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Affordable water treatment solutions for domestic use: a community dugout in the Tolon district, Ghana

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Acknowledgments

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Abstract

This study was conducted in the Northern Region of Ghana, an area renowned for its lack of improved drinking water sources. A dugout in the Kukpehi community in the Tolon district, near the regional capital, Tamale, was chosen for an in-depth analysis. The field study period was from the 7th of February until the 28th of March. Data collection consisted of two parts: field studies, including focus group discussions and observations, and laboratory analysis of the drinking water quality. Preliminary results show concerning numbers of total coliforms present, in addition to high turbidity levels in the water. Volume reduction and water quality deterioration during the dry season leave the residents with a coliform-infiltrated and limited drinking water source. The research revealed a lack of treatment practices among the users collecting water for domestic purposes. Together with low-resource conditions and inadequate drinking water quality, this is leading to severe concerns regarding the dugout users' health. Household water treatment solutions are therefore necessary to secure potable drinking water for the inhabitants depending on this water source. Considering the area's lack of water distribution systems, a household water treatment solution was suggested. Recommendations from this study include a bio-sand filter paired with Moringa seeds as a coagulant, or water evaporation with plastic covers. These were the most affordable and user-friendly methods to purify the collected water from the dugout.

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1 Introduction and Problem Justification

1.1 Introduction

“No single measure would do more to reduce disease and save lives in the developing world than bringing safe water… to all”, cited Kofi Annan, a former UN Secretary-General (United Nations, 2003). A staggering estimate of 1.2 billion one in four people worldwide lacked access to potable drinking water in 2020, with the lowest coverage found in sub-Saharan Africa (WHO and UNICEF, 2021). The erratic supply of safe drinking water affects hygiene practices which, paired with poor latrine systems in underdeveloped countries, are causing microbial infectious diseases (Yaya, 2018). In 2017 diarrhoeal diseases caused approximately 1.6 million deaths globally (Troeger et al., 2018). Children, under the age of five, are dominating the numbers with almost one in a third (Hartman et al., 2023; Troeger et al., 2018). In Ghana, it is estimated that 76% of the households are at risk of drinking water contaminated with faeces (UNICEF, 2022). Contamination with faeces represents the single biggest threat to drinking water safety (Bain, 2014).

With temperatures increasing globally, the climate is changing to the more extreme. This in turn increases evaporation from lakes, rivers, and other water bodies leading to an even further scarcity of surface water resources (Dey et al., 2019). Additionally, the water quantity, especially in Ghana, is becoming more limited, with a rapidly growing population (Cobbinah et al., 2020; Kayaga et al., 2021). Peri-urban and rural communities are normally deprived of piped water supply and therefore more exposed to water scarcity and contamination with *Eschericha coli* causing diarrhoeal diseases. These diseases are more commonly found in surface water (Yeleliere et al., 2018).

The Northern Region of Ghana has gained recognition for its limited availability of improved drinking water sources. As of 2021, approximately 21% of households in this region lacked improved water sources (Ghana Statistical Service GSS, 2022). Inadequate water supply in peri-urban and rural communities in Ghana leaves residents with few alternatives other than consuming water from unprotected surface water sources (CWSA Tamale, 2023; Gyau-Boakye, 2008). Consequently, the combination of rising temperatures, urbanization, and population growth intensifies the scarcity of water resources, particularly in Ghana’s Northern Region, resulting in households heavily relying on unsafe domestic water consumption.

Households deprived of improved water sources spend time and effort fetching water. More than 25 000 of the Northern Regions' households spend more than 60 minutes collecting water each time (Ghana Statistical Service GSS, 2022). Children, especially females, are regularly expected to help with water carrying, which reduces their time and ability to attend school (Jeil et al., 2020; Nauges, 2017). Consequently, the families struggling with unsafe water may not have their children educated and therefore stay in the low-income sector.

On average, low-income households tend to have higher expenditures on water, compared with those with higher income with access to potable water. Ghana's Multidimensional Poverty Index Report from 2020 (Ghana Statistical Service (GSS), 2020), reveals that eight out of ten persons in the Northern Region are considered multidimensionally poor, meaning they are deprived of health, education, and acceptable living standards. Those with limited financial resources and poor hygienic facilities are most affected by diarrhoeal diseases (Cabral, 2010). This situation makes access to purified drinking water difficult, resulting in the consumption of unsafe water.

A survey performed by Ghana Statistical Services revealed that more than a third (35.3%) of the Northern Region's households were depending on surface water sources such as dugouts, ponds, lakes, dams, and canals as their main water supply (Ghana Statistical Service GSS, 2022). As water scarcity characterizes this region, communities have for centuries depended heavily on water stored in dugouts, which are man-made land storages collecting rain and/or runoff water (Cobbina, 2009). Reliance on this water source is linked with several challenges. Dugouts are fully exposed and at high risk of absorbing diverse contamination sources, including industrial and/or agricultural runoff, human activities, animal excreta, bird droppings, and so on.

Inadequate water quality in dugouts, often with high turbidity, facilitates the growth of microorganisms causing waterborne diseases (Cobbina, 2009; CWSA Tamale, 2023). In addition to infectious diseases, excessive consumption of contaminated drinking water can cause cancer, dental and skeletal fluorosis, anaemia, behaviour issues in infants, skin rashes, and more. These diseases are commonly caused by environmental components such as fluoride, manganese, arsenic, mercury, and nitrate.

Peri-urban and rural communities are at the highest risk of consuming contaminated water, as they are not connected with improved piped water. As the groundwater in this area commonly contains too large amounts of salt and fluoride (Araya, 2022), dugouts are essential for domestic water supply, agriculture, and industry in these communities. In the Tolon district of the Northern Region, low-resource communities depend heavily on unimproved surface water sources. Poor financial status affects their willingness to pay (WTP) for the implementation of water purification technologies (Dey et al., 2019). Considering this, this study aims to investigate affordable treatment measures customised to local needs, using the Kukphehi community, in the Tolon district, as a study case.

1.2 Personal motivation

In a desire to take the water challenges of those I, the author, worked with seriously, I was given the opportunity to make a small but significant difference for the Zoolanyili community in the Tolon district. Their initial water source was a muddy-looking, small dugout.

Prior to leaving the area after field studies were finished, an initiative was made to gather financial resources to provide a community in the Tolon district with simple and affordable water treatment solutions. After collecting a large sum of money via social media, a total of 35 households in a community were provided with each of their own cotton cloth filters. Additionally, the sum was sufficient to build a borehole, an improved water source that will collect rainwater. As a result of this effort, this community consisting of 35 households gained an improved water source, which will enable them to gather safer drinking water.

1.3 Problem statement and justification

The increasing population, warmer weather, and prevailing concerns with waterborne diseases are the prominent issues for the justification of this research. These factors are causing a decrease in improved water sources, paired with an increase in water demand. Since the larger part of the population in the Northern Region is struggling with very low financial resources, their consumption of water from contaminated water sources for the main domestic water supply is of great concern. Building upon the recognized need to address the critical problem of domestic water sources in this region, a problem statement is presented below.

Main Objective

Considering the Northern Region's apparent growing water challenges, related to both demand and quality, this thesis will initiate with the following research objective:

To provide an understanding of the prevailing water quality issues, their underlying causes, and potential solutions through an in-depth analysis of a dugout in the Kukpehi community, of the Tolon district of the Northern Region of Ghana.

More specifically, this study will do the following:

- Bring forth an evaluation of the socio-economic situation of the dugout users, their current treatment practices, and their willingness to pay for treated drinking water.
- Identify the possible sources of contamination of the water source.
- Propose suitable water purification technologies for domestic consumption, considering the safety of water, socio-economic aspects, and maintenance procedures.

Research Questions

Three research questions that will define this thesis, are stated below:

1) What are the known challenges and common practices for domestic water collection in the study area?
2) Is the collected water safe enough for human consumption?
3) What are the most feasible options to meet these challenges?

Significance of Study

Today, there is an abundance of studies investigating affordable treatment measures for the numerous communities depending on dugout water. An analysis of the dugout, including the water quality and treatment practices, is of high relevance for similar communities lacking safe drinking water in similar conditions. This study will have significance for similar cases of people who rely upon unimproved water sources, not only in Ghana, but for other low-resource communities within sub-Saharan countries with comparable climatic, socio-economic, and environmental conditions.

2 Literature Review

Existing knowledge on the research topic will be presented in this chapter, with examples from other studies. Possible gaps in the present literature that need to be addressed will be identified.

2.1 Prevailing water quality issues in the Northern Region of Ghana

A prevalent water quality issue with surface water sources is high turbidity levels. This contamination often contains pollutants in the form of particles and colloids, which of whom are described below.

2.1.1 CECs

Unprotected and easily accessible surface water sources, such as dugouts, are subjected to a wide range of contaminants and organic pollutants. Contaminants of emerging concern (CECs) include industrial pollutants, pharmaceuticals, pesticides, personal care, and household products (Baken et al., 2018). Through runoff, CECs find their way to open water sources such as dugouts. Heavy metals are linked with CECs. Adverse effects of CECs include the development of antibiotic-resistant bacteria, ecotoxicological effects, and several endocrine disorders. However, most CECs found in drinking water are not an immediate health risk (Baken et al., 2018).

2.1.2 OCs

In peri-urban communities in the Northern Region, pit latrines are indirectly causing organic contaminants (OCs) to reach open water sources. Mobilized by soil erosion and runoff, wastewater (effluent) transfers OCs to the aquatic environment through multiple pathways (Chaukura, 2017). Faecal contamination is more apparent during the wet season. A study from 2021 (Dongzagla, 2021) investigated several water bodies in Upper East Region, an area with similar climatic and environmental conditions to the Northern Region. It concluded that the dugouts contained the highest average concentrations (420 CFU/1mL) of average faecal coliforms, compared to the other water bodies in this area.

2.1.3 Heavy metals

A study from 2014, revealed frequent contamination with heavy metals such as manganese, iron, and fluoride in the Northern Region (Boelee, 2014). More recent studies investigating the dugouts' water quality in this region are abundant. However, other prevailing issues with the water quality in this region that have been found earlier, are faecal contamination with *E. coli* and other bacteria and parasites carrying waterborne diseases. Sanitation and hygiene practices are generally low due to a general lack of knowledge and resources among the inhabitants.

2.1.4 Lack of water quality data

Several boreholes and wells have been built in this region, provided by NGOs and the government. Once a water source has been improved, maintenance is expected to be covered by the community, which often is poorly managed (Rossiter, 2010). Community committees, WATSANs, operating and maintaining the improved water sources or treatment installations are proven to be effective for the water quality. This often results in poor chemical water quality in these sources. Consequently, rain harvesting in dugouts is preferable for some communities, although the drinking water quality seldom is investigated. There is especially an abundance of studies on the water quality during the dry season, as the sources often dry up during this season. Long-term water quality data on dugouts is hardly existing, with the few studies made during the wet season.

2.2 Treatment measures

In this section, low-cost treatment measures with examples from other studies will be presented. Point-of-use (POU) household water treatment technologies (HWT) that can be implemented in the household or at community-scale are the main given measures. Their levels of treatment efficiency, use and maintenance procedures, and cost of implementation will be considered.

Removal of particles and pathogens are the main reason for treating water for human consumption. Particles reduce water transparency, while at the same time, they increase the colour of the water, which may decrease the aesthetic quality of the water. Particle removal can be achieved using filtration and sedimentation, while coagulation with Alum or Moringa seeds removes colloids from raw water. Efficient coagulation will remove almost all bacteria and parasites but only a part of the viruses. Therefore, it is necessary to have an inactivation method of disinfection to secure the total safety of domestic water.

Providing households with disinfection products is shown to decrease the prevalence of diarrhoea by almost one-quarter (Shier, 1996). Nevertheless, it is essential to treat the drinking water before consumption to mitigate the potential risk of waterborne illnesses. Boiling is an affordable and easy method to inactivate parasites, bacteria, and viruses. Chlorination, a chemical treatment option, is shown to be the most effective, affordable method in the inactivation of microorganisms.

2.2.1 Filtration

Cotton cloth filters

Using hand-sewn cotton cloth filters as pre-treatment is an affordable measure for low-income households (Vigneswaran, 2009). Being easy to use and maintain, they filter dust and mud particles, insects, and plant debris from raw water. However, the effectiveness in filtration of suspended particles is generally low.

Bio-sand filter

In regions suffering from water sources with high levels of turbidity, a bio-sand filter (BSF) is proved to be effective in reducing the diarrheal disease which occurs more frequently in turbid surface waters (Stauber et al., 2012). A BSF is a household-level adaption of the traditional slow sand filter (Nakamoto, 2014). A study from 2008 claimed it to have a high potential of reducing water-borne diseases and deaths related to unimproved drinking water (Sobsey et al., 2008) while sustaining households with an easy-to-use HWTS.

The plastic BSF was implemented in rural communities in the Northern Region's capital city Tamale in 2012 to improve domestic water quality (Stauber et al., 2012). In a region suffering from diarrhoeal diseases due to unimproved drinking water, the filter could bring about a significant improvement in the quality of household water. The study claimed to reduce diarrhoeal disease (60%), *E. coli* (97%), and turbidity (67%).

As most HWTSs, the BSF regularly requires maintenance and quality controls. Another study (Nakamoto, 2014), covering 32 study reports, showed that only 41% of the users knew how to properly clean the filter. It was claimed to be "a simple, inexpensive, socially appropriate technology [..] constructed by local technicians using locally available materials including gravel, sand and cement". In 2014 it was expected to cost from $15 to $40, depending on the country (Nakamoto, 2014). It requires no added chemicals to operate and maintain, making it a simple and affordable solution.

ProCleanse

ProCleanse a HWTS tested on rural communities in Ghana in 2014, purifies unfiltered water using gravity to remove microorganisms and metal ions from the water (Boelee, 2014). Targeting bacteria and viruses, it is ideal for open water sources where *E. coli* contamination from animal excreta, runoff from wastewater, and poor latrine facilities are common dangers. ProCleanse was tested in 600 households, resulting in no change of diarrhoeal occurrence among children under five years of age. It was noted that the sanitation and hygiene practices were poor.

Silver-impregnated porous-pot filters

A study from 2013 investigating several filters, found the silver-impregnated porous filter (SIPP), an improvement of the BSF, to be of the highest efficiency. Being impregnated in a clay and sawdust mixture makes it handy for rural areas as it consists of local materials. Targeting pathogens well with 100% removal, it consistently produced quality water that complied with the microbiological and turbidity limits at the time of the study (Momba, 2013). However, its efficiency was degraded after treating surface water, due to high contents of particles, resulting in clogging of the filter. This was also discovered in another study from 2009 (Halem et al., 2009). It was suggested that highly turbid surface water was treated with sedimentation prior to filtration, to avoid particle clogging.

2.2.2 Coagulation

Alum and Moringa seeds

A common method of water purification in the Northern Region is coagulation with Alum or Moringa seeds. Alum is only capable within a certain pH range (6-8) and loses its efficiency after a too-large quantity is applied (Krupińska, 2020). A study from 2018 claimed Alum to work more efficiently at a pH 6 (Malik, 2018). The filthier the water, the more alum is necessary, causing it to become an inefficient method with very filthy water. However, it is an efficient coagulant in removing suspended particles such as clay, silt, organic matter, and certain microorganisms from the water. Alum also reduces turbidity, destabilises colloidal particles, and can remove organic matter. To some extent, the coagulant can remove certain dissolved substances, including heavy metals such as iron and manganese, and bacteria and viruses (Mehidinejad, 2018). However, there are limited studies available investigating this. As with several chemical treatment measures, excessive consumption of Alum treated water is linked with health consequences (Krupińska, 2020).

Moringa seeds extracted from Moringa trees, *Moringa oleifera*, are a natural coagulant, efficient in removing heavy metals from acidic water (Bancessi, 2022). Being a natural method of water treatment, it is not linked with any diseases, but is rather proven to improve health. When crushed and mixed with water, they can purify water by settling suspended particles. They also reduce turbidity and retain antimicrobial properties, succeeding in removing certain bacteria from water. A study researching the effectiveness of Moringa seeds in surface waters in Guinea-Bissau (Bancessi, 2022) concluded with a 99.9% removal of various pathogenic bacteria, including *E. coli* and *Salmonella typhi.*

Dissolved substances and viruses are not removable by moringa seeds, and their efficiency in removing the other matters depends on the water source and which contaminants are present. A downside with Moringa seeds is the necessity of them to be purified prior of use to avoid organic matter and nutrients added to the treated water (Aarø, 2020).

2.2.3 Others

Boiling is an effective and easy method of purifying water. However, in low-resource communities, the energy demand may be higher than the energy available. For households with sufficient resources, heating the water up to 100 degrees Celsius will eliminate common disease-causing bacteria (Sabir & Farooqi, 2008).

Water evaporation uses a natural distillation process to purify water by separating pure water from impure water. The impurities are left in the initial container, while the distilled water is collected in a second container. Left in solar exposure, the raw water condenses on a plastic cover, where it will be captured. It may also be dug a hole in the ground, filled with raw water, and covered with a plastic sheet, which is elevated just above the water. Water will then condense and be gathered in the centre of the plastic sheet. The water is 100% purified and safe to drink. The plastic cover or sheet will be covered in biofilm over time which requires frequent change.

3 Materials and Methods

In this chapter, the study area and methods used to address the research questions are presented.

3.1 Study methods

The research was conducted using a comprehensive approach:

(i) A qualitative analysis consisting of field studies, using focus group discussions (FGDs) and field observations, to disclose perceptions on the water quality, recognize challenges and current water treatment methods, and identify the water users' socio-economic features.

(ii) A quantitative analysis performing water quality analyses of the dugout to support the idea of contaminated drinking water.

Both approaches will answer the research questions 1) and 2), before the final research question is assessed: What are the most feasible options to meet these challenges?

3.2 Criteria for considering treatment options

As stated in the problem statement in Chapter 1.2, this study will propose suitable water purification technologies for domestic consumption, considering the safety of water, socio-economic aspects, and maintenance procedures. Treatment proposals will therefore need to meet the following criteria:

- i) Produce water that meets WHO standards.
- ii) Easy to construct, operate and maintain.
- iii) Affordable, constructed with locally available materials, and not electricity-driven.
- iv) Able to produce a minimum volume of 20 litres, L, per person per day.

The minimum volume covers the basic needs of a community household. Ranging between 5 and 34 L per person, a basic need of 20 L was chosen, as recommended by the Joint Monitoring Programme (JMP) and the Ghanaian Community Water and Sanitation Agency (CWSA) (Kulinkina, 2016). This study considered piped consumption volume, but while the low-resource community of Kukpehi exists as a peri-urban area on the edge of rural areas, centralisation with piped water supply is not realistic. Therefore, a volume of 20 L was suggested.

3.3 Study area

This study was conducted in the Tolon district, located in the Northern Region of Ghana, shown in Figure 1. Ghana is divided into sixteen regions, where the Northern Region remains one of the three driest, due to its proximity to the Sahara Desert and the Sahel region (UNICEF, 2010). A dugout located in Kukpehi, N 9.416278, -0.966433, a peri-urban area west of the Northern Region's capital city of Tamale, was the study case of this research.

Locally the dugout is known as "Bunker". Reasons for selecting Kukpehi as the study area was (i) the absence of a water distribution system, (ii) geographical proximity to UDS, Nyankpala, and (iii) type of water source (dugout), diverse human and animal activity, and concerning physical appearances, such as clay-colored water. The volume of water in the dugout remains unknown, as no measurements of the terrain or geological data were attained.

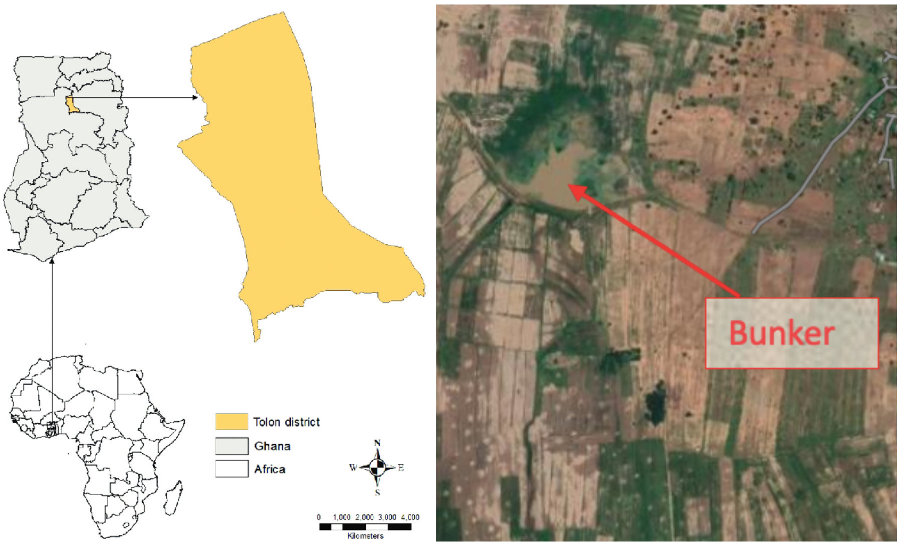

Figure 1. ***Left****: Map of Tolon district (Anang, 2020).* ***Right****: The study area from Google Maps (Maps, 2023) Available through: https://www.google.com/maps. [April 20th, 2023].*

Climate

Located in the dry savannah zone, the district typically experiences its rainy season between the months of May and October (Asante & Amuakwa-Mensah, 2014). Average rainfall throughout the rainy season is normally 800-1100 mm (Anang, 2020; GMET, 2022; Kranjac-Berisavljevic, 2015). The remaining months of November until May are the dry season characterized by scorching heat and little to no rainfall, followed by recurring dry spells during the hottest months of March to April (Kranjac-Berisavljevic, 2014). Dry spells are periods of very dry weather, though less severe than a drought. Temperatures in this period peak with average temperatures reaching over 40 degrees Celsius (Anang, 2020). Potential evaporation of surface water sources in this area is estimated to be 165.2 mm in February and 186 mm in March (Agodzo, 2023).

Seasonal changes due to climate change have led to increasing temperatures and more frequent dry-outs (Agodzo, 2023) impacting the already stressed water resources throughout the dry season (EPA, 2011). Evaporation contributes to the reduction of volume (Kranjac-Berisavljevic, 2014). Rainfall levels have been reduced generally while the heavy rainfall incidents have become erratic (Kayaga et al., 2021).

Bio-physical characteristics

The Northern Region is highly prone to soil erosion, with sparse grassland and light tree vegetation covering the region (Ofori, 2009). Bush burning, runoff and extreme deforestation are additional environmental hazards occurring in this region. During the dry season, the dugout is surrounded by zones of burned grassland and various species of bushes, and economical trees such as mango trees, *Mangifera indica L*. The land is subjected to overgrazing in this period, as the feed resources are scarce, and herds of livestock are grazing by the dugout and chewing on roots within the water source. During the rainy season, maize and other crops dominate the land. The soil is typically shallow and washed out, consisting of clay.

*Figure 2. **Left**: Vegetation by the dugout. February 19th. **Right**: Biodiversity by the dugout. February 7th. Source: Erga, 2023.*

Water quality

The quality of the water in the dam varies over different seasons. During heavy seasonal rainfalls, the area is subject to pollutants, some of which are invisible. Chemical compounds enter the dam through runoff from agriculture, industry, drains, and traffic. Large amounts of runoff water from the road will flow over the land, causing pollutants and organic matter to enter the dugout. These are anthropological pollutions, but also waste from natural pollution may occur, like bird-droppings and animal excreta, as well as inflow from the polluted surfaces.

3.4 Data collection

3.4.1 Fieldwork

The fieldwork, including in-depth studies and laboratory analyses, was carried out by the author during the dry season. Spanning from 7th of February until 28th of March, the fieldwork lasted a total period of seven weeks. Two FGDs were conducted, 18th and 19th of February, representing the qualitative research, together with field observations and dialogues with dugout users on-site. Two days of water sampling were carried out 7th and 27th of March. Throughout the seven weeks, observations on the water collection activity surrounding the dugout were made.

3.4.2 Secondary data sources

Literature studies were assessed to obtain confirmative information on activities regarding observations made in the field. These include natural and anthropogenic observations, such as respectively, biodiversity and climatic factors, agriculture and industry, and customs such as collecting water and washing clothes. Relevant literature was found in scientific databases, to plan the data collection and support the research gathered.

3.5 Part 1: Focus group discussions

To investigate the water treatment practices and challenges with the dugout water, and the socio-economic traits of the users, focus group discussions were conducted.

3.5.1 Design and implementation

The points for the FGDs were developed after several dialogues with relevant individuals within the Faculty of Agriculture and Schools of Engineering at University for Development Studies (UDS), Nyankpala. Every visit to the dam was notified in advance by the local contact person who informed one of the dugout managers. Prior to the fieldwork, approval from the Kukpehi community's chief was necessary to carry out the data collection. The qualitative data from the FGDs were processed by an assistant translator, who interpreted the information in English for the author.

The major sections of the FGD questionnaires contained demographic information, water collection and usage, water quality, and socio-economic information. Demographic information includes age, number of members of the household, marriage status, and educational level. The respondents were asked about their willingness to pay for treated drinking water and for which amount.

To better understand the water collection and treatment practices, the following subjects were of importance: if the water was treated after collection; sicknesses related to drinking water; the quality of the water – taste, colour, smell, turbidity, and organic matter; variation of the quality; distance to water fetching; animals drinking nearby; usage areas of water – domestic, irrigation or industrial. The complete questionnaire can be found in the Appendices (Appendix A;Appendix B).

3.5.2 Sample size determination

The size of the FGDs were carefully chosen, to sustain a lively conversation and avoid verbal pressure, as bigger groups tend to limit details of some respondents (Krueger, 2008). Therefore, seven to eight participants comprised each group, including the author and an assistant translator. A total of 11 local water users participated in the FGDs. Men and women were separated, as men’s voices often dominate women’s during questions regarding their household.

3.5.3 Execution

The FGDs were carried out near the water source and inside the Kukpehi community, with participants assembled by the local guide after agreement. Lack of available participants and collection size for the managers of the dugout and customers of the tricycle drivers, led to the completion of two out of four planned FGDs. The first group (FGD1) represents the tricycle drivers, locally known as motorking drivers, with the living activity of collecting water for commercial use. Being a gender-specific occupation in Ghana, only men participated, consisting of five drivers purposefully selected based on their experience and benefits from using the dugout. The second group (FGD2) consisted of women, domestic users, who collected water daily at the dugout for household or domestic purposes. It was carried out with only females, due to women’s responsibility to collect water in most households (UN, 2022).

3.5.4 Ethical considerations

Each of the participants voluntarily attended the FGDs, with informed consent after being assembled by the local guide. Anonymity was assured but no contract of terms existed, considering that several of the participants were illiterates, and to ensure an informal and relaxed

discussion. Before the FGDs were conducted, the participants were informed of the terms and procedure. They then agreed to participate and were compensated for their time spent.
Before carrying out the fieldwork, dialogues with the managers of the dugout were necessary. By engaging in dialogues, the author could establish a friendly tone with the managers and gain their trust and cooperation. It allowed the author to learn about the specific customs and protocols related to the dugout and its surroundings. By approaching the managers with respect and openness, the author demonstrated a commitment to conduct the fieldwork in a responsible and culturally sensitive manner. This adopted a collaborative relationship and increased the chances of successful and mutually beneficial research.

3.5.5 Field observations

Continuously throughout the fieldwork, observations at the dugout were documented to assess possible contamination sources and pollution entries to the water. Visual observations were made and questions to locals were given during the fieldwork, to achieve a better understanding of the socio-economic practices around the dugout. Part 2: Water sampling procedure and analysis
To determine if the dugout water poses a risk to human health, the quality of the water was assessed by analysing physio-chemical parameters and total coliforms.

3.5.6 Design and sample size determination

The locations in the study dugout Bunker were chosen for water sampling as they represented water points where the users would collect their water. This included both pump outlets and surface water. All locations were in proximity to pollution sources, as animals such as cattle and sheep grazed nearby. Water samples were taken from the less animal-occupied sections, where the pumps and water collectors were.

Two or three water samples were planned for each location, to limit the field work results' susceptibility to faulty or unrepresentative values, and therefore optimize valuable results. Lack of financial resources restricted the number of samples for the laboratory analysis. The physio-chemical samples were collected from four locations in the water point (A-D), three from each location to ensure higher accuracy. Two locations (A*-B*) were tested for total coliforms, with two samples from each location.

3.5.7 Sampling Techniques

Water samples were collected in 300 mL-bottles. The samples were collected either directly from the dugout or from the flowing outlet water. Where the samples were taken at surface water the depth was approximately 0.5 m, with a considerably thick layer of mud in the bottom. The depth of the sampling was just below the surface where it also was collected by the locals. The volume collected in each bottle was 250 mL.

*Figure 3. **Left**: Samples A1-A3 collection point. Source: Erga, 7th of March, 2023. **Right**: Collection point A, including A*, and C. The study area from Google Maps (Maps, 2023) Available through: https://www.google.com/maps. [April 20th, 2023].*

Using gloves, the sterile bottles were rinsed with water three times before they were filled with sample water and sealed with a cap. Two locations in the physio-chemical analysis (A, C) and one location (A*) in the microbiological analysis included sampling from surface water (Figure 3), where the author needed to enter the water to fill the bottles. This led to significant movements in the water, and the sampler waited until the sediments had settled before filling the bottles. The depth was no more than approximately 50 cm and the ground was thick with mud.

The other two locations, Figure 4, in the physio-chemical analysis (B, D) and one location in the microbiological analysis (B*) were collected with water from the outlets of the pump hoses. This is where the tricycle drivers and some domestic users collected their water. The procedures were repeated for the microbiological samples, although they were collected only from two locations, A) surface water and B) a pump outlet.

Figure 4. The samples A1-A3 and C1-C3. March 13th. Source: Erga, 2023.

Figure 5. ***Left****: A boy filling the tricycle plastic containers with raw water. Samples B1-B3 and D1-D3 were taken from the outlet of two different pumps. February 7th.*
Right*: Collection point A. Samples A1-A3 and A1*-A2* were collected here. March 27th.*
Source: Erga, 2023.

3.5.8 Sample preservation and storage

After each bottle was collected, the procedure was to store them in a non-thermic bag inside a rucksack to protect them from sunlight. Shortly after the last sample was completed, they were transported directly to a lab for analysis. The travel route from the sampling site to the lab was within one hour for both laboratory analyses, to avoid them being subjected to major temperature change before analysis.

3.5.9 Laboratory and data analysis

The samples taken on the 13th of March (physio-chemical) and the 27th of March (microbiological) were analysed by UDS in Nyankpala and Ghana Water Company Limited (GWCL) in Tamale, respectively. Details of the laboratory analyses are not known as they were not conducted by the author.

3.5.10 Ethical considerations

The water samples were disinfected before arrival to the field, to prevent leakages from the disinfectant into the environment. A dialogue with the managers in prior of sampling were made to confirm allowance and to not disrupt any policies at the water source.

3.6 Sources of uncertainty

Sources of uncertainty that may affect the validity of the results are listed below:

- The moving of sediments as the sampler entered the water, which might lead to higher turbidity levels.
- Contaminated sampling equipment such as bottles and gloves.
- Human mistakes in the water quality sampling.
- Insufficient number of water quality samples.
- Lack of larger number of participants in FGDs to obtain a representative view.
- Misunderstandings or lack of truthfulness in FGDs, leading to misinterpretations.

4 Results and Discussion

Findings from the data collection, including the qualitative field studies and quantitative water quality analyses, are presented underneath. Considering the research objective:

To provide an understanding of the prevailing water quality issues, their underlying causes, and potential solutions through an in-depth analysis of a dugout in the Kukpehi community of the Tolon district of the Northern Region of Ghana.

The research results are evaluated and discussed after the data is presented in two parts. Field studies (focus group discussions and observations) are presented as part 1, while laboratory analyses of the drinking water quality are presented as part 2. The study limitations' influence on the design as well as on the data will be discussed. Lastly, suggestions for the most feasible treatment solutions will be reflected upon.

4.1 Part 1: Field analysis

This subchapter contains the FGDs analyses and field observations.

4.1.1 Demographic and financial characteristics of participants

The five tricycle participants' ages ranged from 30 to 37 years, with household sizes of 4, 5, 6, and 10 persons (mode: 4). Most were married, engaged in farming and driving, and had varying literacy levels, with three being illiterate, one partially literate, and one literate. Six women participated in the domestic user discussion; all were illiterates except one. Their age ranged from 25 to 33 years, and all were married with a minimum household size of three and a maximum of seven people.

Low- to medium-income domestic users relied on a free dugout as their primary water source since they could not afford treated water. The women reported receiving no payment after collecting water from the dugout, and the dugout managers knew it was not used by the women for profit gain. The domestic users said they would pay 30 pesewas, €0.025, per unit for treated water. For the tricycle users, the amount was 2-5 Ghana cedis, €0.16-€0.41. According to the tricycle drivers, a worsening of the national economic situation has led to a doubled price per can since the previous year. The questionnaires for the FGDs did not include any questions regarding details about their annual income, to prevent mistaken perceptions within the group.

4.1.2 Water shortages and areas of use

The water collected by the tricycle drivers (FGD1) was sold to customers for drinking, washing (including car wash), cooking, construction, rice parboiling, and intensive livestock rearing. For the women (FGD2), it was used for domestic purposes such as cooking, washing, drinking and for tasks such as rice parboiling. During the dry season, the dugout is their main source of water because of its proximity to the community and water availability. The other water source "Gbulahigu", located much further away, was only used for water collection when Bunker became filthy, which was stated to be in the March-April period. It was stated in FGD2 that they collected water from Gbulahigu for domestic purposes, though it was dried up at the time of the data collection.

The participants experienced water shortages from April to May. During this period, water was managed by the local participants. For instance, water that was used by one individual would now be used by two to three individuals. The dugout water served the needs of economically disadvantaged individuals, even when its quality deteriorated. Those who could afford it used the water for non-drinking purposes. Water shortage, defined as unsuitable for drinking, occurred mainly due to declining quality.

4.1.3 Respondents' understanding of poor water quality

When asked about their perception of the water quality, the discussions revealed concern among the locals. They especially pointed out the issues with the taste of clay and the smell of urine during the dry season when the water quantity is decreased. Awareness regarding mortality or morbidity of waterborne diseases was not shown in the discussions. They perceived the water quality to have some side effects on their health but could not say for sure what sicknesses it was causing.

The main challenges identified by the tricycle drivers were 1) quantity of water and 2) quality, after many months of use. FGD1 revealed that the water quality varies which is observed/determined by color, taste, smell, and algae growth. The color changes from clear to white, as the quality is reduced, with green at its worst. The participants of both FGDs perceived the quality to be good when the taste was normal and there was no smell. However, when the dugout became dirty it would taste like urine or clay at its worst. Algae blooming, observed to the participants as green substances on the water, usually occurs from April to May, indicating water quality deterioration. It was also revealed by FGD2 that the quality of the water is determined by starchy substances on the surface of the water often caused by frog eggs and "zuya", similar to fingerlings. These observations were normally made in the water at the dugout after the first rain.

Several of the participants appeared to have skin diseases and stained teeth, which indicate excess consumption of contaminated water. High fluoride levels are found in the groundwater in a district north of Tolon. Whether the participants were affected by consuming fluoride-contaminated groundwater or surface water remains unknown. The questionnaires included questions regarding waterborne diseases if they experienced symptoms such as diarrhoea, upset stomach, fever, fatigue, and headaches. This was not achieved to gather information on during the FGDs.

4.1.4 Water treatment measures

As stated earlier, the participants experience water shortages from March to April. Water quality is then at its worst and the household users are often obliged to use alum coagulation to treat the water before use. Previously they used filters for water treatment, distributed by some organisation(s) to help them treat the water during the drier months, but this was not the case at the time of this study. The tricycle drivers revealed that the water is not treated before the costumers buy it.

Throughout April to May, the only measure made to prevent the water quality from worsening was to stop the cattle from drinking it. The participants suggested that the animals' access to water should be separated from humans' portions to avoid faecal contamination. Also, they pointed out that ideally there should be some way for them to fetch water without physically walking inside the dugout thus helping to curb the deteriorating water quality.

Walls around the dugout were built to keep the rainfall water inside the dugout during heavy rainfall, as well as to prevent urban and agricultural runoff from entering the water source. The locals noted that this wall was poorly maintained and prone to soil erosion, which was attempted to avoid by using rip rap material on the dam wall, demonstrated in Figure 6.

Figure 6. Rip rap lining of the dugout wall as a measure to avoid soil erosion.
Source: Erga, February 7th, 2023.

4.1.5 Field observations

Visual observations revealed children and adults collecting water by walking barefoot 2-3 meters into the dugout to fill their plastic containers. Further observations revealed the same individuals scooping water with their hands to drink directly from the source, which indicates a common practice of consuming the dugout water without any treatment beforehand. this was confirmed in a dialogues with a tricycle driver. It was also observed that cattle would be walking into the water, not far from the point where the individuals were fetching their water.

A bridge-like construction of concrete is established to prevent the runoff water entering the dugout during heavy rainfall. It also serves as a laundry station. The concrete functions as a barrier, hindering the soaped water to enter the surface water after use. Instead, it is discharged on the other side of the concrete, where they would do the laundry.

Water losses were observed where the tricycle drivers collected water from the pumps. The spilled water had formed a dam outside the dugout. Insufficient hoses and clumsy filling of the cans led to water losses. Figure 7 show the volume reduction from the first day of the fieldwork until the last. A visit to the dugout in the end of March confirmed the participants' statement of water shortages during the last months of the dry season. The water in the dugout was becoming significantly smaller in volume, filthier, and therefore less used by tricycle drivers.

Figure 7. Left: February 7th. Right: March 27th. Source: Erga, 2023.

4.2 Part 2: Water quality analysis

In this section, qualitative results from the water sample analyses are presented and discussed.

4.2.1 Physio-chemical analysis

The results of the physio-chemical parameters analysis, completed in the laboratory at UDS in Nyankpala, are presented in Table 1.

*Table 1. Physio-chemical analysis in Bunker. Unsatisfactory numbers are marked in red. *WHO has no guideline on TDS based on health risk, but advises a limit of 1000 ppm, while lower than 600 ppm is considered good quality (WHO, 2022).*

Sample ID	Temperature (℃)	pH	Turbidity (NTU)	EC (µS/cm)	ORP (mV)	TDS (ppm)
A1	26.17	6.56	577	550	189.4	276
A2	26.18	7.12	721	273	167.3	136
A3	26.03	7.22	732	263	161	131
B1	26.13	7.04	265	265	170	133
B2	26.28	7.11	260	260	157.7	130
B3	26.31	7.1	260	260	154.7	130
C1	26.16	7.02	273	273	158.3	136
C2	26.36	7.02	272	272	155.3	136
C3	26.33	7.01	272	271	153	136
D1	26.19	6.93	271	271	155	136
D2	26.3	6.92	272	272	151.5	136
D3	26.36	6.94	272	272	148	136
WHO standards (2022)	22-29	6.5-8.5	5	1500		600/1000*

4.2.2 Microbiological analysis

Results from the laboratory analysis at GWCL in Tamale are shown in Table 2. The microbiological samples were tested for total coliforms (TC), where three out of four samples contained too numerous TC to count. All four samples were contaminated with TC. Total coliforms include both faecal and environmental coliforms. The distribution of each type is unknown.

Table 2. Microbiological results from Bunker dugout. TNTC = Too numerous to count.

<table>
<tr><th>Parameter</th><th>Unit</th><th>Method</th><th>GHANA STANDARDS</th><th colspan="4">Sample ID</th><th>WHO standards (2022)</th></tr>
<tr><td rowspan="2">Total coliforms</td><td rowspan="2">CFU/100mL</td><td rowspan="2">Membrane Filtration</td><td rowspan="2">Not detected</td><td>A1*</td><td>A2*</td><td>B1*</td><td>B2*</td><td rowspan="2">0</td></tr>
<tr><td>TNTC</td><td>250</td><td>TNTC</td><td>TNTC</td></tr>
</table>

4.3 Understandings of results

4.3.1 Part 1: field analysis

The insight from the in-depth analysis of the dugout reveals few to no treatment practices among the users, despite the numerous water quality challenges, including smell and taste. Possible explanations for this are a lack of knowledge of the perils of contaminated drinking water and low financial resources available for treating the water. The dugout water serves various purposes beyond drinking, such as clothes washing, providing water for cattle, and fishing. The observations of users doing laundry directly on the dugout wall, poses a risk of chemical cross-contamination. However, this study does not assess the contamination risks associated with these practices, only recognizing them as potential factors.

Burning of plastic and poor waste disposal practices in the area could contaminate the dugout. Some small amounts of garbage were observed to be floating in the dugout, as well as on the land close by. As mentioned in Chapter 2.1, CECs are an increasing contamination source of severe health concerns if consumed excessively. Other potential sources of contamination to the dugout include agricultural activities such as fertilizers, animals' and birds' excreta, algae blooming, road runoff, humans entering the water, and industrial waste. During the rainy season, contamination from industrial and street pollutants accumulating in the soil can potentially contaminate the water through runoff. However, this was not tested in the water quality assessment and requires further investigation.

The numerous economical trees in the area surrounding the dugout may cause potential water losses, as mango trees, for instance, require some volumes of water each day. Other water losses can be due to evaporation and animal consumption.

4.3.2 Part 2: water quality analysis

The physio-chemical results reveal very high values of turbidity in every sample, which was expected, considering the clay-coloured water. Samples A1-A3 have significantly higher values (577-732) of turbidity than the rest (260-273). Possible reasons could be stirring of sediments as the sampler entered the water. The values in samples B, C and D are still far above WHO's recommended limit of 5. Settling the water before consumption will lower these values, but not enough for the water to be safe to drink.

Except for turbidity, the other parameters are within the World Health Organization's (WHO) standards for drinking water (WHO, 2022). An example is pH, which ranges between 6.56 and 7.11, within recommended values, 6.5-8.5, for drinking water. Electrical conductivity (EC) levels (260-550) are well under the limit of 1500. However, acceptable values for EC depend on other factors such as the mineral composition (WHO, 2022), a more thorough water analysis is necessary to evaluate EC.

The most significant parameters indicating contamination with human health risks are turbidity, ORP, and total coliforms. The WHO guidelines for drinking water standards (WHO, 2022) do not imply any limit for Oxidation Reduction Potential (ORP). As ORP is considered an important indicator for polluted water, lower values imply that the water is less anaerobic than it should be. Therefore, low values of ORP, could pose a risk to human health as the faecal disease *E coli* survives easier in anaerobic conditions (Roslev et al., 2004).

The microbiological results from the analysis at GWCL laboratory are worrying, with three out of four samples containing too numerous to count numbers of total coliforms (TC). Significant amounts of total coliforms in the water relate to the high microbiological contamination possibly caused by the animals and humans walking into the dugout. It is therefore evident that the water source is contaminated to the levels that humans face significant health risks by drinking it.

However, it was not tested for faecal coliforms, which are a more evident proof of the presence of *Escherichia coli.* Faecal contamination with *E. coli* or other waterborne diseases is therefore not proven. Further water quality tests are necessary to investigate this. Heavy metals and CECs are also not investigated in the water quality analysis. They will therefore not be heavily accounted for when evaluating which treatment measurement is most suitable. It can only be assumed that these substances could reach the dugout through runoff contamination.

4.3.3 Relevance of research

The outcomes of qualitative and quantitative methods employed in this study have provided insight into the challenges and practices related to water quality and quantity in Kukpehi community. Despite limitations in accessing previous data on the water quality, the two tables with analyses prove obvious contamination in the dugout. The in-depth analysis of the dugout is of significant relevance in this field, with previously discussed literature that revealed a lack of in-depth analyses of the dugout users' treatment practices. Additionally, the water quality analysis exists as highly relevant and important, as there is an abundance of studies on dugout water quality in the recent years. However, a more thorough analysis can be assessed with a larger quantity of samples to provide more data and insight.

4.4 Reflections and limitations of study

Available resources, both financial and equipment, are limitations affecting the research data outcomes. Lack of these resources have an impact on the conclusions drawn from this research. Size of sample selection may also affect the results. The number of participants could be higher to increase the levels of trustworthy qualitative data. However, the participants were carefully chosen to be a representative group with assorted demographic information. They were all daily users of the dugout and had the necessary knowledge required. Therefore, the number of 11 participants was considered a suitable amount to obtain the required information to answer the research objective.

One-to-one interviews could be made to obtain more detailed information about the dugout users' financial status. Their annual income for each household would be informative to suggest the most optimal HWTS. Using an assistant translator during the FGDs consequently led to the author not participating in the conversations, and for this reason, additional follow-up questions to their answers were not made. Another reason was to not spend more than one hour per group, so the participants were not deprived of their time. However, the FGD questionnaires were carefully planned prior to execution, with assistance from the translator and other experienced academic personnel, mentioned in the Acknowledgements, at UDS in Nyankpala.

The absence of previous research on this topic will also affect the conclusions. Most notable is the absence of previous data on the water quality, which would be useful in comparison of dry to wet seasons. Naturally, the currently limited sample size affects the reliability of this research. Despite limitations in accessing previous data on the water quality, the two tables with analyses certainly prove contamination in the dugout at the time of the sampling.
Few studies on the geological terrain and the socio-economic attributes of the inhabitants in the Tolon district also affect the results.

As there were only made water samples for one day each for the parameters, the only comparisons that can be made are for the WHO standards for drinking water values. The possible variations in the values over time can therefore not be ascertained. However, the main interest in the water samples was to obtain an indication of the current quality traits of the dugout, which was manifested in the laboratory results. The people were collecting water to drink and use in their households from the exact locations as the sampler did the same day. This results in dangers of contamination in their domestic water use.

4.5 Solutions for improvement

Validating the necessity to address the improvement of drinking water quality from the dugout, suitable water treatment solutions will be discussed to answer the final research question;
3) What are the most feasible options to meet these challenges?

Considering mean annual income in rural households in Ghana, in Table 3, the participants' income (low to medium) does not cover much. Reflecting upon their willingness to pay (WTP) for treated water, while considering 20 L per collected can, a calculation for the maximum cost for treated water per household per year is shown in Table 3. The maximum cost covers the domestic users' WTP.

Table 3. Estimated cost for treated water for a household. WTP = willingness to pay, p = person, d = day, h = household. Source: (Ghana Statistical Service, 2019).

Mean annual income/h	WTP/collection	Mean h size	Water consumption p/d, h/d	Cost h/d	Cost h/year
17,830 GHC = €1,476	0.3 GHC = €0.025	6	20 L, 120 L	€3.0	€54.75 (3.75% of annual income)

Bearing in mind that this is the mean annual income in the rural areas in Northern Region, some of the dugout users will have less income than average. For example, the low economical state of the dugout users requires them to prioritize energy for cooking, rather than boiling the water for purification. Boiling as a treatment measure is therefore not applicable. Considering low to medium annual income water treatment measures for households might be recommended sharing between several households to minimize costs and to optimize maintenance procedures. Another solution is a water management committee, regulating the HWTS in the community square. Additionally, community participation is proven to increase the sustainability of an improved water source (Marks et al., 2014).

Considering the dugout water users' financial status, affordable solutions to treat the water are essential. Simple treatment measures are also of attention, to ensure the dugout users' capability in treating the water themselves. Three areas of recommendations for improvement are of interest:

1: Solutions that may be implemented in households or at agglomerated levels.
2: Measures to sustain quality and avoid contamination on-site.
3: Reduction of volume loss to sustain higher quantity throughout the dry season.

4.5.1 1: HWTS recommendations

The discoveries of the water contents concerning turbidity and microbial life pose a challenge for some types of household water treatment technologies. As explained in Chapter 2.2, certain filtration technologies do not work efficiently for high turbid water, such as the bio-sand filter or cotton cloth filters, which are commonly used in households with low economical resources. This implies that filtration technologies for high turbid water or coagulation sedimentation are necessary measures for domestic water purification.

Considering the high evaporation rates during the dry season in the Tolon district (Agodzo, 2023), evaporation as a treatment measure is highly effective. It is a natural process that requires only a plastic cover and containers to store the purified water. The material will be covered with biofilm over time, which will need frequent replacement. This is a solution recommended for the dugout managers or for a water treatment committee within the community, to operate and maintain.

It is necessary to implement a disinfection station by the HWTS, to avoid faecal contamination when people fetch their purified water. This is due to the fact that diarrhoeal diseases often occur by poor latrine systems and hygiene practices, in low-resource communities (Dongzagla, 2021). As presented in the Literature Review, maintenance of improved water sources is known to be poor within communities. The implementation of water and sanitation management committee is of requirement, to secure the supply of safe water within the communities.

Lastly, after evaluating the properties of the solutions presented in Table 4, the recommendations for this case are the following:

- A bio-sand filter (BSF) or the SIPP, coupled with Moringa coagulation.
- A water evaporation station for a single household or for a few households to share.

To implement BSFs on household levels, it is necessary to monitor the BSFs with regular quality controls and to educate the users on proper maintenance and use. Considering the low income of the dugout users, the cost of one BSF in each household might be unfeasible. Therefore, community-scale treatment measures would be more affordable. Implementing a small number of BSFs in the community square, or somewhere close to the collection point at the dugout, will not only decrease the total cost for each household but also increase the level of proper maintenance of the filter. If the BSFs are placed alongside the dugout, the cleaning of the filter could be the responsibility of the dugout managers. Likewise, if placed in the community square, a chosen group in each community could be educated on how to maintain the filter. This way, the dugout users can consume safe drinking water, without subjecting themselves to immense costs.

Table 4. Properties of different solutions for drinking water treatment.

	Boling	Evaporation	BSF, SIPP	Cotton cloth filter	Alum	Moringa seeds
Pros	User-friendly. Effective disinfectant. No maintenance.	User-friendly. No energy demand. Can be stored anywhere. !00% purifier. Medium affordable. Sufficient alone.	User-friendly. Local materials Medium turbidity removal. Effective bacteria removal. Medium affordable.	User-friendly. Local materials. Affordable.	User-friendly. Medium turbidity removal. Medium heavy metal removal. No maintenance. Affordable.	User-friendly. Health benefits. Natural Effective disinfectant. Medium heavy metal removal. Affordable.
Cons	High energy demanding. Poor turbidity removal.	Require maintenance. Frequent material replacements, might be costly.	Does not remove viruses. Require maintenance.	Poor turbidity removal. Require maintenance.	Health risks.	Needs purification. Poor turbidity removal.

4.5.2 2: Measures to sustain water quality

External factors that might affect the quality are the runoff contamination sources, presented earlier. These can be avoided by ensuring a more enclosed water source, with these recommendations:

- Build a more stable wall around the dugout.
- Blockage to prevent the animals from entering the dugout.
- Make sure people are not collecting water directly from the source, rather educate them on collecting water from the hoses to prevent diseases.

4.5.3 3: Measures to sustain water quantity

Unnecessary water loss occurred at times. Tricycle drivers used improper pump outlets to fill cans, losing volume to the ground and water gathering was sometimes faulty. Economical trees require large amounts of water each day, which might be subtracted from the dugout via infiltration in the soil. Measures of recommendation are the following:

- Make pipes or hoses in the ground to lead water out of the dugout and into another pond for animals to drink.
- Separating water portions for animals and humans to prevent cross-contamination.
- Water losses during the filling of the cans for the users can be collected and stored in the same pond.
- Adopting more efficient water-filling techniques to minimize water loss.

4.5.4 HWTS committee

Lastly, this study also suggests the implementation of a HWTS management committee, consisting of community members to follow up on operation and maintenance. This will sustain continuously purified drinking water. A water treatment committee consisting of local community members, frequently inspecting and maintaining the water purification systems, will increase the efficiency of the treatment and provide the communities with more knowledge regarding sanitation, which could prevent the occurrence of diarrhoea among the households. As water collection chores are mainly females' responsibility in the Northern Region's communities depending on unimproved sources, a water committee consisting of females would be preferable. However, socio-economic conditions may not let females acquire managing positions, and therefore this needs to be evaluated for further research.

5 Conclusions and Recommendations

5.1 Conclusions

This study provides a throughout comprehension of the research objective:
To provide an understanding of the prevailing water quality issues, their underlying causes, and potential solutions through an in-depth analysis of a dugout in the Kukpehi community, of the Tolon district of the Northern Region of Ghana.

Based on the results of the in-depth analysis of the study dugout and its users, this study concludes that the collected water is not safe to consume and should be treated to avoid possible human health risks. The main points derived from the research findings include a strong suggestion of drinking water quality challenges, with turbidity and coliforms exceeding the recommended limits. Meanwhile, the focus group discussions reveal a lack of water treatment practices and financial resources. Visual observations on-site indicate possible contamination sources, of both human and animal activity inside the water source. The in depth-analysis of the dugout therefore clearly demonstrate the necessity of addressing an improvement of the collected dugout water, which per se is not safe for domestic consumption.

In summary, the recommendations for treatment of the dugout water are a comprehensive combination of the following methods:

1: To ensure the users of safe consumed water, a bio-sand filter in combination with Moringa seeds, or water evaporation with plastic cover.
2: To prevent further contamination in the water source, measures in securing water quality were suggested.
3: To secure the volume to last throughout the dry season, measures to sustain the water quantity include a separation of humans' and animals' water portions and more efficient water filling.

Consequently, this study has formerly managed to answer the three research questions:

1) What are the known challenges and common practices for domestic water collection in the study area?

This research clearly demonstrates challenges with both water quantity and water quality in a dugout. Some potential sources of contamination were identified, but not all were confirmed through water analysis. It was found that households with low resources used little or no water treatment before consuming domestic water. Undoubtedly this strengthens the significance of the effort made in this thesis.

2) Is the collected water safe enough for human consumption?

While this study clearly illustrates that the collected water is not safe for human consumption, it also raises the question of whether there are pathogens such as *E. coli* present. It does not investigate the variation of water quality during a period but recognises the contamination present at the time of the analysis.

3) What are the most feasible options to meet these challenges?

Throughout this thesis, it has been argued for the necessity of HWTS in communities depending on dugouts. Recommendations suitable for low-resource communities were made, but the completion is yet to be explored further.

As shown in this thesis, there are too few studies investigating the dugout water quality, and it is therefore of high relevance and necessity to address this issue. While the less resourceful inhabitants in communities like Kukpehi continue to consume contaminated water, health issues such as waterborne diseases will linger. Recognising the significance of educating individuals facing unimproved water sources, it becomes crucial to emphasize the importance of domestic water treatment, sanitation, and hygiene practices.

5.2 Recommendations for further research

Further research is needed to establish more data on whether the dugout contains *E. coli* and heavy metals, which are common in the region. A terrain analysis to decide the catchment area, and possible inflow of pollutants, including their sources, is also recommended for further work. Whether the dugout bottom is solid or includes infiltration to the groundwater is also relevant to decide whether the water balance is controlled by surface inflow and evaporation, or by other factors. To evaluate the significance of evaporation and other water losses to plants and animals, it is recommended to investigate the volume of the dugout throughout the season. Thus, one could ascertain if the dugout can serve all the inhabitants throughout the year, with proper treatment and lesser loss of its quantity. A more thorough analysis of the costs of implementing and maintaining different HWTS can provide a more concise recommendation for treatment. Investigating the users' financial attributes, such as their mean annual income, will increase the suitability of the HWTS recommendation.

References

Agodzo, S. K. B., E.; Nyatuame, M. (2023). A review of the water resources of Ghana in a changing climate and anthropogenic stresses. *Frontiers in Water*. https://doi.org/10.3389/frwa.2022.973825

Anang, B. H. A., G. Danso-Abbeam. (2020). Estimating technology adoption and technical efficiency in smallholder maize production: A double bootstrap DEA approach. *FOOD SCIENCE & TECHNOLOGY*. https://www.tandfonline.com/doi/full/10.1080/23311932.2020.1833421?scroll=top&needAccess=true&role=tab&aria-labelledby=full-article

Araya, D., Podgorski, J.E., Kumi, M.A., Mainoo, P.A., & Berg, M. (2022). Fluoride contamination of groundwater resources in Ghana: Country-wide hazard modeling and estimated population at risk. Water research, 212, 118083 . *Water research*. https://doi.org/10.1016/j.watres.2022.118083

Asante, F., & Amuakwa-Mensah, F. (2014). Climate Change and Variability in Ghana: Stocktaking. *Climate*, *3*, 78-99.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., & Bartram, J. (2014). Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. *PLoS medicine*. https://doi.org/https://doi.org/10.1371/journal.pmed.1001644

Baken, K. A., Sjerps, R. M. A., Schriks, M., & van Wezel, A. P. (2018). Toxicological risk assessment and prioritization of drinking water relevant contaminants of emerging concern. *Environment International*, *118*, 293-303. https://doi.org/https://doi.org/10.1016/j.envint.2018.05.006

Bancessi, A., Teodósio, R., Duarte, E. et al. . (2022). Moringa as a household water purification method – community perception and pilot study in Guinea-Bissau. https://doi.org/https://doi.org/10.1186/s12889-022-14344-w

Boelee, F. A. E. (2014). Household water treatment and storage in Savelugu-Nanton Municipality, Northern Ghana. https://www.ircwash.org/blog/household-water-treatment-and-storage-savelugu-nanton-municipality-northern-ghana

Cabral, J. P. S. (2010). Water Microbiology. Bacterial Pathogens and Water. https://doi.org/10.3390/ijerph7103657

Chaukura, W. G. N. (2017). Organic contaminants in African aquatic systems: Current knowledge, health risks, and future research directions. https://doi.org/10.1016/j.scitotenv.2017.11.121

Cobbina, S. J. A., L.Y; Nyame, F.; Hodgson, I.O.A. . (2009). Water quality status of dugouts from five districts in Northern Ghana: implications for sustainable water resources management in a water stressed tropical savannah environment. https://link.springer.com/article/10.1007/s10661-009-1059-6#citeas

Cobbinah, P. B., Okyere, D. K., & Gaisie, E. (2020). Population Growth and Water Supply: The Future of Ghanaian Cities. In I. R. Management Association (Ed.), *Megacities and Rapid Urbanization: Breakthroughs in Research and Practice* (pp. 96-117). IGI Global. https://doi.org/10.4018/978-1-5225-9276-1.ch005

CWSA Tamale. (2023). Water quality, pollution & the impact of polluted water in rural areas. In S. E. (author) (Ed.).

Dey, N. C., Parvez, M., Saha, R., Islam, M. R., Akter, T., Rahman, M., Barua, M., & Islam, A. (2019). Water quality and willingness to pay for safe drinking water in Tala Upazila in a coastal district of Bangladesh. *Exposure and Health*, *11*, 297-310.

Dongzagla, A. J., S.; O'Hara, S. (2021). Seasonality in faecal contamination of drinking water sources in the Jirapa and Kassena-Nankana Municipalities of Ghana. https://doi.org/10.1016/j.scitotenv.2020.141846

EPA, E. P. A. (2011). Ghana's Second National Communication to the UNFCCC. 102-105. https://unfccc.int/resource/docs/natc/ghanc2.pdf

Ghana Statistical Service (GSS). (2020). Multi Dimensional Poverty - Ghana. https://www.undp.org/ghana/publications/ghanas-multidimensional-poverty-index-report

Ghana Statistical Service, G. (2019). *Ghana Living Standards Survey (GLSS)*. https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/GLSS7%20MAIN%20REPORT_FINAL.pdf

Ghana Statistical Service GSS. (2022). *Water and Sanitation* https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/Volume%203M_Water%20and%20Sanitation_240222a.pdf

GMET. (2022). 2022 Seasonal Forecast. *Ghana Meteorological Agency*. https://www.meteo.gov.gh/gmet/download/seasonal-forecast-for-the-northern-sector-and-seasonal-forecast-update-for-the-southern-sector-of-ghana-june-aug-jja-and-jul-sept-jas-for-the-country-2022/?wpdmdl=11542&refresh=644b7a326f0821682668082

Gyau-Boakye, P. K.-Y., K.; Darko, P.K.; Dapaah-Siakwan, S.; Duah, A.A. (2008). Groundwater as a vital resource for rural development: An example from Ghana. In *Applied Groundwater Studies in Africa* (Vol. 1st Edition, pp. 22). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9780203889497-12/groundwater-vital-resource-rural-development-example-ghana-gyau-boakye-kankam-yeboah-darko-dapaah-siakwan-duah

Halem, D., Laan, H., Heijman, S., Dijk, J., & Amy, G. (2009). Assessing the Sustainability of the Silver-Impregnated Ceramic Pot Filter for Low-Cost Household Drinking Water Treatment. *Physics and Chemistry of the Earth, Parts A/B/C*, *34*, 36-42. https://doi.org/10.1016/j.pce.2008.01.005

Hartman, R. M., Cohen, A. L., Antoni, S., Mwenda, J., Weldegebriel, G., Biey, J., Shaba, K., de Oliveira, L., Rey, G., Ortiz, C., Tereza, M., Fahmy, K., Ghoniem, A., Ashmony, H., Videbaek, D., Singh, S., Tondo, E., Sharifuzzaman, M., Liyanage, J., . . . Nakamura, T. (2023). Risk Factors for Mortality Among Children Younger Than Age 5 Years With Severe Diarrhea in Low- and Middle-income Countries: Findings From the World Health Organization-coordinated Global Rotavirus and Pediatric Diarrhea Surveillance Networks. *Clinical Infectious Diseases*, *76*(3), e1047-e1053. https://doi.org/10.1093/cid/ciac561

Jeil, E. B., Abass, K., & Ganle, J. K. (2020). "We are free when water is available": gendered livelihood implications of sporadic water supply in Northern Ghana. *Local Environment*, *25*(4), 320-335. https://doi.org/10.1080/13549839.2020.1744118

Kayaga, S. M., Amankwaa, E. F., Gough, K. V., Wilby, R. L., Abarike, M. A., Codjoe, S. N. A., Kasei, R., Nabilse, C. K., Yankson, P. W. K., Mensah, P., Abdullah, K., & Griffiths, P.

(2021). Cities and extreme weather events: impacts of flooding and extreme heat on water and electricity services in Ghana. *Environment and Urbanization*, *33*(1), 131-150. https://doi.org/10.1177/0956247820952030

Kranjac-Berisavljevic, G. (2015). Transformations of traditional landuse systems. *ICDD Working Papers*. https://web.archive.org/web/20180416064134id_/http://www.uni-kassel.de/upress/online/OpenAccess/978-3-7376-0032-3.OpenAccess.pdf

Kranjac-Berisavljevic, G. A.-G., S.; Gandaa, B.; Abagale, F. (2014). Dry Spells Occurrence in Tamale, Northern Ghana – Review of Available Information. *9*, 468-474. https://doi.org/10.20965

Krueger, R. A. C., M.A. (2008). Focus groups: A practical guide for applied

research. *4th*. https://www.ccsu.edu/oira/assessment/files/FocusGroupsHints.pdf

Krupińska. (2020). Aluminium Drinking Water Treatment Residuals and Their Toxic Impact on Human Health. *Molecules*. https://doi.org/10.3390/molecules25030641

Kulinkina, A. V., Kosinski, K. C., Liss, A., Adjei, M. N., Ayamgah, G. A., Webb, P., Gute, D. M., Plummer, J. D., & Naumova, E. N. (2016). Piped water consumption in Ghana: A case study of temporal and spatial patterns of clean water demand relative to alternative water sources in rural small towns. *The Science of the total environment*. https://doi.org/10.1016/j.scitotenv.2016.03.148

Malik, Q. H. (2018). Performance of alum and assorted coagulants in turbidity removal of muddy water. *Applied Water Science*, *8th*. https://doi.org/https://doi.org/10.1007/s13201-018-0662-5

Maps, G. (2023). *Map of the study area*. Google Maps, https://www.google.com/maps/@9.4179344,-0.9704885,4006m/data=!3m1!1e3

Marks, S. J., Komives, K., & Davis, J. (2014). Community Participation and Water Supply Sustainability:Evidence from Handpump Projects in Rural Ghana. *Journal of Planning Education and Research*, *34*(3), 276-286. https://doi.org/10.1177/0739456x14527620

Mehidinejad, M. H. B., B. (2018). Application of Moringa oleifera coagulant protein as natural coagulant aid

with alum for removal of heavy metals from raw water. *Desalination and Water Treatment*. https://doi.org/10.5004/dwt.2018.22546

Momba, J. M. B. M. M. (2013). Removal of waterborne bacteria from surface water and groundwater by cost-effective household water treatment systems (HWTS): A sustainable solution for improving water quality in rural communities of Africa. https://doi.org/10.4314/wsa.v39i4.2

Nakamoto, N. G., N.; Collins, M.R.; Gimbel, R. (2014). *Progress in Slow Sand and Alternative Biofiltration Processes*. IWA Publishing. https://doi.org/10.2166/9781780406381

Nauges, C. S., J. (2017). Water Hauling and Girls' School Attendance: Some New Evidence from Ghana. *Environmental and Resource Economics*. https://link.springer.com/article/10.1007/s10640-015-9938-5#App1

Ofori, F. K. A. N. K.-B. E. (2009). Degradation of the Nasia River Basin in Northern Ghana. *Development Studies*, *6*. http://www.udsspace.uds.edu.gh/bitstream/123456789/722/1/DEGRADATION%20OF

%20THE%20NASIA%20RIVER%20BASIN%20IN%20NORTHERN%20GHANA.pdf

Roslev, P., Bjergbæk, L. A., & Hesselsoe, M. (2004). Effect of oxygen on survival of faecal pollution indicators in drinking water. *Journal of Applied Microbiology*, *96*(5), 938-945. https://doi.org/10.1111/j.1365-2672.2004.02209.x

Rossiter, H. M. A. O., P.A.; Awuah, E.; MacDonald, Alan M.; Schäfer, A. I. . (2010). Chemical Drinking Water Quality in Ghana: Water Costs and Scope for Advanced Treatment *Science of the Total Environment* https://nora.nerc.ac.uk/id/eprint/9668/1/Rossiter_et_al_2010_revised_HR.pdf

Sabir, N., & Farooqi, B. J. (2008). Effectiveness of boiling in eradication of common pathogens in water. *JPMA. The Journal of the Pakistan Medical Association*, *58 3*, 140-141.

Shier, R. P. D., N.; Ross, D.A.; Binka, F.N.; Quigley, M.; Smith, P.G. (1996). Drinking water sources, mortality and diarrhea morbidity among young children in Northern Ghana. *Tropical Medicine & International Health*. https://doi.org/10.1046/j.1365-3156.1996.d01-55.x

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M., & Elliott, M. A. (2008). Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World. *Environmental Science & Technology*, *42*(12), 4261-4267. https://doi.org/10.1021/es702746n

Stauber, C. E., Kominek, B., Liang, K. R., Osman, M. K., & Sobsey, M. D. (2012). Evaluation of the Impact of the Plastic BioSand Filter on Health and Drinking Water Quality in Rural Tamale, Ghana. *International Journal of Environmental Research and Public Health*, *9*(11), 3806-3823. https://www.mdpi.com/1660-4601/9/11/3806

Troeger, C., Blacker, B. F., Khalil, I. A., Rao, P. C., Cao, S., Zimsen, S. R. M., Albertson, S. B., Stanaway, J. D., Deshpande, A., Abebe, Z., Alvis-Guzman, N., Amare, A. T., Asgedom, S. W., Anteneh, Z. A., Antonio, C. A. T., Aremu, O., Asfaw, E. T., Atey, T. M., Atique, S., . . . Reiner, R. C. (2018). Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Infectious Diseases*, *18*(11), 1211-1228. https://doi.org/https://doi.org/10.1016/S1473-3099(18)30362-1

UN. (2022). *Water and Gender*. Retrieved 07.04.2023 from https://www.unwater.org/water-facts/water-and-gender

UNICEF. (2010). Northern Regional Profile. *Child Protection Baseline Research*. https://www.unicef.org/ghana/media/2896/file/CP%20Profile%20-%20Northern%20Region.pdf

UNICEF. (2022). Water: UNICEF works to ensure that every child has access to safe drinking water. https://www.unicef.org/ghana/water#:~:text=Seventy%20six%20per%20cent%20of,not%20treat%20water%20at%20all.

United Nations. (2003). *World must act now to provide safe water, further delay entails great risk – Annan*. Retrieved 8.06 from https://news.un.org/en/story/2003/08/78022

Vigneswaran, S. (2009). *Wastewater Recycling, Reuse, and Reclamation - Volume II* https://books.google.no/books?id=uCYyCwAAQBAJ&lpg=PA84&ots=a_YxHxM8-

4&dq=community%20cloth%20filter%20domestic%20water%20&lr&pg=PA84#v=onepage&q=community%20cloth%20filter%20domestic%20water&f=false

WHO. (2022). Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. *Environment, Climate Change and Health, Water, Sanitation, Hygiene and Health*. https://www.who.int/publications/i/item/9789240045064

WHO and UNICEF. (2021). *Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs*. https://washdata.org/reports/jmp-2021-wash-households

Yaya, S., Hudani, A., Udenigwe, O., Shah, V., Ekholuenetale, M., & Bishwajit, G. (2018). Improving Water, Sanitation and Hygiene Practices, and Housing Quality to Prevent Diarrhea among Under-Five Children in Nigeria. *Tropical medicine and infectious disease*, *3*. https://doi.org/10.3390/tropicalmed3020041

Yeleliere, E., Cobbina, S. J., & Duwiejuah, A. B. (2018). Review of Ghana's water resources: the quality and management with particular focus on freshwater resources. *Applied Water Science*, *8*(3), 93. https://doi.org/10.1007/s13201-018-0736-4

Aarø, S. S. (2020). *A review of selected natural coagulants in water and wastewater treatment* Norwegian University of Life Sciences (NMBU),]. https://hdl.handle.net/11250/2721601

Appendices

Appendix A

QUESTIONNAIRE FOR TRICYCLE DRIVERS

Name of Enumerator ……………………………………………………………………

Community……………………………………………………………………………

GPS Location: ………………………………………………………………………….

The aim of this meeting is to express and share our thoughts on the questions below where we can agree and disagree on answers/ideas until we can all come to a consensus. Note that, this is a learning process and there is no wrong answer.

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

1. Name of the participant
2. Marital status
3. Age of the participant
4. Household size
5. Occupation & Income
6. Educational level (i.e literate or illiterate)

We can take all this before the discussion commences.

SECTION B: USAGE AND WATER QUALITY

1. Distance from your supply to watering point (dugout) in km. *Maybe we should investigate this ourselves using the coordinates*.
2. How often do you use water from this watering point for sells?

[0] Everyday [1] Seasonally [2] Others (specify)………… ……

3. Do you have other source of water for sell apart from the dugout? Please state.
4. What are your customers usage areas for your water collection? Multiple choice, Tick.
   i. Domestic [ ]
   ii. Irrigation [ ]
   iii. Rice parboiling [ ]
   iv. Industrial purposes/construction works [ ]
   v. Others (please specify) ……………………………..

7. Do you pay for the use of water from the watering point (dugout)?
   If yes, how much and how is the payment done?
8. What are the challenges you have at your watering point, dugout (*e.g. competition, water quality, water quantity, etc*.)?
   a) How is the water quality normally?
      i. Color …………………..
      ii. Taste ……………………

iii. Smell …………………….

iv. Others ……………………..

b) Does the quality vary? During which months is it worse?

9. Do you treat the water before sell? [0] Yes [1] No

If yes, which methods?

SECTION C: FINANCIAL MATTERS

1. How many times a day do you fetch from the dugout?
2. How much fuel do you consumed per trip?
3. Do you pay per collection (instant cash payment upon arrival) or monthly?
4. How much do you charge per can?
5. What happens when there is a shortage of water at the dugout?

i. How much do you pay for the other sources?

ii. How much would you be willing or able to pay for water treatment? Please state the amount.

SECTION D: DUGOUT ATTRIBUTES

1. Would you say the source of water you mainly depend on serves all your water needs throughout the year? i) Yes [ ] ii) No [ ]
2. Do you face seasonal water shortages in your watering point (dugout)? i) Yes [ ] ii) No [ ]

If yes;

i. During which months?

ii. How long does it last?

iii. How do you make the water last during water shortages? (water management, etc).

We then summarized all the answers to the questions and ask if they are okay or someone wants to add something.

Appendix B

CHECKLIST FOR DOMESTIC USERS

Name of Enumerator ………………………………………………………………………

Community…………………………………………………………………………………

GPS Location: ……………………………………………………………………………

The aim of this meeting is to express and share our thoughts on the questions below where we can agree and disagree on answers/ideas until we can all come to a consensus. Note that, this is a learning process and there is no wrong answer.

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

10. Name of the participant
11. Marital status
12. Age of the participant

13. Household size
14. Occupation & Income
15. Educational level (i.e literate or illiterate)

We can take all this before the discussion commences.

SECTION B: USAGE AND WATER QUALITY

5. Do you buy from the tricycles or you fetch the water yourselves from the dugout?
6. How many times a day?
7. Distance from household to watering point (dugout) in km. *Maybe we should investigate this ourselves using the coordinates*.
8. How often do you use water from this watering point for household use?

[0] Everyday [1] Seasonally [2] Others (specify)………… ……

9. Do you have other source of water apart from the dugout? Please state.
10. What are the usage areas for your water collection? Multiple choice, Tick.
    i. Drinking [ ]
    ii. Cooking [ ]
    iii. Cleaning [ ]
    iv. Washing clothes [ ]
    v. Others (please specify) ……………………………..

16. Do you pay for the use of water from the watering point (dugout)?
    If yes, how much and how is the payment done?
17. What are the challenges you have at your watering point, dugout (*e.g. competition, water quality, water quantity, etc*.)?
    c) How is the water quality normally?
        i. Color …………………..
        ii. Taste ……………………
        iii. Smell …………………….
        iv. Others ……………………..
    d) Does the quality vary? During which months is it worse?
18. Do you experience sicknesses related to drinking water?

If yes, please describe the symptoms.

    i. Headache [ ]
    ii. Fever [ ]
    iii. Stomach aches [ ]
    iv. Fatigue [ ]
    v. Others, please specify…………………

19. Do you treat the water before use? If yes, which method?
    i. Boiling [ ]

ii. Chlorine [ ]

iii. Alum [ ]

iv. Filter [ ]

v. Sedimentation [ ]

vi. Others (specify)………………………………………………..

SECTION C: FINANCIAL MATTERS

3. If you buy water from the tricycles;

i. How much do you pay for the water per can?

ii. Is the price for the water reasonable?

iii. Do you pay per collection (instant cash payment upon arrival) or monthly?

4. If you fetch on your own from the dugout;

iii. What happens when there is a shortage of water?

iv. How much do you pay?

5. How much would you be willing or able to pay for water treatment? Please state the amount.

6. Would you say the source of water you mainly depend on serves all your water needs throughout the year? i) Yes [ ] ii) No [ ]

7. Do you face seasonal water shortages in your watering point (dugout)? i) Yes [ ] ii) No [ ]

If yes;

iv. During which months?

v. How long does it last?

vi. How do you make the water last during water shortages? (water management, etc).

vii. Do you pay for water when the watering point is dried up? i) Yes [ ] ii) No [ ]

viii. How much per day?

ix.

We then summarized all the answers to the questions and ask if they are okay or someone wants to add something.

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