanding that it of superior quality in terms of reliability. To determine the educational achievement of each household, the highest achievement level was documented. The respondents in Preak Prosob Ler village and in OAm village have similar educational achievements, with 4 households obtaining a basic primary education, and 6 households graduating from secondary education. Only one household member in the household interviews graduated from university. Figures 4 and 5 provide greater insight into education levels of those interviewed.

Figure 4: Education level in household by villages

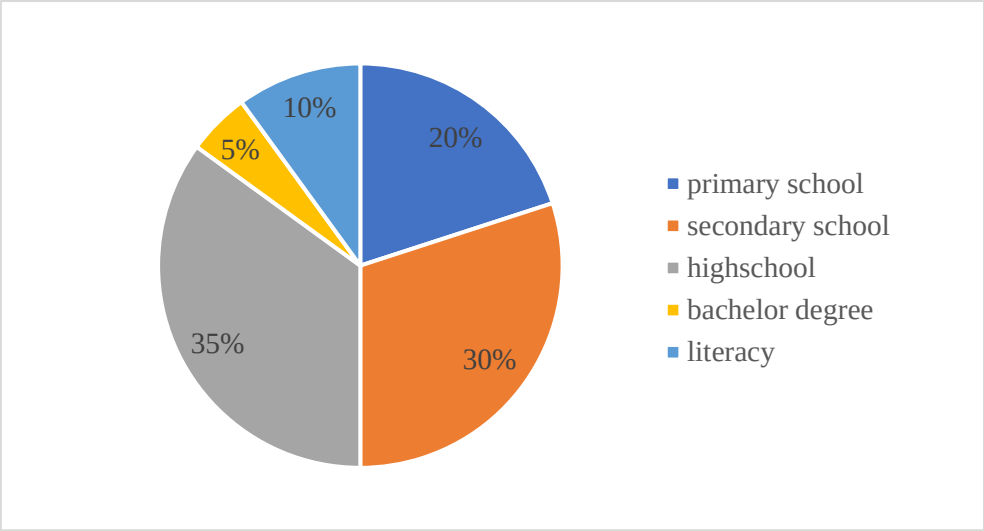
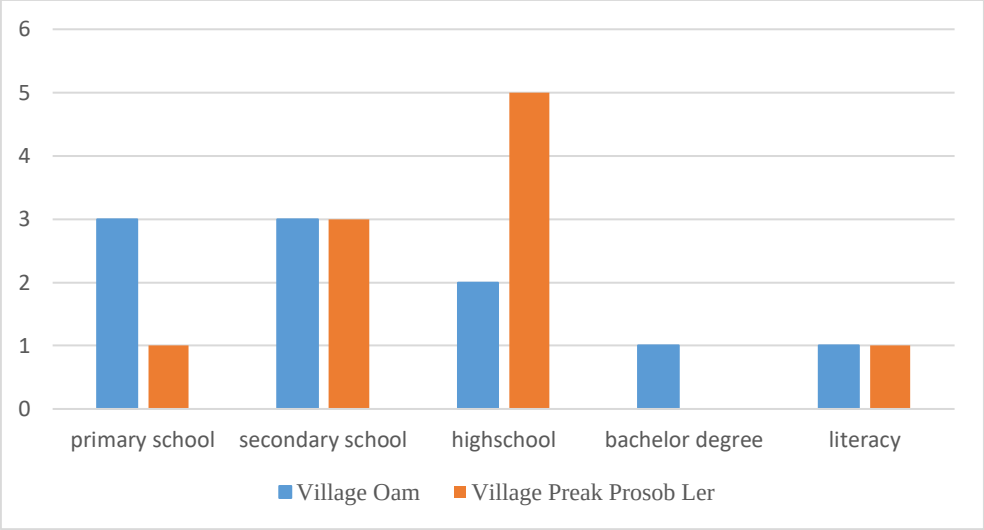


Figure 5: Education level in village



To compare education and water user group, the piped water user group has higher education level as seen from the finishing in bachelor's degree.

There are five sources of water used for domestic purposes in both the rainy season and the dry season: (1) piped water, (2) well, (3) rainwater, (4) portable water, and (5) bottled water. Portable water and bottled water are mostly used for drinking purpose as they are generally cleaner and safer for consumption. Most households source their water from a mix of these five sources. For the purpose of this research, the water sources used by respondents are divided into the following water user groups. In both seasons, the respondents living in Preak Prosob Ler are divided to 4 groups:(1) rainwater and piped water user group, (2) rainwater user group, (3) piped water and piped water user group, and (4) portable water user group. In OAm village, the respondents are divided to 6 groups:(1) piped water and portable water user group, (2) well and portable water user group, (3) piped water user group, (4) piped water and bottled water user group, (5) well and rainwater user group and (6) piped water, well and portable user group.

4.2 Two case studies on the current status of piped water supply

Site study 1: Preak Prosob Ler village

Preak Prosob Ler is one of three villages in Preaek Prasab commune in Kratie province. Based on the data provided, via face-to-face interview by the head of the village, there are a total of 367 households in the village. The sources of water used for domestic purposes is piped water, well, rainwater and portable water. In Preak Prosob Ler village, the formal piped water supply is owned privately by only one operator.

This operator has been involved in the water business for approximately 10 years: eight initial years as a vendor (providing raw, untreated water from sources including river and ponds) and now two years as a formal small-scale piped water operator. The operator's license covers two villages in Preak Prosob Commune, Beoun Leach Village and Preak Prosob Ler Village. In the two years of operating as a piped water supplier, 210 households have been connected to utilize the service. This equates to 57 percent of households in the village that are now connected to piped water service. As the site's location is situated along the Mekong River, there is sufficient quantity of water to be for the piped water delivery. According to the private operator, the quality of the sourced water is good.

Site study 2: OAm village

OAm village is in Srae Khtum Commune of Mondulkiri province. There are 724 households in the village, who mostly depend on water from a well and rainwater collected in large clay pots.

There is one supplier of piped water in the village, and despite only receiving their license in 2016, the operator had been supplying piped water for two year prior (from 2014). In 2016, the operator received their license allowing them to cover six villages in Srea Khtum commune, but currently, due to insufficient financial resources, only the households in OAm villages are connected to piped water. 330 households in OAm village have been connecting to piped water since 2014 (less than 50%), but there have been no additional households connected since then despite a feasibility report undertaken by a third party suggesting the existence of higher demand.

4.3 Sustainability Framework

This framework consists of four main criteria: (1) economic (2) environmental (3) social, and (4) technical. These four criteria are used to evaluate the current performance of piped water supply moving towards, or away from, sustainable functioning. All four factors must be considered to ensure an accurate evaluation.

1. Economic Criteria

There are three criteria for economic sustainability (1) life-cycle cost, (2) wiliness to pay, and (3) affordability.

Life Cycle Cost

Life-cycle cost is the associated costs of ensuring adequate water, sanitation and hygiene (WASH) service to a specific population, in a specific area, indefinitely; it includes the cost of constructing new systems, and short- and long-term maintenance costs. Although

life-cycle costs cover all associated costs (i.e. initial investments, infrastructure costs, maintenance costs), adjustments to the identified framework used in this research resulted in information gaps, and only average monthly expenditure was captured. However, during their interview, both operators reported one of the reasons for the low-cost recovery (operating and maintaining cost), especially during Cambodia's wet monsoon season, is low consumer demand, despite data collected during household interviews showing demand remaining high throughout the year (table 1). Piped water demand in Preak Prosob Ler is approximately 78.36 liter per person per day in dry season, and 78.36 liter per person per day in Rainy season. In OAm village the piped water user group demand for piped water approximately accounted for 123.47 liter per person per day and 123.47 liter per person per day in dry season.

Table 1: Water Demand

Village	Rainy Season			Dry Season		
	Water User Group	**Water Demand Per Person Per season (L)**	**Water Demand Per Person Per Day (L)**	**Water User Group**	**Water Demand Per Person Per season (L)**	**Water Demand Per Person Per Day (L)**
Preak Prosob Ler	Rainwater & Piped water	11,895	66.08	Rainwater and Piped water	12,061	67
	Rainwater	15,000	83.33	Rainwater	20,000	111.11
	Piped water	14,106	78.36	Piped water	14,106	78.36
	Piped water & Portable water	5,560	30.88	Portable water and piped water	19,048.66	105.82
OAm	Piped water and Portable water	4,061.44	22.56	Piped water and Portable water	8,597	47.76
	well & Portable water	11,656.5	64.75	Well & Portable water	7,800	43.33
	Piped water	22,225	123.47	Piped water	22,225	123.47
	Piped water & Bottled water	15,202.5	84.45	Well and bottled water	21,000	116.66
	well and rainwater	21,192.83	117.73	Rainwater & Well	21,192	117.73
	Piped water, well and portable	11,656.5	64.75	Well & Portable water and Piped water	13,155	73.08

Table 2: Operator's monthly expenditure

Expenditure per month	Preak Prosob Ler Village (USD$)	OAm Village (USD$)

Staff	300	450
Chemical cost	120	200
Energy cost	125	500
Maintenance	25	N/A
Total	570	1,150

Another issue identified by operators in both villages is irregular payment from the consumers, where they estimate approximately 30 percent of their total consumer base fail to make regular payments.

Willingness to Pay

Wiliness to pay for clean water (not necessarily piped water) was determined by asking each respondent during the household interviews what their maximum price limit is for piped water. Unfortunately, willingness to pay could not accurately be determined, as responses from those interviewed represented a lower willingness to pay than what was being paid by each household. Instead, inferences are made from the data to understand *ability* to pay.

Figure 6: Water spending and demand during dry season in OAm village

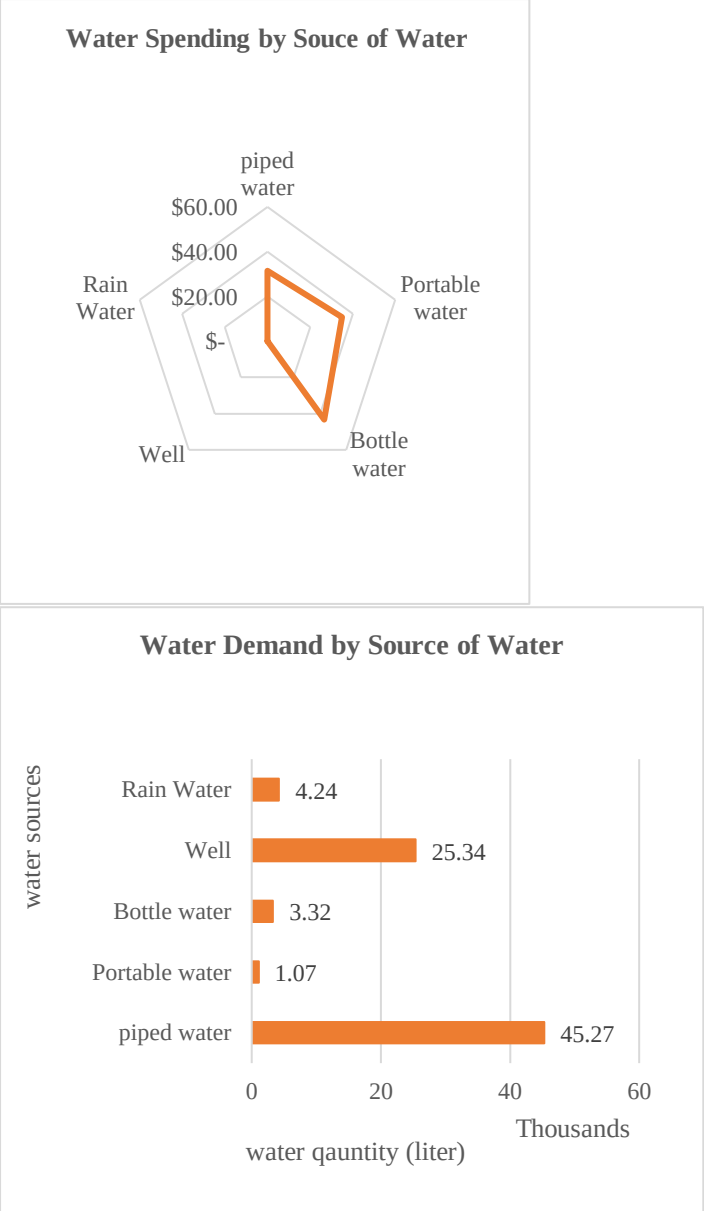
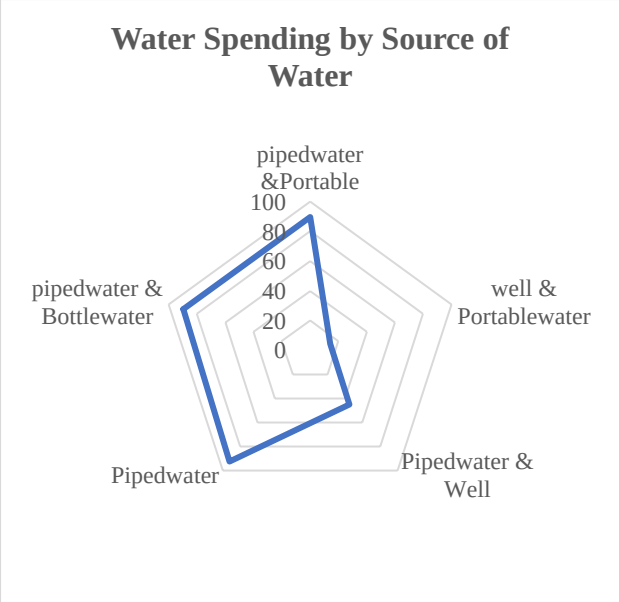


Figure 7: Water spending and demand during wet season in OAm village


Water Spending by Source of Water
pipedwater &Portable
100
80
60
40
20
0
well & Portablewater
Pipedwater & Well
Pipedwater
pipedwater & Bottlewater

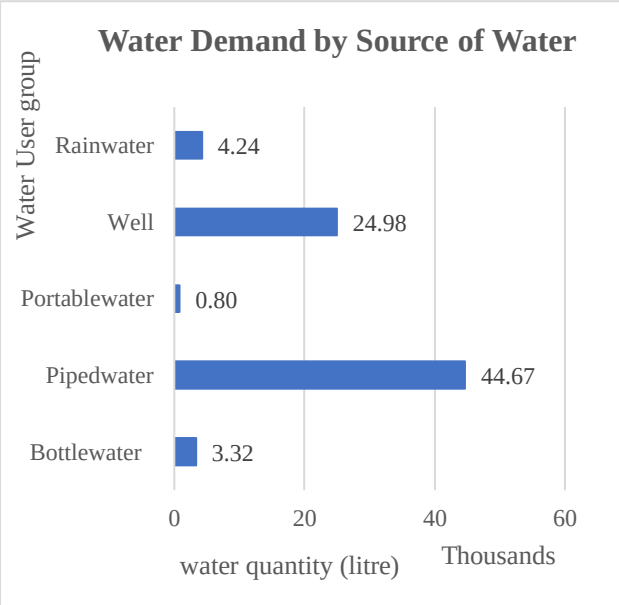
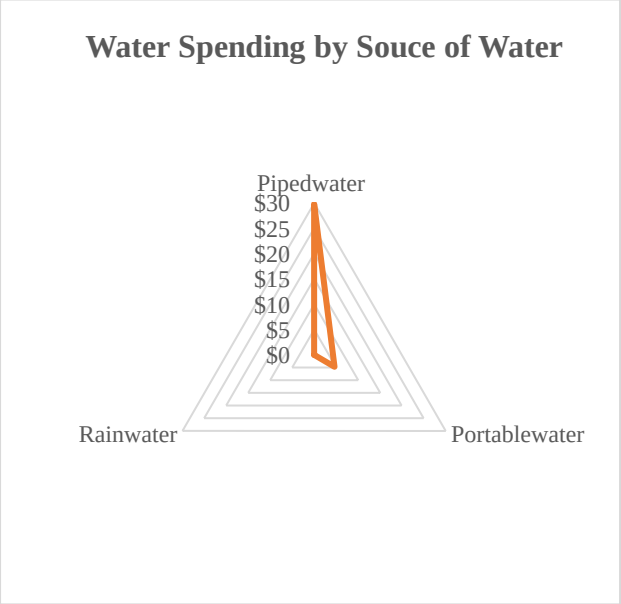

Water Demand by Source of Water
Water User group
Rainwater
4.24
Well
24.98
Portablewater
0.80
Pipedwater
44.67
Bottlewater
3.32
0
20
40
60
Thousands
water quantity (litre)

Figure 8: Water spending and demand during dry season in Preak Prosob Ler Village



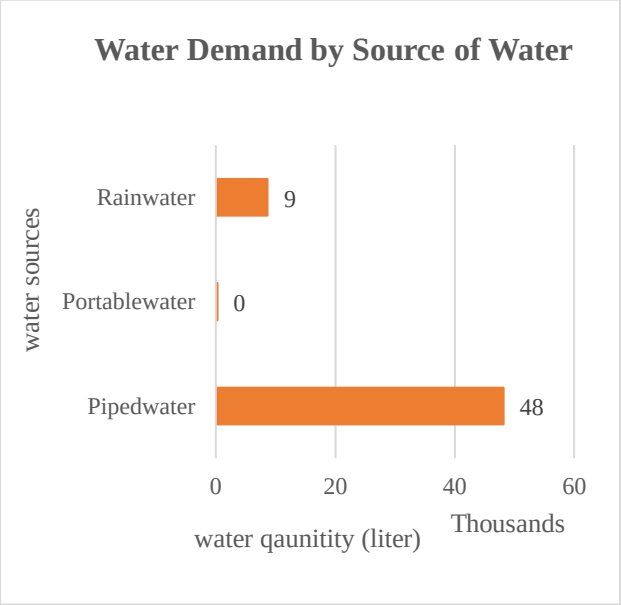
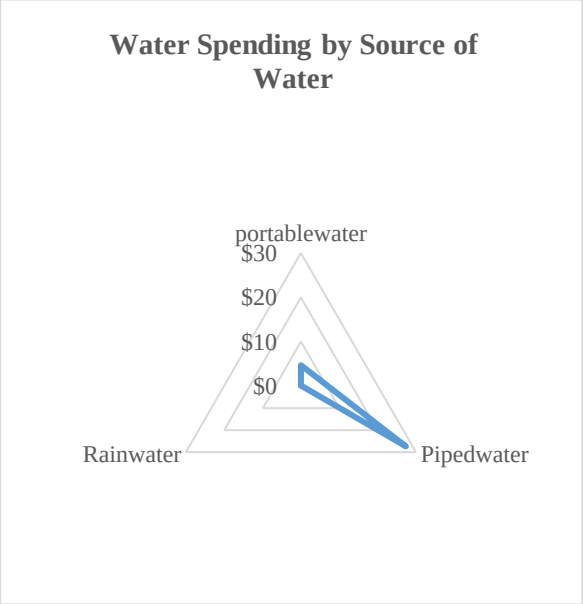
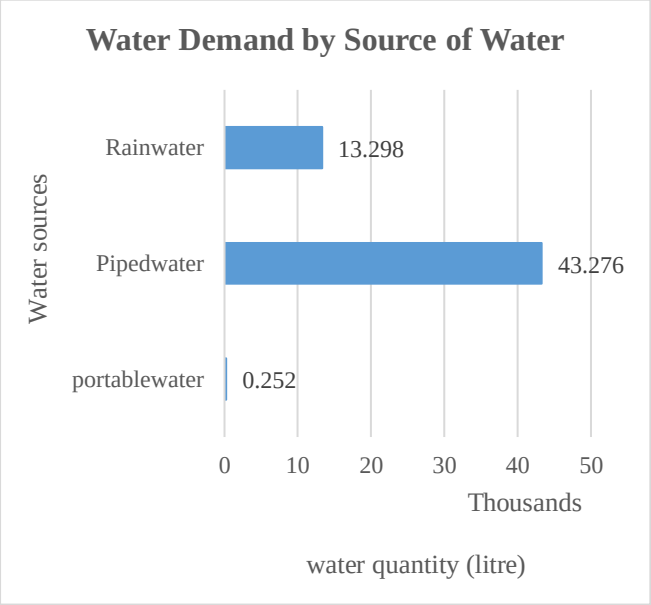


Figure 9: Water spending and demand during wet season in Preak Prosob Ler Village





Affordability

The last economic criterion is affordability, which is sub-divided into two categories: water tariff and connection fee. The water tariff of Preak Prosob Ler village is a flat rate 6 cents (2400 Riel) per cubic meter. OAm village is slightly lower, charged at 47 cents (1900 Riel) per cubic meter if the total water consumption is below 4 cubic meters, and charged 57 cents (2300 Riel) per cubic meter if the total water consumption is higher than 4 cubic meters. The question was asked directly to the consumers during the household interviews about how much piped water they felt was affordable to them.

More than half of all respondents reported they can afford the set price as stated above, but approximately 40 percent of all respondents connected to piped water ask for reduction the price. On average, they requested a price reduction ranging from 25 cents (1000 Riel) to 50 cents (2000 Riel) per cubic meter. Approximately 40 percent of respondents connected to piped water reported a general disagreement to the costs of piped water, suggesting it should be

lowered to the range of 1000 to 2000 Riel, or equal to 0.25 to 0.50 USD, despite continuing to pay for more expensive sources (bottles/portable water)

It can be difficult for operators of piped water when they first begin trading, as economies of scale are low due to low client numbers. Thus, determining cost and profitability, while understanding affordability and willingness to pay of the customers, can be challenging. In Preak Prosob Ler village, piped water materials including water meters, and hard infrastructure (e.g. pipes within the home) are fully paid for by each household, but the operator will connect the household to the main distribution point for free. In OAm village, households are charged USD 60 (240,000 Riel) which covers: 10 meters of pipe (anything beyond this must be paid for by the household) connected from the main distribution, water meter installation, and connection service. Additionally, there is a cost of USD 10 (40,000 Riel) for a refundable deposit, which clients can obtain after the cost of water connection has already been paid. In exceptional cases, poor households can avoid these upfront costs, but will be charged an additional one cubic meter every month until they stop using piped water service. This largely results in poor households paying more for piped water in the long run. The barrier for many households wishing to source piped water is the large connection fee, as they are not necessarily deterred by the water tariff.

2. Environmental Criteria

There are three primary environmental criterions to be focused on (1) resource utilization, (2) environmental impact, and (3) service provision.

Resource Utilization

In Preak Prosob Ler village, piped water is sourced directly from the Mekong River. The operator in this village informed that the total water demand from villagers during the wet monsoon season is 1,000-meter cube per month, except in dry season, where demand is twice as much; the Mekong River does not deplete during this higher period of demand. In OAm village, however, the water resource is not as reliable - the operator sources water from three different locations. During the wet monsoon season, a small pond, located close to the treatment plant, is used as the primary source, but during the dry season, the pond shrinks significantly in size, thus is difficult depend on. In this case, the operator sources water from a lake far from the operating site, and sometimes from a well. Pumping water from both the well and the lake, which are further from his operating site, involves greater costs.

Conditions in both villages is not a concern for piped line design in terms of slope and elevation, but construction on the road post pipe placement has damaged much of this hard infrastructure, impacting the distribution process and water quality. This can result in increases to non-revenue water quantity due to leaking and damaged pipes. The distance from one house to another can also be problematic to deal with; large distances require additional hard infrastructure, and thus further investment from the operator.

Environmental Impact

Water source protection must also be considered from the perspective of the effluence from the piped water system. The current method for backwashing the system is impactful to the water resource – the use of chemicals and their incorrect disposal back into the Mekong River in Preak Prosob Ler village, and the pond in OAm village harm water quality. Based on each operator's description of their own systems, there is no sludge management or treatment before releasing the wastewater from system back to the source of water. During an interview with the operator from Preak Prosob Ler village, there was no mention of sludge management treatment. In a third-party feasibility study report, however, there are clear infrastructure guidelines for this, suggesting the operator is unaware of the correct treatment process.. Because the Mekong River is not a closed water source, the quality of water extracted for

consumption is not of high concern[1]. In OAm village however, the water source is a closed system, thus the chemicals dumped into the pond present a concern when extracting water for consumption.

Service Provision

The last criterion concerning the environment is the service provision. The operators in both villages claim that the water is able for delivery 24 hours a day, unless the electricity is cut off or there are leakages in the pipes. However, more than half of the respondents reported that water is not accessible as often as this. In Preak Prosob Ler village, some of the respondents and the village head claimed that the water is closed regularly from 9 pm until in the approximately 7 am the following morning, and even when water is available, the pressure is weak. In OAm village, there are issues regarding the quantity of water, which is insufficient during the dry season, particularly when the water is cut off.

3. Social Criteria

These criteria include: (1) access to, and quality of, the water service, (2) stakeholder satisfaction, (3) public understanding and awareness, and (4) social inclusion.

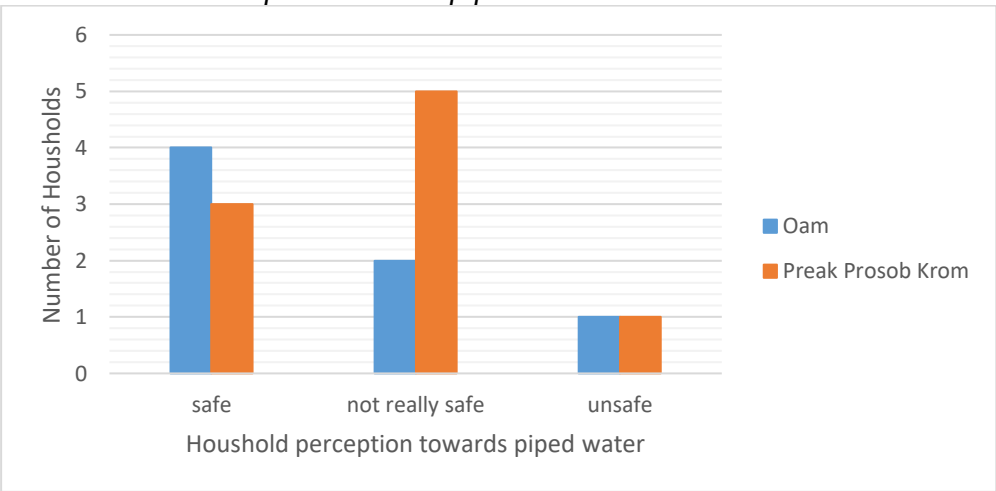
Access

According to both village headers, the percentage of people with access to piped water is less than half of the total number of households in each village. Some respondents reported they stopped using piped water because of water- related diseases. Though village headers and operators do not believe sicknesses in the village are a cause of the piped water supply, there is little available healthcare data to confirm either suspicion.

Stakeholder satisfaction

Village population and village head satisfaction in both OAm and Preak Prosob Ler village is not high (figure 10). The reasons for this are (1) water from the tap sometimes contains the dirt, moss and other particles and (2) it is not clear. The respondents also request operators to improve the water treatment process and the water storage.

Figure 10: Consumer Perception towards piped water service



[1] This study recognises that, whilst chemicals in the water are not of large concern in Preak Prosob village, their environmental impact further down the system is of concern.

Public Understanding and Awareness

Considering public understanding and awareness, both communities still require sound public awareness related to health and clean water. Less than half of the respondents have received any training about clean water and public health. Many households do not believe piped water operators are filling a gap in providing such a service, rather they view them as businessmen charging high prices for and important commodity.

Many households connect to piped water through choice, but some use piped water as they have no alternative – building a well is a burden on finances, time, and labor. The perception of non-connected households to piped water compared with their own water source is that piped water of their neighbors is better quality than theirs. However, connected households do not necessarily trust the water quality provided by the operators. In the OAm village, unconnected households sourcing their water from a well hold the perception that only groundwater can provide good water quality.

Social Inclusion

Information regarding piped water investment in both villages is made available to all consumers and other stakeholders, via pinned notices in the commune offices, however it is not presented in an accessible form, thus villagers struggle to gain sufficient insight., In the case of Preak Prosob Ler village and OAm village, the operators spread the information to the household about the piped water service, and make themselves available to any answer question or concern households may have. This is the extent of public engagement and inclusivity prior to investment; neither villages have a sound public engagement policy. Based on the villagers' perceptions, they all demand to have an inclusive public engagement to enable their voice to be heard for the water project improvement since its benefits not only belong to the provider but to the client as well. Additionally, they demand to have greater female participant in the engagement as women play a vital role in the family household, and thus are better positioned to represent the customers' demands.

4. Technical

These criteria focus on the: (1) performance, (2) flexibility, and (3) adaptability, of piped water supply.

Performance

Performance focuses first on water quality. Through the household survey interview with the villager heads, it is apparent the water quality does not yet satisfy the needs of the consumers. They believe the operators do not comply with drinking water quality standard of Cambodia permitted in 2004. In both villages, there is no test of raw water prior to confirming a water resource to be used, and the frequencies for water testing do not follow the guideline as set out by the MIH. Adequate water quality is required to have a routine testing (Pedro, 2017) to ensure it meets the required standards. In the MIH guideline, operators are required to undertake sampling frequencies for residual chlorine parameter and physical parameters everyday (appendix 4.) The operator in Preak Prosob Ler village confirmed during an interview that he does not undertake this testing – water is tested every three months when a MIH officers requests the operator to collect water for testing off-site. Testing does take place in OAm village using a water testing kit to test pH and CL concentration, but the testing frequency is irregular and does not test at and all physical parameters. Operators in both sites depend on the testing results from MIH, which occurs tests every three months. However, the sampling method conducting by the MIH public officer in Preak Prosob Ler village does not follow MIH guidelines (see appendix 4), the public officer requests water samples to be collected and stored

in a 0.5liter plastic bottle, which is used to transport the water to the MIH for testing. To base on MIH guideline, different parameters require different type of containers (e.g.: microbial parameter requires glass container). The preservation of parameters is vital, and each parameter must have proper preservation.

As per the MIH guidelines, onsite testing should occur to test for parameter such as pH, turbidity, residual chlorine and color. The guideline requires that samples from remote areas to be tested to determine chemical and physical parameters should be taken from both the water source and the distribution point, e.g. tap; however, both operators confirmed they only obtain samples from the distribution point.

As discussed previously, poor operator performance is witnessed when chemicals used during the backwashing process are dumped back into the water source. Additionally, operators do not correctly manage the river bank in Preak Prosob Ler, where waste such as plastic is an increasing issue. Increased enforcement from the MIH is required to prevent these wrongdoings.

Flexibility and Adaptability

The operator in OAm village has superior flexibility and adaptability to the operator in Preak Prosob Ler Village. The operator in Preak Prosob Village does not have enough land to extend the water supply operation system in the event of increased demand. The operator in OAm Village has enough land for expansion. The operator in OAm Village displays adaptability with their water source as they are often required to draw from more than one source.. They have also already completed pipeline construction across the whole village, while the operator in Preak Prosob Ler is yet to do so, though plans are in place for this. The Operator in OAm village installed high quality pipes from the beginning, whereas in Preak Prosob Ler, the choice to use poor quality pipes has resulted in many now needing replaced.

V. Conclusions

Data gathered from Kratie and Mondulkiri province enhances the understanding of the challenges faced in piped water investment and whether the piped water operator can function in the long run towards, or away from, sustainability. Based on the criterions in the framework, piped water supply by operators lags far behind the long run functioning, moving away from sustainability. The weakest of those four criteria (economic, environment, social and technical), tend to lead to negative output of the water supply investment and worsen the service to the community. Between those four criteria, technical and social have an influence on the output of other criteria, environment and economy. The social criteria, especially the lack of accessing information and absence of social engagement, gives a negative impact to the economic criteria. In limitation in technical criteria, the output related to environment and the economic presented in undesirable. The critical issue is to ensure that decisions consider those criteria, otherwise the sustainability implication of piped water supply service cannot be delivered by private operator.

VI. Policy Recommendation

Cambodia has a vision and commitment to meet the target of providing safe water across Cambodia by 2025[2]. To meet this vision, piped water is one key to ensure the quality and accessibility in sustainability. In achievement on the piped water supply, the government should focus on private sector involvement, in order to accelerate this service. other policy recommendations are as follows:

[2] As identified in an interview with a representative from the Ministry of Industry and Handicraft

6.1. Ensure compliance of private operators on water quality, accessibility and source protection at the service provision level:

Currently, operator practices are not in compliance with the Prakas on Clean Water standard and Guideline on Water Safety Plan. Piped water supply interruption across Cambodia can occur during plant maintenance. During this time, households connected to piped water cannot receive an adequate supply of water to meet their demands. Additionally, the water quality is not acceptable to all customers and the lack of compliance by operators can lead to insufficient quality and quantity of water. To overcome this, the Ministry of Industry and Handicraft should enforce the guidelines more strictly and hold the operator accountable for failing to conduct adequate water testing but should also provide training and support to help them overcome this issue. Additionally, operators should follow standardized protection practices when drawing form raw water sources.

6.2. Ensuring the compliance of state-agency on water quality Surveillance

The water supply is monitored by the state agency, yet quality surveillance continues to fall short of requirements. Water quality surveillance should be made compulsory following the guidelines on water sampling, and ministries should enforce operators to keep records of important data, and to share this data with the relevant authorities.

6.3. Inclusive community engagement

There is an asymmetry of information between the community and operators regarding water fees, connection fees, and the role of the government, authorities, and operators in solving any problems related to piped water (i.e. quality, quantity, and prices of water). Informing and engaging the community is one way to minimize this asymmetry and will help understand the willingness of people to use the service and assist in strengthening the relationship between operators and the community. Community engagement should be introduced in the pre-stage of the project, and the State should act as a facilitator between the operator and the user.

6.4. Delegating the role of problem solving in piped water service to the Private Sector

Local government have a key role in ensuring the effective provision of this public service, however, the current system for filing complaints results in an ineffective back and forth between local and central government. Role clarification is a critical tool in collaboration which can lead to sustainable high performance and faster response to any problems. The local government should delegate the task to the private operator in solving any concerns more directly to the user. The issue related to the water service provision should follow the accountability between the operator and consumer, helping reduce the length of time taken to tackle an issue, and increasing the effectiveness of a solution.

6.5. Financial and Technical Support

Technical support continues to be an issue in piped water service. It not only covers how to build, operate and fix the piped water systems, but involves the technical skills in investment too. However, there is currently no consistent monitoring and evaluation system in place.

Finance is another key challenge that operators struggle with. One of the ways is the DBL (Design-Build-Lease) model which shall can introduce financial assistants to the private operator for undertaking the water supply system construction. It is recommended to be the role of state to find suitable partners or NGOs to lead money without interest rate for water supply system construction to help incentivize the private operator to mobilize their capital for the rest of business.

6.6. *Raising Awareness in promoting and understanding the clean water usage*

Review of current literature suggests most communities that decide to use piped water do so due to its quality, but also because there is little alternative. Though not without its own flaws in quality (as discovered from both site studies), it is generally considered a superior source of water in terms of quality. 7 households in Preak Prosob Ler Village and 9 households OAm Village have never had any education or training relating to water and health issues, which reduces the willingness of households to undertake piped water supplies. This should be a role to state agency, for example the Ministry of Health, Ministry of Industry and Handicraft and Commune and District Commune, and NGOs in supporting the operator through provision of relevant education to the village.

Appendices

Appendix 1 "Questions for local authority (Head of Village)"

1. Name, age
2. How many years have this village got access to piped water supply?
3. Before having piped water, what kind of water source did the villagers use?
4. In your perspective, how have your village changed after having piped water supply?
5. Do you know the price of water fee and water connection?
6. Have you joint in making decision on water tariff and water connection fee?
7. Since the piped water became operational, what kind of activity have you joint?
8. Were the village invited to join in making decision in this water project?
9. If so, what do you this about the environment in the meeting between operator and villagers?
10. Are there any conflict between operator and villagers? If so, what are they? How could you deal with that?
11. What are your suggestions to ensure the sustainability of piped water supply project?

Appendix 2 "Questions for Private Operators"

1. Name, Duty, Year of involvement in this water project
2. Describe about the process of requesting license and water business
    - Starting time of requesting to the ending time of requesting?
    - What kind of processes have you been through?
    - What problems did you have in requesting process?
    - How did you deal with those problem?
    - Did the community join in the project for making decision? If have, which phase?
    - What is the type of your business? (BOO, BOT…)
3. When did you receive the license and permission for this business?
4. When have this project started?
5. How many villages do this project cover? What are they? How many households connect to piped water in each village? **(*request for document)**
6. How much the water can be produced (m3) per day?
7. Which water source do you use?
    - Why did you choose that source?
    - Before that water source was chosen, did you do any testing related to water quality? **(*request for document)**
    - What issues do you have related to this water source? What are your solution?
8. Which energy source do you use?
    - Why did you choose that energy source?
    - What issue do you have related to the energy? How can you deal with those issues?
    - How much do you spend for energy? **(*request for document)**
9. What are the major problems in water supply project (from the designing scheme to operating scheme? How do you deal with those problems?
10. Did the villagers participant in making the decision or make an agreement before the water fee and connection fee are set? Water fee? Water connection? Is the water fee paid regularly? Is the water fee sufficient for maintaining the business?
11. When do you expect to recovery the initial cost? How?
12. Have the relevant ministry or provincial level come to monitor this project? If so, what did they monitor? **(*request for document)**
13. Did you have the conflict or issue with the user? If so, what are the issues? How do you deal with? Are there any intervention from local authority?
14. Are there any issue in term of service? How do you respond to that issue?
15. Do you get any supporting from the ministry or any stakeholders (in terms of capacity building or finance)?
16. What are the benefit do you get from this project?
17. In your perspective, what are the suggestion for the operating of the existing water supply project?

    ***Requesting for feasibility study report
    ***Requesting for expenditure and income statements
    *** Requesting for water testing document
    ***requesting for water treatment plant

Appendix 3 "Questions for Household"

Household Questionnaire

My name is…….I am a young research fellow from Future Forum focused on public policy and research. This questionnaire is meant to assess the determinants of community participation and factors affecting sustainability piped water supply, and thereby making invaluable contribution towards the future development, management and sustainability of piped water supply schemes. To that effect, I would like to assure you that all information gathered will be used solely for the study purposes and the identity of the community members, who share their view, or that of any individual within the community and organization will be confidential. If you have any question, you can raise for clarify.

Code questionnaire .....Name Interviewer .....
Date ..... Stating time ..... Ending time .....
village..... Commune.....District .....Province.....

I Information about interviewee

1.1 Name.....age.....
Gender 1. Male 2. Female Contact number:.....
1.2 How many year have you been living here?.....
1.3 How many member do your family have? **.....**
1.4 What is your ethnic group?
1.Khmer 2 ethnic group
*if you are not Khmer, what is your ethnicity?.....

II Socio-economic Information

2.1 Main job …… Secondary jobs…….

Name	Sex	Age		literacy	Job	Income per month	Income per year

***Choose the choice below to complete**

- **In family** 1. Husband 2. Wife 3. Son/daughter 4. Parents 5. Parents in law 6. Son/daughter in law 7. Grandparents 8. Grandson/daughter 9. Head of family 10. Other (**specify)**
- **Literacy** 1.illiteracy 2. Kindergarten 3. Primary school 4. Secondary school 5. High school 6. Bachelor 7. Master 8. Can read only 9 other (**specify**)
- **Job**: 1. Stay home/Housewife 2. Student 3. Government officer 4. Employee 5.labor worker 6. Own small business at home 7. business 8. famer 9. Retired 10. Other **(specify)**

III. **Water source and Water usage**

3.1 water source sung for drinking

Rainy season						Dry Season					
Water source	Rating	Qauntaty		Expense		Water source	rating	Quantity		expense	
		Per Family	Per person	Per family	Per person			Per fmaily	Per person	Per family	Per person
total						total					

***choose the choice to complete**

- Water source: 1. Pond 2. Well 3. Rainwater

4. Bottle water 5. Buy water from vendor 6.Piped water

- Rating: 1. Rarely 2. Sometimes 3. Often

3.2 Do you treat the water before drinking?

. Never 1. Every time 2. Sometimes

3.3 How do you treat the water?

1. Boil 2. Filter water jug 3.Other…….

3.4 Water source for cooking

Rainy season						Dry Season					
Water source	Rating	Qauntaty		Expense		Water source	rating	Quantity		expense	
		Per Family	Per person	Per family	Per person			Per fmaily	Per person	Per family	Per person
total						total					

***choose the choice to complete**

- Water source: 1. Pond 2. Well 3. Rainwater

4. Bottle water 5. Buy water from vendor 6.Piped water

- Rating: 1. Rarely 2. Sometimes 3. Often

3.5 Water source for cleaning

Rainy season						Dry Season					
Water source	Rating	Qauntaty		Expense		Water source	rating	Quantity		expense	
		Per Family	Per person	Per family	Per person			Per fmaily	Per person	Per family	Per person
total						total					

***choose the choice to complete**

- Water source: 1. Pond 2. Well 3. Rainwater

4. Bottle water 5. Buy water from vendor 6. Piped water

Rating 1. Rarely 2. Sometimes 3. Often

3.6 Why do you choose piped water to use? **(Skip this question if the respondent do not use piped water?**

.Expensive 1.Cannot afford 2.Do not need piped water

3. Do not trust on water quality 4. Other.....

IV. Piped water Usage and Service Responsiveness

(If the respondent do not use piped water, skip this section)

4.1 How many years have your family using piped water?.....

4.2 Is the water supply is owned by public or private?.....

4.3. Why do you choose to use piped water?

1. Time saving 2. Health 3. water scarcity in dry season 4. spend less than other sources 5. other.....

4.4. Can you access to piped water every time you need?

1. yes 2.No

*if not, why?.....

4.6 What time cannot you access to piped water? .....

4.7What do you think to the pressure of piped water?

1. Low pressure 2. High pressure

*If low, Why?.....

4.8 What time do the water pressure is low?.....

4.9 Have you ever had problem or not? If yes, what are they?

1.yes 2. no

.....

.....

4.10 Have you ever contact to the water agency for solving the problem you had? Why?

1. [redacted]ry easy to contact 2 easy 3 normal 4.not easy

5. Very hard to contact

.....

...

4.11 How responsive do the agency respond to the customer? Why?

1. [redacted]ry good 2.good 3.normal 4.bad 5.very bad

.....
...

4.12. What do you think for piped water service you are using?

1. [redacted]ry satisfied 2.satisfied 3.normal 4.dissatisfied 5.very dissatisfied

*If dissatisfied, why?.....

4.13 What do you think about the price?

[redacted] 1. expensive [redacted] 2.normal [redacted].cheap [redacted]4.don't paid

4.14 If expensive, which price do you want?.....

4.15. If you do not pay, why?

.....

4.16. Have you spent for connection fee?

[redacted] 1. yes 2. no (skip to 4.20)

4.17 If yes, How much?.....

4.18 Please brief the process of connection

.....

.....

4.19 How many day did the connection require?.....

4.20. If not, why?.....

4.21. When do you pay for water fee?

1. End of month 2. Start of month 3 other .....

4.22 Is the water fee required to pay regulator?

1. yes 2.no

4.23. If no, why?.....

V. community perspective on piped water

5.1 To your understanding, what are the signs of safe water quality?	( ) taste (1) color (2) transparency (3) odor (4) other.....
5.2 Do you think the water quality in your village?	( ) safe (1) kind of safe [redacted](2) unsafe (3) very unsafe [redacted](4) other .....
5.3 In your perspective, what factors do impact to water quality?	....
5.4 In your perspective, do you think water quality can cause disease?	( ) yes (1) no If yes, what are they? ....
5.5 have you ever joint program on water usage?	[redacted]( ) No (1) Yes *If yes, the program conducted by whom?

	……. *if yes, what do you remember from that program?..... .....
5.6 Do you think water is the main problem in your village?	[redacted]1) No (1) Yes
5.7 If important, what are the problem? [redacted]	( ) far (1) taste (2) quality [redacted]3) disease (4) other:.....
5.8 What are your suggestion to solve this problem?	( ) Protect the exist water source [redacted]1) make the water source better [redacted]2) monitor water storage (3) treat water [redacted]4) other:.....

VI. community and piped water supply project

5.1 Have you joint in making decision process in piped water supply project?	(1) yes (2)No **(skip to 5.5)**
5.2 If yes, which process?	(1) before starting project (2)during project (3)other.....
5.3 How was the participation?	....
5.4 How do you think to the participation?	....
5.5 Have you raised idea in the meeting process? If not ,why?	(1) yes (2) no ....

5.6 Did the authority give chance to you to join in making decision? If not, why?	(1)yes (2)not ....
5.7 Did you feel safe to raise the idea? If not, why?	(1)yes (2)No ....
5.8 Have the comment of the villagers raised in meeting been implemented or not? If yes, what are they?	(1)yes (2)No .... *If not, why? ....
5.6 Have the women joint?	(1)yes (2)no
5.7 If not, why?	....
5.8 Do you think women should join or not? Why?	(1) yes (2) No ....
5.9 Do you think villager should join in the project of water or not? Why?	(1)yes (2)No ....
5.10 If yes, how?	....
5.11 Do you think piped water should be charged or not? Why?	(1) Yes (2)No ....
5.12 Do you think piped water should be managed by public or private?	(1)public (2) private (3)other ....

Appendix 4

Table 3 Water Sampling Preservation

Parameters	Frequency Testing			Specific Raw Water
	Every Day	Every 3 months	Every Year	
Microbial Parameter				
E.coli	No	Yes	No	
Chemical Parameters				
Aluminum (Al)	No	Yes	No	P.A.C power/ Liquid is used
Ammonia (NH4)	No	Yes	No	
Arsenic (As)	No	No	Yes	Ground Water
Ba	No	No	Yes	
Cadmium (cd)	No	No	Yes	
Residual Chlorine	Yes		No	Chlorine is use for defection
Chromium (Cr)	No	Yes	No	Copper Material is used
Copper (Cu)	No	Y3s	No	Ground water
CN	No	No	Yes	
Fluoride (F)	No	No	Yes	Ground water
$CaCO_3$	No	Yes	No	Ground water
Iron (Fe)	No	Yes	No	Ground water
Lead (Pb)	No	No	Yes	
Manganese (Mn)	No	Yes	No	Ground water
Mercury (Hg)	No	No	Yes	
Nitrate(NO3)	No	Yes	No	
Nitrite (NO2)	No	Yes	No	
Sodium (Na)	No	No	Yes	Coastal Area
Sulfate (SO4)	No	Yes	No	
Zinc (Zn)	No	No	Yes	
Physical Parameters				

pH	Yes	No	No	
Total dissolved Solid (TDS)	Yes	No	No	
Color	Yes	No	No	
Turbidity	Yes	No	No	
Taste	Yes	No	No	
Odor	Yes	No	No	

Table 4 Water Testing Frquency

Parameters	Frequency Testing			Specific Raw Water
	Every Day	Every 3 months	Every Year	
Microbial Parameter				
E.coli	No	Yes	No	
Chemical Parameters				
Aluminum (Al)	No	Yes	No	P.A.C power/ Liquid is used
Ammonia (NH4)	No	Yes	No	
Arsenic (As)	No	No	Yes	Ground Water
Ba	No	No	Yes	
Cadmium (cd)	No	No	Yes	
Residual Chlorine	Yes		No	Chlorine is use for defection
Chromium (Cr)	No	Yes	No	Copper Material is used
Copper (Cu)	No	Y3s	No	Ground water
CN	No	No	Yes	
Fluoride (F)	No	No	Yes	Ground water
$CaCO_3$	No	Yes	No	Ground water
Iron (Fe)	No	Yes	No	Ground water
Lead (Pb)	No	No	Yes	
Manganese (Mn)	No	Yes	No	Ground water

Mercury (Hg)	No	No	Yes	
Nitrate(NO3)	No	Yes	No	
Nitrite (NO2)	No	Yes	No	
Sodium (Na)	No	No	Yes	Coastal Area
Sulfate (SO4)	No	Yes	No	
Zinc (Zn)	No	No	Yes	
Physical Parameters				
pH	Yes	No	No	
Total dissolved Solid (TDS)	Yes	No	No	
Color	Yes	No	No	
Turbidity	Yes	No	No	
Taste	Yes	No	No	
Odor	Yes	No	No	

(MIH, 2015)

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