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Water quality in the Apac, Mbale & Lira districts, Uganda

- A field study evaluating problems and suitable solutions

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Cover picture: Man walking in a street of Kampala with an important message on his t-shirt, photo by Behrens and Gardell (2015). All photos throughout the report are taken by Behrens and Gardell (2015).

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Abstract

Safe water is a widespread problem in developing countries. In 2004 The United Nations formed the *Lake Victoria Region Water and Sanitation Initiative*, which focuses on increasing the water quality and basic sanitation in both rural- and urban areas. The government of Uganda is a part of the initiative, since the quality of the drinking water in the country persists to be a widespread problem. In Uganda the socio-economic situation in the rural areas are contributing to the problems regarding development, safe water and sanitation. This small study contributes to filling the gap regarding the peoples own experiences and ideas about their water and sanitation situation in rural Uganda, as there is a lack of studies bringing up this aspect and its importance for a successful implementation of household water treatment methods. To investigate the water situation in rural areas in Uganda, a field study was preformed and households in seven villages were interviewed about how they experience their water quality.

The aim of this study was to investigate how residents in the villages experienced the water situation in relation to experienced health effects. Potential solutions in form of six general household water treatment methods and their suitability to solve the problems found at site were also a part of the aim. The methods weighted and discussed were boiling, Solar disinfection, ceramic filtration, Biosand filtration, chemical disinfection and coagulation systems. Common problems found in the villages were diarrhoeal diseases and undefined stomach complications. Many households brought up human pollution and cattle drinking in the water stations as examples of polluting sources that were contributing to contamination of the water. The study sites were chosen by the help of local guides and limited by time and the resources for this study. To analyse if there is a significant differences between the villages' answers regarding health and water quality, a chi-square test was preformed. The tests showed a difference between the villages in how unhappy they were with the water quality. The problems that have been pointed out by The United Nation were confirmed during the field study. Many of the visited water sources were in need of restoration and water related health problems were pronounced by households in all the villages. Water purification methods are uncommon in all the villages except for one, where a well working system is already in order. By some of the most commonly used point-of-use methods, the biosand filter and solar disinfection (SODIS) was found to be most suitable for several of the studied villages along with restoration of the water sources.

Key words: point-of-use method (POU), water borne disease, water quality, water source.

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All graphs, maps and tables and sections not mentioned above, as well as all preparatory work and the field study have been produced together.

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1. Introduction

During a field study in Uganda 2014 the opportunity to visit and investigate the water quality in a small rural village was given. The village of Namasale had big issues concerning their water quality and with further research we found out that the problem is widespread throughout rural Uganda. This encouraged us to investigate the water quality situation further in rural parts of the country. Throughout the exploration of the issue we found that the personal experiences by the locals were seldom considered in reports regarding implementation of household water treatment methods. This is often resulting in a short-term usage of the implemented solution. These discoveries and a great interest in the matter resulted in this report. The report therefor partly wants to shine light on the importance of considerations for local traditions to reach a sustainable water situation.

By 2015 the United Nations (UN) has decided on 8 international Millennium Development Goals (MDG) and the 7th target is to achieve and ensure environmental sustainability. One part of the initiative is to halve the proportion of the world's population without sustainable access to safe drinking water and basic sanitation. The target, known as 7C, is partly achieved in terms of improved access to drinking water in Eastern Asia, Western Asia, Northern Africa, Latin America and the Caribbean. Progress has been made worldwide towards reaching the targeting goal by 2015, although the safe drinking water situation in Africa is still an on going problem. The issue of water quality is most vital to satisfy the human needs. The expansion of agriculture and manufacturing has not only increased the demand for water, but also contributed to the pollution of ground- and surface water (UN, 2010).

To collect data considering water quality is a difficult task. So far UN (2010) has only achieved pilot surveys, limited by high cost of rapid and reliable ways to measure the quality of the water on a local basis. This issue needs to be identified to overcome both the high costs and the current technological limitations. Despite the progresses made in supplying drinking water to rural and urban areas, the rural sections still have a large disadvantage in developing regions. This is partly due to the fact that piped water is more common in the urban areas, estimated to be 79% more common than in the rural areas. At the year of 2010 only 8 out of 10 people in the rural areas had access to safe drinking water (UN, 2010).

In the UN-Water Global Annual Assessment of Sanitation and Drinking-Water report (2010) the issue of poor health is in many cases a result of unsafe water, lacking hygiene and insufficient sanitation (UN Water, 2010). Unsafe water for drinking and cooking, as well as substandard hygienic customs increase the ingestion of pathogens, which often results in diarrhoeal diseases. It is estimated that about 90% of the worldwide cases of diarrhoea are due to the lack of hygiene and unsafe contaminated water (UN Water, 2005). Increasing the access to safe drinking water and sanitation clearly improves health issues and broaden the livelihood benefits. Many countries have improved the water and sanitation access and approximately 1,3 billion people gained access during the period of 1990 to 2008. Although the worldwide progress, several countries in northern, central and east Africa still remain within limited access to clean water and sanitation (UN Water, 2010).

Starting in 2004 UN has, together with governments around Lake Victoria such as Kenya, Tanzania and Uganda, developed an initiative to change the countries lack of high quality water. There are multiple factors accounting for the water quality of today and the issue is increasing with the population growth in the area around Lake Victoria (UN Habitat, 2010).

Generally the population in the rural areas and secondary cities have a lower income than the national average. This is a limiting factor for the ability to get clean water and the option to purify it. In its turn, this leads to negative consequences for the health and productiveness. The governments limited possibilities and capacity to address the problem complicates the situation and the rural inhabitants ability to collect water of high quality with appropriate sanitation even further (UN Habitat, 2010).

The issue of basic water and sanitation is of most importance for Uganda's development concerning the socio-economic situation in the rural areas. The subject of matter is targeting the poorest and the most vulnerable citizens of the Ugandan society. The available amount of safe water for drinking and domestic use in rural areas of Uganda, falls below UNs recommendations. To collect the water women and children, who often carries the responsibility of fetching water, usually have to walk long distances to do so. Basic sanitation is a lasting issue in the rural areas of the country. Clean drinking water persists as a widespread problem, even if the water is collected from a safe water source. It often ends up contaminated due to storage and unhygienic water handling. Approximately 20% of the infant mortality in Uganda is due to diarrhoeal diseases. Water-borne diseases, such as cholera, dysentery and intestinal worms, are also part of the main health problems in Uganda (UN Water, 2005).

1.1 Point-of-use household water treatment methods

There are various methods for improving the taste, appearance and quality of drinking water in a household. Filtration systems using natural coagulants and flocculants such as porous rocks and sand to reduce suspended particles have been utilized for centuries. Boiling water, exposing it to the sun and storing it in metal containers were successfully used by generations before microbes was discovered. Today well-known approaches such as filtration, sedimentation and disinfection methods are used to inactivate and demolish microbial pathogens (Quick et al., 1996; Luby et al., 2001; Rangel et al., 2003; Souter et al., 2003; Caslake et al., 2004; Clasen and Cairncross, 2004).

The Point-of-use (hereby referred to as POU) approach to household water treatment technologies has allowed communities and individual households to treat unsafe water directly in the house. Although, a variety of methods have been developed, none of them have been able to provide a sustainable worldwide solution. POU water technologies have verified a reduction of 30-40% of diarrhoeal diseases, by improving the quality of water treated in the safety of the household and not direct at the source. Several different POU technologies are available, supplying the different needs of particular populations and circumstances, both in rural and urban areas in developing countries (Sobsey et al., 2008). The technologies presented in this report are all established worldwide and acknowledged by international organs.

Many studies have shown that it is hard to implement a POU method in a long-term approach. Studies in Kenya showed that boiling was considered to be too inconvenient, time consuming and changing the taste of the water and the method was therefore not widely used (Wellin, 1955; McLennan, 2000). Many attempts to implement the ceramic filter has been made in for example countries such as Cambodia, Nicaragua and Guatemala where it has become obvious that the breakage rates of these filters were too high for a continuous use to be established

(Brown, Sobsey and Proum, 2007). The chemical solution is also proven to be short-term, if an outside funder is unavailable (Makutsa et al., 2001).

1.2 Aim

The aim of the report is to examine the water quality in seven villages located in Uganda. By investigating how the residents cope with the potential issues regarding the quality from different type of water sources, potential solutions can be proposed. With this in mind the report aims to answer the following questions:

- How does the water situation in the seven studied villages look and how do the residents experience the water quality?

- Which of examined point-of-use methods (boiling, SODIS, Biosand, ceramic filter, chemical disinfection or coagulation) would be suitable for implementation in the villages and in areas with similar circumstances as the studied sources in Uganda, considering needs and traditions?

1.2.1 Limitations

There are many purification methods available, this study is limited to six general and common types of POU methods, analysed according to the problems at site. Given more time, the many different techniques within the more general POU-methods could have been researched. Due to time limitations the amount of villages and interviews preformed had to be constrained.

As this is a pilot project there are many parts of the study that can be developed, specifically involving the field trip. An elaborated questionnaire and expanded preparatory work would have benefitted the report. An extended field trip would have made visits to health institutions and more villages with implemented POU methods possible. This would create opportunities for comparisons between health statistics, the acceptance and implementations of different POU methods.

2. Background

The Point-of-use methods are described in section 2.1. A description of the climate can be found in section 2.2. For guidance and ways to approach the field study, meetings with people working within the field in Uganda are described in section 2.3.

2.1 Point-of-use water treatment methods

To implement household water treatment methods several requirements and limitations are to be considered. By studying already applied methods, limitations and recommendations for implementing household water disinfection systems can be made. Sobsey et al. (2008)

presents several requirements to be considered for sustainable point-of-use water treatment methods:

- *Quality* – water quality should be able to vary without the technology losing its efficiency
- *Quantity* – process a sufficient amount of water to meet the daily household needs
- *Time* – method should not be time consuming, therefore demand as little time as possible without interfering with the daily household tasks
- *Maintenance* – accessible and affordable supply chain, if a unit is damaged it should not demand expensive technology to repair the device
- *Cost* – method should be insensitive to changes in the income, not causing households to stop treating water due to reductions of income.

2.1.1 Boiling

The oldest method to disinfect water used at household level is boiling and is estimated to be used by more than 350 million people worldwide (Sobsey, 2002; Rosa and Clasen, 2008). Although only 4.7% report that they are boiling their water in sub-Saharan countries (Rosa and Clasen, 2008).

Some waterborne pathogens, bacteria and protozoan cysts have shown hard to inactivate with chemical disinfection (Block, 2001). When water has been heated over 55°C, it has shown to kill most waterborne pathogens. Further it was discovered that when water is heated over 70°C, the amount of coliforms are drastically reduced (Lijima et al., 2001). Boiling is a commonly recommended method for the purification of water globally, when the conventional water is polluted (CDC, 2005). The standard recommendation from WHO is that the water should come to a rolling boil before it is clear to drink it (WHO, 2004).

In many households in developing countries it is difficult to boil the water due to unavailable or to costly firewood (Clasen et al., 2008). 1 kilo of wood is estimated to be enough to boil 1 litre of water (Davis and Lambert, 2002). Studies preformed in India has shown that the annual cost to boil the drinking water is US$ 1.66 per person using firewood, considered fairly high (Clasen et al., 2008). Over half of the world's population relies on firewood, charcoal and similar biomass products for energy and cooking (Rehfuess and Prüss-Üstün, 2006). In recommendations from the 1980s, governments in developing countries have been discouraged to advice the populations to use the boiling method, due to the pressure on the supplies of firewood etc. (Gilman and Skillicorn, 1985). In general the method of boiling water has been advised by governments and NGOs (Wellin, 1955). A campaign by the *Ministry of health* to implement household boiling in the 1950's was very successful. Currently the recommendation by the *National Red Cross Societies* in the Southern Africa Region is that drinking water should be boiled for 10 minutes before intake (AFRC, 2000). There are programmes, run by UNICEF, promoting mothers (Lozinski, 2006) and educating students in school and to boil water at household level (UNICEF, 2004).

There are many negative aspects along with the positive effects after boiling of water on household level. The costs and time required along with the emissions of the fuels as the stoves often are situated indoors with poor ventilation are causing health hazards (Rehfuess, Mehta and Prüss-Üstün, 2006). Apart from the influenced air quality there is a risk of burn incidents and in many countries the fuel used is environmentally unsustainable (Clasen, T. 2009).

During a study in a village, highly affected with diarrhoea in Kenya, it became obvious that even if boiling was the primary choice of purification method, it was not widely used. This was due to a number of factors, such as the inconvenience, the matter of time, as well as the change in the taste and the lack of knowledge about the effects of drinking unsafe water (Wellin, 1955; McLennan, 2000). Furthermore boiled water has a high risk of becoming recontaminated, due to the unsecure storage in private households (Wright, Gundry and Conroy, 2003; Brick et al., 2004).

2.1.2 Solar disinfection (SODIS)

Professor Aftim Acra at the American University of Beirut was the first to conclude researches on solar water disinfection in the 1980s (Acra, Raffoul and Karahagopian, 1984). The antimicrobial effect by using ultraviolet and infrared radiation together was confirmed by Swiss Federal Institute for Environmental Sciences and Technology and Department of Water and Sanitation in Developing Countries (SANDEC) (Wegelin et al., 1994). The study showed that only a quarter of the ultraviolet light was needed at water temperatures of 50°C to inactivate and demolish the same amount of faecal coliforms as water with a temperatures of 30°C (Wegelin et al., 1994). Further field studies were accomplished by SANDEC to investigate suitable materials and configurations when exposing water to the sun. Materials that were tested were such as plastic bottles, plastic bags and glass. Conclusions were that the weather condition and turbidity, using plastic polyethylene terephthalate bottles filled with water, is affecting the antimicrobial effect and the exposure time (SANDEC, 2002).

Except for boiling, using solar disinfection is the second most common household water treatment and non-commercial option implemented according to SANDEC (2002). The SODIS water disinfection method is based on the effect of ultra-violet rays provided by the sun. The SODIS method is based on using a transparent polyethylene terephthalate bottles (PET bottles), or other see-through containers such as glass, to treat aerated water. When exposing the water-filled bottle during the most effective hours of sun, pathogens present in the water can be inactivated and demolished (Sobsey et al., 2008). When exposing the water to the UV rays, the disinfection is caused by the combination of radiation and thermal treatment of the water. If the water reaches a temperature of minimum 50°C, 1 litre of water requires approximately six hours of exposure (SANDEC, 2002). The SODIS method requires the water to be clear. If the water has a high turbidity and discolouration, it may cause the penetration of UV light to be less effective. This also requires the surface of the container or plastic bottle to be unscratched/undamaged, which can decrease to penetration of UV rays (Sobsey et al., 2008).

The effectiveness of the SODIS method can be increased when installing metal panels, causing the rays to hit the water container from all directions. Solar disinfection has been well documented and proven to effectively prevent diarrhoeal diseases and faecal pathogens, both in laboratory and in field conditions. A cost-effective investigation for implementing solar disinfection in 13 different countries has shown that, including hardware such as plastic bottles, the total costs was US$ 0.63 person/year (Clasen et al., 2007)

2.1.3 Ceramic filters

The ceramic filter was introduced by John Doulton in 1827. It was soon evolved into clay filters, these were in their turn further developed by the British Army (Warwick, 2002). The ceramic filter became available to the general public in 1904. The filters looked like hollow cylinders and contained a portion of silver (Russel and Hugo, 1994). Annually 10-15 million ceramic filters are sold worldwide (Lantagne, 2001).

The ceramic filter consists of porous fired clay, which purifies water by filtering organic matter and microbes by size exclusion. The two main types of ceramic filters have a pot- or candle like design, which both efficiently distract microorganisms. The design varies due to production methods and filter effectiveness (Sobsey et al., 2008). The candle design is generally produced by commercial companies and mainly used in developed countries. Candle style filters have reached relatively large coverage worldwide, but are usually not found in developing countries where water born diseases are more common. Alternatives such as the open pot design, have a lower cost and are therefor more common in the developing countries (Lantagne, 2001). Both candle- and pot designed filters have shown to effectively reduce diarrhoeal diseases (Sobsey et al., 2008).

The ceramic filter can reduce turbidity and the flow rate of the filter can differ between 1 to 3 litres per hour. At optimal flow rates, the ceramic filter produce 8 litres in 4 hours, and 20 litres in 10 hours. The flow usually decline with use, due to elements piling up covering the surface of the filter. The ceramic filter can provide a long time usage, if the filter is regularly cleaned and particles removed to obtain a constant flow (Sobsey et al., 2008).

The most successful projects implementing ceramic filters in developing countries have been made in Cambodia, Guatemala and Nicaragua by different NGOs. Filters have been produced and sold by the production cost of US$ 7.50 in the Cambodian Red Cross factory. The filters produced by the Red Cross were tested in a four-year project, where 2% were subject of breakage every month. The pot style filter has shown to be cost-effective and sufficient when removing microorganisms. Lack of technical support and funding have suspended the development and coverage in developing countries (Brown, Sobsey and Proum, 2007). There is an issue regarding breakage and reparation of the ceramic filters. Often the lack of affordability to replace the parts is the main reason why the use of ceramic filters is declining in developing countries (Sobsey et al., 2008).

2.1.4 Biosand filters

Mr David Manz developed the first biosand filters in 1991 in Canada. The method allowed slow sand filters to operate in a rapid rate. This discovery made the sand filtration method more suitable for household usage (Buzanis, 1995). The product was first tested in Nicaragua 1995, to investigate the possibility of implementing the technique in low-income settings. This led to certain improvements of the design, simplifying the maintenance and decreasing the need for sand-bed removal (Baker and Duke, 2006).

The point-of-use biosand filtration is a modification of the large-scale filtration system using sand in various sizes to slowly filtrate water by excluding microorganisms and organic matter. Turbidity in the water can also be reduced (Sobsey et al., 2008). Simple household biosand filtration systems can be built in clay material, plastic devices or metal devices. By filling the vessel with layers of sand and gravel, a pipe can be installed to either push the water to flow upwards or downwards through the material (Baker and Duke, 2006).

The most common version of the biosand filter is made out of concrete using steel moulds. Depending on its size the transportation costs can increase, if it is not produced close to the implementation site. When fabricated close to the implementation site the estimated material and production cost is about US$ 10-12 using cement and polyvinyl chlorine pipes (Fewster, Mol and Wiesent-Brandsma, 2004).

Using the biosand filtration, water can be processed at the rate of 0.25 to 1 litre per minute, which allows great volumes of water being treated during the whole day. The biosand filter can be a long lasting solution if cleaned properly, which also increases the rate of the water flow. The biosand filtration system is insensitive, which highlights the one-time costs for the device, not effecting the household economy after implementation (Sobsey et al., 2008). A survey made by Sobsey et al. (2007) shows that circa 85% of the population still uses the biosand filter eight years after implementation in Cambodia.

2.1.5 Chemical disinfection

Chemicals used for disinfection are substances such as free chlorine, chlorine bromine, ozone/oxidants, strong acids and bases, ferrates, but can also be antimicrobial metals like silver or copper. The most commonly used method in households is free chlorine, because of its availability and cost effectiveness. Many of those technologies share the same mechanistic features, though some, such as iodine and strong acids- or bases, are not recommended for extended use as they have toxic effects. Acids in lime or lemon can be used to inactivate the cholera bacteria. Ozone production is expensive to generate and hard to apply in correct doses to the water (Sobsey, 2002). The effects of silver and copper as disinfectants are uncertain at this point.

Important for the chemical purification to function properly is to add the doses correctly to the water, mix it and leave it over the accurate contact time. Variables that influence the purification efficiency are pH, temperature, turbidity and chlorine-demanding solutes, the water should be tested to establish the efficiency. To reduce chlorine-demanding solutes, such as ammonia or organic matter, the water can be neutralised by adding sodium thiosulfate (WHO, 2011).

The US Centre for Disease Control and Prevention is recommending the use of free chlorine together with safe storage as a water purification method. This method has been proved to reduce diarrheal disease by 29% on average, but can be as effective as 59%. Chlorine is added to the water in tablet- or liquid form and can be used to purify large quantities of water, after only approximately 30 minutes of contact time. Further, chlorination does not need maintenance and has the ability to clean 1000 litres of water at the cost of US$ 1. At some extent particles that get in contact with the chlorine can cause it to be less efficient and create an unappreciated taste or smell, causing scepticism against the method (Sobsey, 2008). A survey conducted in Kenya showed that implementing this method is hard. Only 33,5% of the people in the villages continued to use it 6 months after the implementation and as few as 18.5% used safe containers (Makutsa et al, 2001).

Waterguard is another common chemical used for the purification of drinking water. It is sold in tablets or as a liquid, where 1 tablet or 1 cap is enough to purify 20 litres of water. 240

millilitres of waterguard can provide safe water for 6 persons during 45 days at a cost of US$ 0.5. The total cost per person annually is US$ 0.68 (Robin, 2008).

During a flood in Nepal 2008, the groundwater got contaminated and UNICEF together with Humanitarian Aid Department of the European Commission (ECHO) and a couple of NGOs launched a point-of-use purifying project, with the goal to prevent an outbreak of diarrhoea within the local population. This pilot project provided the community with waterguard and soap, as well as knowledge about the importance of proper sanitation and hygiene. As a part of the hygiene education the importance of constructing proper latrines was promoted, as it is contributing to the contamination of the water sources. The project decreased the outbreak of diarrhoea in 6 weeks (Robin, 2008).

2.1.6 Coagulation/Chloration systems

Flocculation and disinfection agents have their origin in the late 20th century in South Africa. The products developed were supposed to reduce turbidity and chlorine-resistant protozoan cysts along with the inactivation of bacteria and viruses. The coagulation method can purify up to 20 litres of water at the same time, but is still a minor application in development areas (Clasen et al., 2007).

The coagulation and chlorine method is based on the use of tablets or sachets, which are a combination of dry coagulant-flocculent and chlorine. The coagulator is added to a specific amount of water, normally 10 litres. After a few minutes of stirring the water should stand for 30 minutes and the process is completed. During this time the coagulated material will flock and settle to the bottom of the container. To get rid of the coagulated materials the water need to be filtered through a cloth. Further the method has the ability to remove organic matter, microbes and turbidity (Sobsey et al. 2008).

Treating the water with this method costs the user approximately US$ 0.01 per litre and has a production cost of US$ 0.003 per litre (MacGregor-Skinner et al., 2004.). It has become evident that the knowledge of where to find the product and the willingness to pay for it is low (Brown, 2003). These are barriers, along with the household economies, that have shown to have a great influence on the continuation and long-term use (Colindres et al., 2007).

In 2002 a US-based company developed a ferric sulphate/calcium hypochlorite, where the ferric sulphate acts as the flocculent. The cost of the product is US$ 0.01 per litre, which can be considered high in comparison with other purification methods (Clasen et al., 2007). According to Souter et al. (2003) laboratory testing of this method has shown results reduce almost all bacteria, viruses and cysts. The method also reduces arsenic to a certain extent (WHO, 2011). Flocculants and the coagulation method were adapted in Uganda in 2005, although any results from the implementation made by Population Services International (PSI) have not yet been documented (PSI, 2006).

2.2 Climate and solar irradiation

According to the Köppen classification system the biggest part of Uganda is covered by Aw climate or *tropical wet and dry*. The second biggest class is *Am*, *tropical monsoon climate*. There are also areas covered by *Af*, *Tropical wet*, *As, Tropical wet and dry* with the variation that he dry season occurs during the period with longer days instead of during the time with shorter days as in the case with *Aw,* and *Cfb*, *Marine climate* (Chen and Chen, 2013).

Lira- and Apac district are located in *Aw* and *Am* climate zones and Mbale is completely covered by the *Am* zone, which means that all these areas have an annual average above 18°C (Chen and Chen, 2013). *Aw* climate is subtropical and defined by a pronounced dry season, with less than 60 millimetres of rain during the driest months. The *Aw* climate is humid and influenced by moist winds from southwest and dry winds from northeast. The mean temperature is 23°C, with minimum and maximum temperatures ranging between 15°C and 28°C (Wong et al., 2012). The *Am* climate is a result of the change in direction in the monsoon winds, according to season. There is a pronounced driest month, which normally occurs close after winter solstice. The rainfall is less than 60 millimetres annually (Strahler, 2007). From March until the beginning of June, Uganda receives the highest amount of precipitation and it reaches a total of 500 millimetres during this period, as the rainfall pattern follows the cloud coverage (Funk et al., 2012). There are two wet seasons, the most pronounced one is between March to May and the second is from September to October. April receives the most rainfall, on average 150 millimetres. The wet seasons are followed by dry seasons and the driest period appears between December and February. The second dry season, which is less pronounced, occurs between June and July. The driest month, February, has an average precipitation of 40 millimetres (The World Bank Group, 2015).

For some purification methods, such as SODIS, the radiation rates are important for its efficiency. The higher amount of radiation received at ground level, the better the method purifies the water. The solar irradiation rates differs between 15 and 25 MJ/m^2 annually from the northeast to the southwest Uganda. The south western parts receive the least irradiation, increasing towards northeast (Mubiru and Banda, 2011). During the year changes in the cloud patterns can be noted, explained by the northern movements of the Inter Tropical Convergence Zone (ITCZ), a low pressure belt occurring when the northern and southern trade winds meet. In November, December, January, February and March the clouds are less pronounced resulting in a higher rate of irradiation. In April and May the cloud coverage is increasing over the whole country, reaching its greatest coverage in June and July, when the irradiation hits its lowest rate. This is especially pronounced in the south and western parts of the country. In August the coverage changes with the retreat of the ITCZ, increasing the irradiation rates until the end of the year (Ovediran, 1974).

2.3 Engaged peoples and their view of the water situation at site

Three meetings took place during the field study, to reach a wider perspective regarding Uganda's rural water situation. Nora Sadik, Joseph Arineitwe-Ndemere and Daniel Ololia, all working within separate areas regarding water in the country, were approaching the problem from different angles. Miss Sadik was a research student at master level from University of Illinois at the College of Engineering and Environmental Engineering and Microbiology Newmark Environmental Engineering Laboratory. Miss Sadik was researching the water quality in the city of Kampala. Mr Arineitwe-Ndemere was working as a lecturer at the department of Engineering at Makerere University and is involved in the organisation *Centre for Integrated Research and Community Development Uganda*, CIRCODU (2015). Mr Arineitwe Ndemere has also been a part of projects with the organisation *Solvatten (2015).* The third meeting held in Kampala was with Daniel Ololia, who worked with TivaWater sand filtration system.

The general water quality in Uganda is bad and the national water quality may even be worse than declared (Arineitwe-Ndemere, 2015). During the oral communication Sadik, Arineitwe-Ndemere and Ololia (2015) stressed the problem regarding water quality and the size of the issue was clarified. Bad water quality in Kampala is partly due to the way it is stored in containers where the water stands still until used, which enhances the bacterial growth. This is an issue in many parts of the country as well as in some parts of the rural areas. Sadik and Arineitwe-Ndemere (2015) informed about how the visual quality is important for the people drinking the water, regardless of what actual bacteria level it contains. This can be a misleading sign of the water quality, leading to unexpected consequences in the family's health. The importance of gaining a well established contact within a researched village is especially important if a water purification system is planned to be implemented in the future. Information regarding health issues in a specific area can be gained from the health institutions. However, this can be problematic, as many do not seek help for stomach problems. Stomach problems are in many cases a part of normal life and is therefor not regarded as something one has the time or money to see the doctor for (Sadik, 2015).

The organisation CIRCODU hands out stoves driven on solar power to households, in areas with sparse firewood. The main purposes for the organisation are to save the little remaining forests in Uganda and to reduce the collection of firewood around the villages. The stoves are driven by solar power produced by a panel handed out along with the stoves. Why the stove is needed is hard to pass on to the households, since traditions are hard to alter. In many cases the traditional, well-known method that has been used for generations is still preferred. Regardless of the reason why an implementation of a new device is needed, a conflict with the traditions often occurs. This means that the purpose is hard to reach and implementing an idea in the community before implementing any technology is of high importance (Arineitwe-Ndemere, 2015). Another point made by Arineitwe-Ndemere (2015) is how communities are more open to change if there is a currently on-going problem. The chances of a new technology to be accepted increases drastically if it is implemented when a problem is present. According to Ololia (2015) many solutions are too alien for the communities, causing the residents to neglect implementations of new technologies. If there is too much work involved in the purification method of the water the community will avoid using the method (Ololia, 2015). Another problem brought to attention is how the water stations built for cattle in rural areas are utilized by humans as well, even though the quality is known to be unhealthy (Arineitwe-Ndemere, 2015).

3. Site description

Figure 1 shows the location of Uganda in Africa. The locations where the interviews took place are three districts in the east and central parts of northern Uganda (figure 2). The total of 133 households were interviewed in 7 different villages (figure 3).

Figure 1. Presented in the map over Africa is the location of Uganda, which can be found in the eastern part of the continent (Flannery, 2014).

3.1 District information

The districts of Mbale, Lira and Apac are presented in figure 2 and this is where the field study has been carried out.

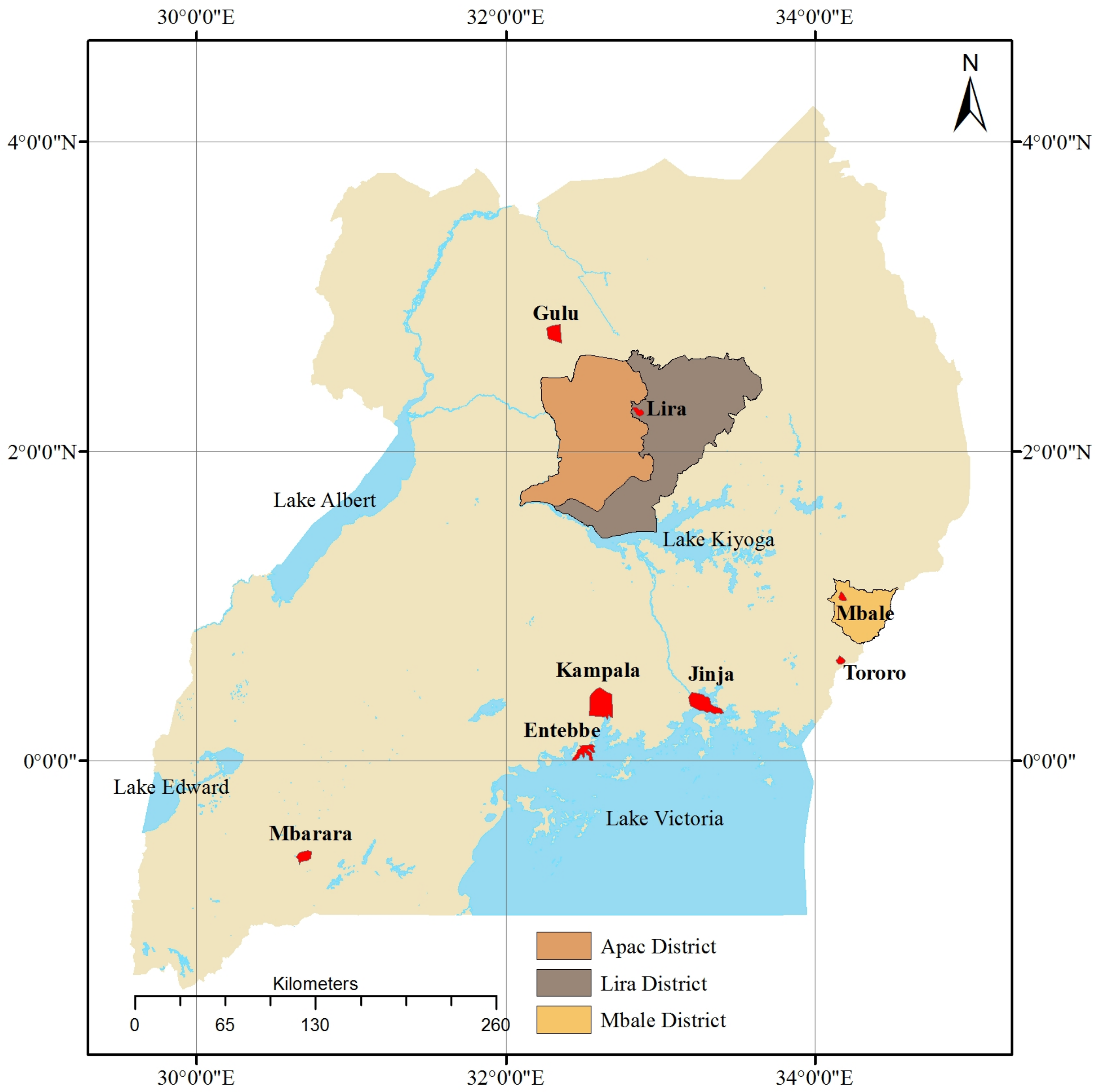

Figure 2. Map displaying the three districts of interest and their locations where field studies have been made. Data containing the administrative borders are collected from Global Administrative Areas (2009). Data containing the water bodies of Uganda is collected from World Resource Institute (2009).

The government of Uganda is covering the main part of the costs of the different water sources in two of the three districts. In table 1 it is shown that the responsibility of the maintenance of a water source after the implementation is layed on the local communities. In Lira and Apac deep boreholes are most common, but in Mbale protected springs is a more usual source of water.

The municipalities in all studied districts provide the central management of the water sources. The Government of Uganda contributes with the main funding in Mbale- and Apac districts (71.9% and 74.7%). In Lira district the main funding of the water sources are made by NGO's, 55.4% (Ministry of Water and Environment, 2010).

Table 1. Maintenance, funding and type of water source in studied districts information collected from the Ministry of Water and Environment (2010) shown in percentage

	Mbale	Lira	Apac
Type of water source (%)			
Protected spring	**39.1**	28.9	14.0
Shallow well	5.9	33.0	24.4
Deep borehole	30.7	**35.5**	**59.9**
Rain water tank	0.0	0.1	0.4
Public tap	24.2	2.5	1.4
Total	100.0	100.0	100.0
Management of water source (%)			
Community	**89.0**	**85.1**	**67.4**
Private individual	4.3	0.1	1.8
Private operator	0.4	0.2	0.9
Institutional	6.2	13.2	29.2
Other	0.1	0.3	0.7
Total	100.0	100.0	100.0
Funding of water sources (%)			
Private	4.9	2.1	3.0
NGO	18.8	**55.4**	21.2
Goverment of Uganda	**71.9**	41.1	**74.7**
Other	4.3	1.5	1.1
Total	100.0	100.0	100.0

3.2 Studied villages

Throughout all the districts two or three villages have been investigated (figure 3). The three villages Masanda, Shikoye and Lucisy are found in the central parts of Mbale district. The villages of Ogalie and Tebung were visited in Lira and in the villages Abolo Nye and Abolo Yero can be found in Apac.

Figure 3. Map presenting the locations of the seven villages where fieldwork was preformed. Three villages are situated in the district of Mbale, two in the district of Lira, and the remaining villages in the district of Apac. Data over the administrative borders is retrieved from Global Administrative Area (2009). Data containing the water bodies is collected from World Resource Institute (2009).

3.2.1 Mbale

In northeast Uganda, the district of Mbale is located. The district contains two counties, 14 sub-counties and one municipality located in central western part of the district. In 2010 the total domestic water points were estimated up to 997, where eleven of them had been out of order for the last 5 years. Total population of Mbale is almost 417,000, where 327,600 of the inhabitants are situated in the rural areas. 62% of the population has access to safe water, which includes water points such as protected springs and deep bore holes (Ministry of Water and Environment, 2010).

Masanda

Masanda, the first village to be investigated, is located 0°59'16"N, 34°12'33"E. The examined well in the area was built and managed by the residents of the village that could not afford piped water. This well provided water for approximately 150 households. The depth of the well is 4,5 meters, and the water table is stable even during dry season. To fetch the water, the residents used a plastic bucket, connected to a wooden construction surrounding the well.

When interviewing 20 households using the well, several complications with the water source were found. A few examples of the problems concerning the well were that the water contained worms, leaches and frogs, and had a distinct smell. More problems and concerns regarding the water can be found in appendix 2.

Figure 4. Well water in Masanda, constructed by the residents of the village. Presented in the figure is the bucket, which the inhabitants use to fetch the water.

Shikoye

The village of Shikoye is located at 0°56'27"N, 34°16'48"E. The main water source for the residents living in this part of Mbale is the Manafwa River, which flows from Manafwa district into Mbale district.

Numerous problems regarding the quality of the water was established when interviewing 20 households of Shikoye village. Not only were sicknesses such as diarrhoea, typhoid and dysentery common. One of the persons whom participated in the interviews lost a child due to diarrhoea, caused by the river water (appendix 2).

Figure 5. The water collecting point at Manafwa River for the locals from Shikoye village to fetch their water. Displayed in the figure are several men washing both clothes and their motorcycles. In the background two men are on their way to collect their drinking and domestic water.

Lucisy

The village of Lucisy is located at the coordinates 0°55'59"N, 34°14'45"E. In the area several water pumps are located, about 29 meters deep and provided by the government. The water pump in the village was provided with waterguard and chlorine tanks that portioned out a small amount of chemicals direct in the water containers used by the residents.

The total of 15 households were interviewed about the water source. During the interviews it was established that some residents experienced complications with the stomach, presented in appendix 2, even if waterguard or chlorine was used.

Figure 6. The residents of Lucisy use water containers that can hold 10 litres of water. To seal the container, leafs are used to prevent the water from escaping and for dirt to contaminate the water.

3.2.2 Lira

The district of Lira is situated in the central north of Uganda and contains four counties, 19 sub-counties and one municipality. The total population in 2010 was estimated to almost 700,000 of which nearly 565,000 are living in the rural areas. The domestic water points in the district are 2,423, where 88% of the overall population has the accessibility to safe water. This includes deep boreholes, protected springs, piped water and shallow wells. In 2010, approximately 65 of these had been out of function for five years. 15% of the inhabitants of Lira had access to the piped waterlines, while the remaining 85% were obliged to the point water sources, such as spring wells (Ministry of Water and Environment, 2010).

Tebung

Tebung village is situated in the northwest Lira district, with the coordinates 2°19'38"N, 32°55'52"E. The spring well, containing one pipe was provided by the NGO *The Wild Geese*. The spring well was installed 12 years before this field study took place. It provides drinking and domestic water for approximately 200 households. During the dry season, the spring occasionally dries out.

19 households were participating in the field study in Tebung village. Talking to the residents using the well some problems were identified such as salty taste, stomach-aches and that leaking sewage systems occasionally reached the spring water (see appendix 2 for further comments).

Figure 7. Spring well showing a discolouration of the water.

Ogalie

The village of Ogalie is situated in the west of Lira district, with the coordinates 2°14'15"N, 32°57'49"E. The water source consists of a two-piped spring well, founded by the government and supports the total of five villages. Only one of the pipes functioned during the dry seasons. The total of 20 households participated in interviews regarding the water quality.

Figure 8. Spring well in Tebung, Lira. The problem of animal using the water source was brought up. This is a common issue and contributes to contamination of the water source.

Interviews with the local residents of the village revealed that the water contains visible particles and worms, and complications such as stomach-ache and diarrhoea affected the locals occasionally. Larger particles were visible in the water and cattle came to the source at a daily basis, polluting it further.

3.2.3 Apac

In the central part of Uganda the district of Apac is located. The total population number in 2010 was estimated to 543,000, almost 530,000 of the inhabitants are living in the rural areas. The district contains three counties, 14 sub-counties and two municipalities. 62% of the population in Apac has access to safe water resources. In 2010 the domestic water points were nearly 1,600, and 78 of them had been out of order for five years. The district has a piped water system, but only 7% has access to it. The main water supply in the district comes from deep boreholes (Ministry of Water and Environment, 2010).

Abolo Nye

The water hole in the village Abolo Nye is located at the coordinates of 2°18'41"N, 32°42'29"E. The waterhole was constructed ten years before preforming the interviews. The inhabitants of the area constructed the water hole themselves. This source provides three villages with water for both drinking and domestic work.

Figure 9. The process of collecting water can be difficult and time devastating. Presented in the figure, a woman is collecting water by the use of a small boule to fill up the two bigger containers.

The depth of the water level is about 30 centimetres and is visible from the surface. 20 households were interviewed regarding the water quality of the source. The water is clear making the worms easy to spot and residents complain about the taste, which is sour. Children are the most vulnerable for the complications the water brings, but adults in the area also incur complications such as diarrhoea, and in some cases amoeba.

Abolo Yero

The spring well of Abolo Yero is located at the coordinates 2°20'03"N, 32°41'03"E. Two pipes are connected to the water line, provided by the government of Uganda. At the time the interviews were done, the water source had been in work for five years. In total, 19 households participated in interviews regarding the water quality of the source.

The residents in the village of Abolo Yero were uncertain considering the number of villages using this water as the main source, but numerous inhabitants of the area were traveling long distances by bike to fetch from this source. During the rain seasons debris and water flow downwards into the spring well is blocking the fresh water supply. The water is clear during the dry season and therefor many locals do not consider it to be contaminated. Stomach-ache is brought up by the residents as a common problem (table 6).

Figure 10. Spring well in Abolo Yero, Apac. The current state of some of the wells visited during the field study is in an acute need of reconstruction, as shown in the figure.

4. Method

Section 4.1 describes the work done before the field trip to Uganda. Section 4.2 describes the field study, which is one of the main parts of the report. Other contributing information sources about the point-of-use methods are explained in section 4.3.

4.1 Preparation

To reach the aim and to find out the personal experiences about the water quality in rural Uganda, where people have limited or no access to an internet connection, widespread analfbethism and to ensure that the answers were unmodified, it was concluded that there was a need for a field study where interviews could be preformed. To reach the residents in the villages located in the rural areas of the country it was required to use an interpreter and a local guide to accomplish the personal meetings due to the language barrier.

A questionnaire was prepared, see appendix 1, which was the base of the interviews preformed during the field study. It was important to organise the questions in a way without implying or creating an answer as a consequence. Therefor the 11 questions were asked in a way so that the interviewees had to explain their view on the situation with their own words. Organising a translator, a car and a driver was important for the maximum gain of the field study. The real introduction of our study was given on site in Uganda where an explanation of the aims was given and how we wanted the questions to be asked.

4.2 Field study

Seven villages were visited and the water quality was studied through interviews. The goal was to reach 20 interviews in every village to find out more about how the water quality was experienced and the health effects caused by the drinking water. The field trip took place 1st - 13th March 2015. Meetings were held in Kampala with people, who are working with water related questions within the country.

The main criterion for picking a village was that it had to be situated in a rural area. Another important factor when selecting a village was that the water from the waterhole had to be free of charge. The first stop during the field trip was Mbale district where the first three villages were visited. The villages were chosen through the help of the local guide, who also helped out with communication and translation. The guide referred to areas known to have poor water quality and from that information villages got picked. To randomise the picking of interviewed people, the technique was to stand next to the studied water sources. This way the usage of the same water source was secured as the interviewees were randomly picked, an important criterion to get a general picture of the situation. The interviewees were asked to answer the questions representative to the opinions within the entire household and the interpreter to give direct translation of the answers. After visiting Mbale district, the field study continued on in the districts of Lira and Apac.

4.3 Contributing literature

The studied areas were further examined as well as the different point-of-use methods. To gain further knowledge in the subject of water purification, sanitation and drinking water quality, databases such as *Web of Science*, *Science Direct* and *Jstore* has been utilized. The search was limited to keywords used such as: “water quality”, “Uganda water quality”, “Point-of-use”, “household water treatment”, “water and sanitation”, “water purification”, “rural water” etc. Many authors and researchers within the field of study were reoccurring in the throughout the literature and reports, for example X Sobsey and X Clasen. These authors also contribute to many reports within big organisations. Reports from the UN, WHO and UNICEF also provided relevant information about the current situation within the field of water and sanitation. Within all types of purification methods, there are a large number of techniques available. The POU methods have been selected and studied regarding to their ability to reduce the amount of pathogens in the water and the effectiveness to reduce diarrhoea. Other factors such as time, cost and cultural values have also been an important part of the selection regarding which POU-methods focused on. Amongst those some are more popular than others and the aim was to reach a wide range of different methods. The POU methods focused on and evaluated in this report are of general type and were chosen as they are all fairly common and accepted by organs such as the UN, WHO and UNICEF. The results from the fieldtrip and the information gained by the literature study were compared and from this the conclusions were drawn. Firstly the results gathered in the fieldtrip were produced and secondly the POU methods were compared.

4.3.1 Evaluating the POU methods

For evaluating the different POU methods investigated, Sobsey et al. (2008) have a rating system where 3 equals good performance, 2 fair and 1 low performance. The results from the studied POU methods are presented in table 2.

Quality
If the method reduces turbidity, organic matter and microbes, resulting in high water quality, it scores a 3. A technology only reducing microbes, resulting in high water quality, scores a 2. If the technology only affects the microbes to a certain extent, resulting in a poorer water quality, it scores a 1.

Quantity
Technologies that produce 20 litres of water in 4 hours, with one required amount of chemicals or a single filtration of water, scores a 3. This is regarded as a sufficient amount of water for a family per day. If scoring a 2, the same requirements apply, but with the usage of 2-4 doses of chemicals or 2-4 times of filtration. If scoring a 1, 5 or more doses or filtrations are required.

Time
Technologies that provides 10 litres of safe water in 30 minutes score a 1, and if more time is needed it scores a 0. If the treatment method requires more than one step it scores a 0, if it only demands one step it scores a 1. If the process demands repetitive maintenance it scores a 0.

Costs
When evaluating the cost of the method the scores are rated as followed:
<0.001 US$ /litre equals score 3
0.001–0.01 US$ /litre equals score 2
>0.01 US$ /litre equals score 1

Maintenance
If continuous supply is not required the method scores a 3. If there is a reappearing need for supply it scores a 2. If there is a continuous need of supplies the method scores a 1.

In table 2 the points assigned to the evaluated methods are based on the criteria's' given by Sobsey (2008). The biosand filtration method scores the highest due to the evaluated variables and the ceramic filter reaches the second highest score.

Table 2 Evaluation of Point-of-use methods
Evaluation of the examined point-of-use methods using the scoring rates according to Sobsey et al. (2008) and WHO (2009).

Method	Quality	Quantity	Time	Maintanance	Costs	Overall score
Boiling	3	2	1	1	3	10
Solar disinfection (SODIS)	1	1	1	3	3	9
Ceramic filters	2	3	2	2	3	12
Biosand filters	3	3	2	3	2	13
Free chlorine	3	1	3	1	3 liquid, 2 tablets	11 liquid, 10 table
Coagulation/chlorination disinfection	2	3	1	1	1	8

4.4 Background data

To produce maps over the studied villages the coordinates were collected in the field and imported to ArcGIS10.2.2 (ESRI, 2014). Shape files over the water bodies was provided by World Resource Institute (2009) and is a combination of three datasets collected at National

Forest Authority (1996), National Imagery and Mapping Agency (1997) and Brakenridge et al. (2006). To present the location of Uganda shapefiles over the African continent was collected from the ArcGIS homepage (Flannery, 2014). All maps have the reference system WGS84.

Chi-square tests were conducted to test if the differences between the villages in terms of water quality experience are statistically significant. The Chi-squared tests were conducted on the collected nominal field data, to justify the conclusions. To preform these tests the null hypothesis were:

- "There is no difference between the villages in how content they are with the experienced water quality".
- "There is no difference between the villages in how unhappy they are with the experienced water quality".
- "There is no difference between the villages in experienced health effects".
- "There is no difference between the villages in unexperienced health effects".

If the probability was below 5% (α<0.05) the difference is significant.

5. Results

The average of residents in the 133 households studied households was calculated to 6.7. The information and data collected has been complied in tables and graphs presented in section 5.1. The evaluation of the point-of-use methods is given in section 5.2.

5.1 Results from field study

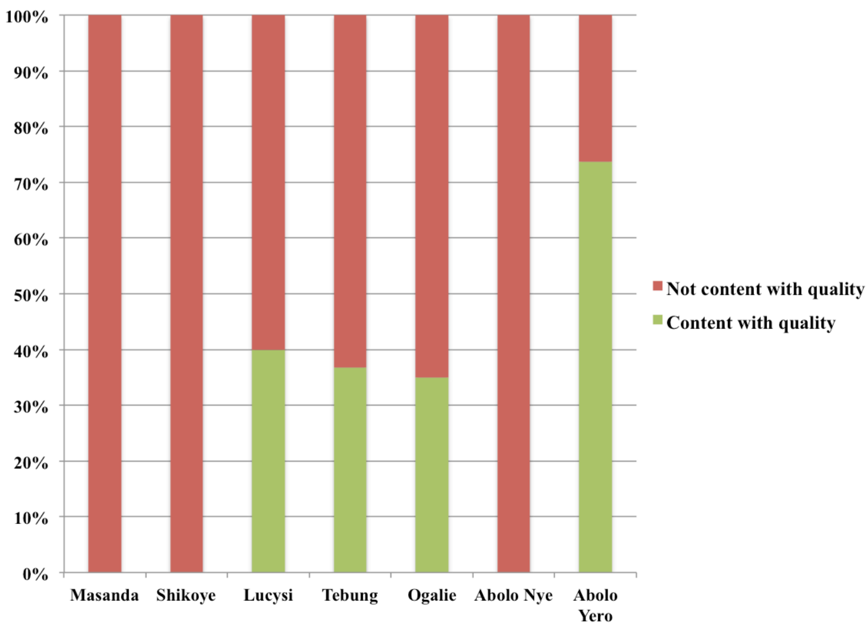

Figure 11. Percentage of the 133 households content and not content with water quality. In Masanda, Shikoye and Abolo Nye the households are unsatisfied with their water quality. The highest rates of households content with their drinking water are found in Abolo Yero (74%). A more positive attitude towards the quality is shown in Lucisy (40%), Tebung (37.0%) and Ogalie (35%).

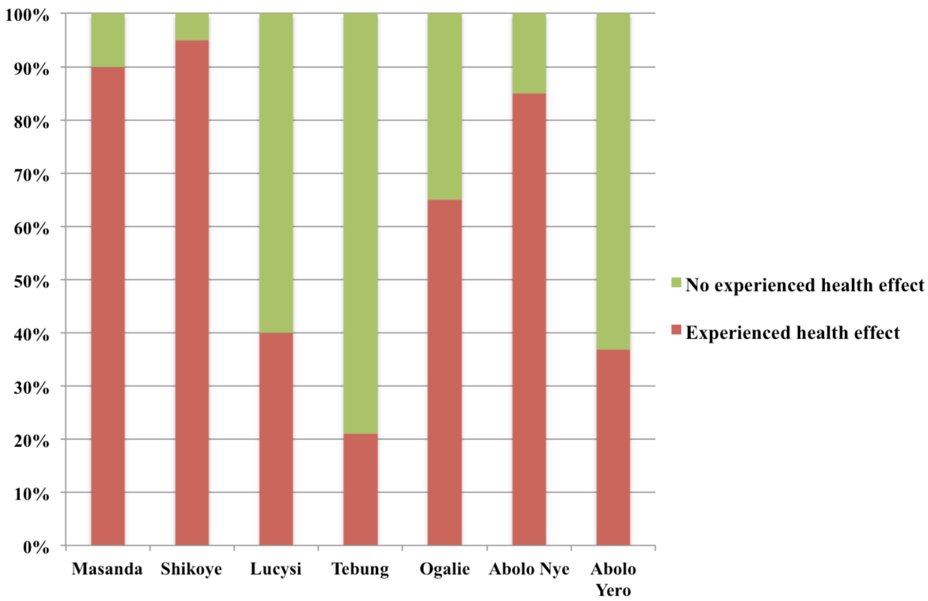

Figure 12. Percentage of the 133 households experiencing health effects. The village that experience the highest rates of health issues is Shikoye (95%) and the village with the least experienced health issues related to the drinking water is Tebung (21%). The villages Lucisy, Tebung and Abolo Yero have experienced less health issues than 50%. In the villages of Masanda and Abolo Nye high rates of experienced health effects are pronounced (90% and 85%).

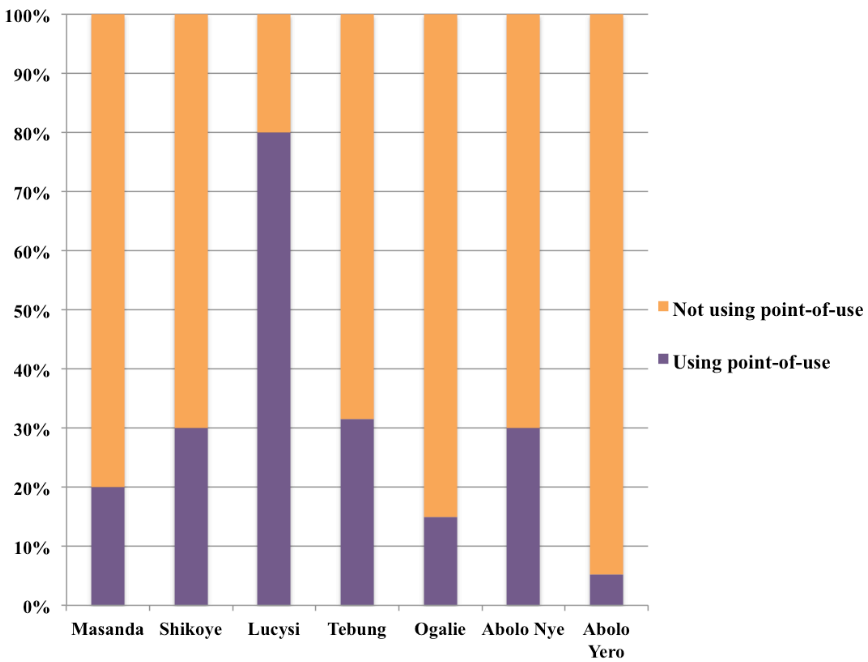

Figure 13. Percentage of the 133 households using a point-of-use method. Lucysi has the highest rates (80%) of the households using a purification method in the seven villages. Lowest rate using a point-of-use method is in Abolo Yero (5%). In all other villages the rate is less than 32%. The purification methods found at site are boiling, Waterguard and chlorine.

Presented in table 3, totally 31.5% of the 133 households utilize a point-of-use method. 15% of the households boiling their water are content with the quality, contra 85% that are not satisfied. In the households using waterguard 36.8% are content with the quality, and 63.2% are not. In households using chlorine as a point-of-use method 33.3% of them are satisfied with the quality, but 66.7% are not.

Table 3. Contentedness with water quality after usage of a point-of-use method
Results show percentage of households content with water quality amongst the 42 households using a point-of-use method

Type of point-of-use	Content with water quality	Not content with water quality	Total
Boiling	15.0	85.0	100.0
Waterguard	36.8	63.2	100.0
Chlorine	33.3	66.7	100.0

In four out of seven villages more than 50% of the households are experiencing health issues related to their drinking water. Overviews of these results are shown in table 4. The point-of-use methods applied in the villages are boiling of the water and the use of chemicals such as waterguard and chlorine. Only in the villages of Tebung and Abolo Yero the amount of households content with the water quality excess the amount of people experiencing water related health problems. In Abolo Yero the rate of using a point-of-use method for purification of the water is only 5% although the amount of households that are content with the water quality is 74%. In Lucisy the highest amount of households (80%) uses a point-of-use method and the most common is the use of waterguard. The highest rates of experienced health issues are in Shikoye where no one is content with the water quality.

Table 4. Contentedness with water quality, experienced health effects and main point-of-use methods in the villages
Results shown in percentage out of the 133 interviews

Village	Content with water quality	Experianced health problem	Using point-of-use	Main type of point-of-use
Masanda	0.0	**90.0**	20.0	Boiling
Shikoye	0.0	**95.0**	30.0	Boiling
Lucisy	40.0	40.0	**80.0**	Waterguard
Tebung	37.0	21.0	32.0	Boiling
Ogalie	35.0	65.0	15.0	Boiling
Abolo Nye	0.0	**85.0**	30.0	Waterguard
Abolo Yero	**74.0**	37.0	**5.0**	Waterguard

Table 5 is presenting how many of the households that are not treating the water and the main reasons not to. Data over households already using a point-of-use solution or a different water source than the exanimated one are not included in the calculations. 60% of the households in Masanda and 41.1% in Shikoye cannot afford to implement a point-of-use method. In Tebung 33.3% also had problems financing a point-of-use method.

In Ogalie (70.6%), Abolo Nye (71.4%) and Abolo Yero (94.4%) few households acknowledged a problem regarding the absence of a point-of-use method. In Shikoye (29.4%), Tebung (8.3%), Abolo Nye (21.4%) and Abolo Yero (5.6%) traditions are considered more important than utilizing a point-of-use method.

Table 5. Main reasons for not using a Point-of-use method according to local population
Results shown in percentage out of the 133 interviews

Village	Traditions	Can not afford	Do not acknowlege a problem	No comment	Total
Masanda	0.0	**60.0**	40.0	0.0	100.0
Shikoye	29.4	**41.1**	23.5	5.8	100.0
Lycisy	0.0	0.0	0.0	**100**	100.0
Tebung	8.3	**33.3**	25.0	**33.3**	100.0
Ogalie	0.0	5.9	**70.6**	23.5	100.0
Abolo Nye	21.4	0.0	**71.5**	7.1	100.0
Abolo Yero	5.6	0.0	**94.4**	0.0	100.0

Of the households in Masanda participating in the field study, 23.5% stated that the smell of the water was the main problem of contamination (table 6 and 7). In Shikoye problems contributing to contamination of the water was majorly pronounced to be human pollution (15.4%) and corpses of animals and humans found in the river (15.4%). In Lucisy and in Abolo Yero the households stated that human pollution is the main reason for contamination of the water source. 26.1% of the households in Ogalie stated that small animals and insects are the reasons for contamination of the source. Abolo Nye has a problem with cattle drinking and littering in the water source and complications, such as flood water carrying dirt particles and litter, during the wet season.

Table 6. Contamination problems of water source according to local population
Results shown in percentage out of the 133 interviews

Problem	Masanda	Shikoye	Lucisy	Tebung	Ogalie	Abolo Nye	Abolo Yero
Cattle	5.9	0.0	0.0	0.0	4.3	**21.7**	21.7
Dry season	5.9	3.8	0.0	9.5	4.3	4.3	4.3
Wet season	5.9	3.8	0.0	**19.0**	4.3	**21.7**	13.0
Human pollution	0.0	**15.4**	**14.3**	4.8	8.7	4.3	**34.8**
Connected to sewerage	0.0	11.5	0.0	0.0	0.0	0.0	0.0
Smell	**23.5**	0.0	0.0	0.0	4.3	0.0	0.0
Corps	0.0	**15.4**	0.0	0.0	0.0	4.3	0.0
Small animals/insects	17.6	3.8	0.0	9.5	**26.1**	13.0	13.0
Discoloration	0.0	3.8	7.1	4.8	8.7	4.3	0.0
No comment	41.2	42.3	78.6	52.4	39.1	26.1	13.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 7. Declaration of experienced problems brought up in table 5

Problem	Explanation
Cattle	Open water sources are exposed to cattle walking, drinking and littering in or nearby
Dry season	Pollution get concentrated in low standing water during the dry season
Wet season	Pollution get flushed into open water sources in the floods during the wet season
Human pollution	Human bathing, wahing clothes and machines in or nearby the water source
Connected to sewerage	Feaces are contaminating the water source
Smell	The water has a distinct oder
Corps	Dead bodies pollute the water source
Small animals/insects	Insects and small animals (frogs, leches, worms, bugs) contaminate the water
Discoloration	The water is discoloured or contain a lot of particles
No comment	Interviewed households have no comment

The foremost pronounced diseases, amongst the households, who have acknowledged health effects due to the drinking water, is undefined stomach complications (table 8). This includes problems such as stomach-ache and burping. All 40 % of the households that are experiencing any water related health effects in Lucisy have undefined stomach complications. In Shikoye the diarrheal diseases including typhoid, diarrhoea, cholera and dysentery have the highest rates (56.8%). In Tebung the rates of experienced undefined stomach complications and diarrhoeal diseases have the same rates. Examples of other diseases mentioned includes malaria, blindness and rashes.

Table 8. Main experienced diseases

Results show percentage out of the 85 households experiencing health effects

Village	Undefined stomach complications	Diarrhoeal diseases	Parasites	Other diseases	Total
Masanda	**54.5**	27.3	0.0	18.2	100.0
Shikoye	35.1	**56.8**	2.7	5.4	100.0
Lucisy	**100.0**	0.0	0.0	0.0	100.0
Tebung	**40.0**	**40.0**	0.0	20.0	100.0
Ogalie	**43.8**	31.3	6.2	18.7	100.0
Abolo Nye	**33.3**	27.3	18.2	21.2	100.0
Abolo Yero	**66.7**	11.1	0.0	22.2	100.0

The types of water sources examined in the field study are shown in table 9. In the villages Masanda, Tebung, Ogalie, Abolo Nye and Abolo Yero the maintenance of the water sources is assigned to the communities. In Shikoye, the source of the water is a river therefore no funding or maintenance is stated. The water source in Tebung is provided by an NGO, *The Wild Geese*. The government of Uganda is the funder of the water sources in Lucisy, Ogalie and Abolo Yero.

Table 9. Funding, maintenance and type of water sources exanimated

Village	Type of water surce	Funding of water source	Maintenance
Masanda	Hand dug well	Community	Community
Shikoye	River	-	-
Lucisy	Borehole	Government	Government
Tebung	Spring well	NGO	Community
Ogalie	Spring well	Government	Community
Abolo Nye	Hand dug well	Community	Community
Abolo Yero	Spring well	Government	Community

The chi-square test showed a strong significance (<5%) that there is a difference in the experienced contentedness regarding water quality between the seven studied villages, as shown in table 10. It also shows that there is no difference between how unhappy the seven studied villages are with the water quality. There are significant differences in experienced health effects and no experienced health effects between the seven villages.

Table 10. Results from Chi-square test

	n	df	α	Critical value	X^2	Significant
Content with water quality	7	6	0.05	12.592	35.412	Yes
Not Content with water quality	7	6	0.05	12.592	12.162	No
Experienced health effect	7	6	0.05	12.592	15.704	Yes
No experienced health effect	7	6	0.05	12.592	26.921	Yes

As presented in table 11 the rating of the reduction of diarrhoeal diseases by boiling is hard to evaluate, due to the impacts of unclean containers and poor handling etc. Ceramic filters have been rated as the most efficient method reducing diarrhoeal diseases (63%). The least efficient method is solar disinfection (SODIS) and coagulation/chlorine disinfection, both reducing 31% on average.

Table 11. Rate of reducing diarrhoeal diseases
Results present data supplied by Sobsey et al., (2008) and WHO (2014).

Method	Rate of reducing diarrhoeal diseases	Refereces
Boiling	No data*	WHO, 2014
Solar disinfection (SODIS)	31% (26%-37%)	Sobset et al., 2008
Ceramic filters	63% (51%-72%)	Sobset et al., 2008
Biosand filters	47% (21%-64%9	Sobset et al., 2008
Free chlorine	37% (25%-48%)	Sobset et al., 2008
Coagulation/chlorination disinfection	31% (18%-42%)	Sobset et al., 2008

*No data: Do to WHO (2014) the rating the reduction of diarrhoeal diseases by boiling is hard to evaluate due to the impacts of unclean containers and poor handling.

6. Discussion

6.1 Contentedness and health effects

The results given by the statistical tests (table 10) imply that there is significant difference between the villages in all cases but one, which is the level of unhappiness concerning the experienced water quality. From this result the conclusion can be drawn that the unhappiness with the water quality is widespread throughout all the villages, which also was a strong impression during the field trip. The chi-square tests showed significant differences between the villages in experienced health effects. This tells us that the type of water sources can make a difference as some are more covered than others and that the residents do not always connect the health effects to the water.

The results of our study show that the number of households that are content with their water quality is very low. This is most pronounced in the three villages Masanda, Shikoye and Abolo Nye where none of households are content with the water quality, not unexpectedly these three villages also have the highest percentages of experienced health effects. Abolo Yero differs with a pronounced contentedness (figure 11), contradictive to the even higher amount of households experiencing health effects (figure 12). Again, his could be a result of the households not relating their health issues with the water. In Shikoye the most pronounced health effects was found and as they use a river as their main water source this shows that the source it self is very important for a safe water situation. These results would probably be different if a village closer to the rivers outlet had been studied n Shikoyes' place.

Amongst the experienced diseases the most common within all the villages is undefined stomach complications. Due to cultural differences it was somewhat hard to understand parts of the complications brought up. It was hard to get the interviewees to develop their answers, a result of cultural dissimilarities not accepting open discussions about issues such as diarrhoea. In most villages, the diseases occasionally suffered from is unrecognised, only in Shikoye diarrhoeal diseases was acknowledged as the biggest problem. In some of the villages studied, stomach problems are a more or less a normal condition and therefor visiting the doctor every time this occurs is unusual. When visiting the doctor, the issues have to be comprehensive, so the time and expense will be worth it. To deepen the study even further it would therefor have been of great interest to get statistics of actual diagnoses from the doctors' offices in the visited areas.

6.2 Practise of point-of-use methods

A way to approach the problem regarding water quality and to improve the sanitary situation is to use purification methods (section 4.2). Lucisy stands out from the rest of the villages, since a big part of the households are using a POU method on a daily basis (figure 13). The main purification methods applied in the households are boiling, waterguard and chlorine. Boiling is the most common method, closely followed by waterguard. Regardless of the three used POU methods, the majority are not content with the water quality even when treated (table 3). This might be due to the lack of knowledge regarding the purification techniques. Brought up by Arineitwe-Ndemere, Ololia and Sadik (2015), the reason for this is often due to the unclean containers where the treated water is stored and gets re-contaminated. The process of disinfecting the containers is time consuming, which is an issue for many households (table 5). It was confirmed by the interviews that the time spent on cleaning the containers conflicts with how they traditionally distributes their time. Time management has been proven to be an important factor in the daily decisions, therefore this has to be carefully considered when implementing a purification technique.

The government built a well working water pump and are providing a free supply of waterguard and chlorine to Lucisy continuously. This is most likely the reason why the water situation is different here and the purification method is utilised in a great extent. The fact that many residents' still experience health effects in Lucisy is probably due to the lack of secure storage. Some of the residents avoid using the supplied chemicals, since it causes them negative stomach effects, this could be due to the lack of knowledge and education regarding how to use it. Even in the areas where a POU method is accepted the knowledge gap in how to utilize the methods and the storage is still a problem.

The main reason why households are not using a POU method varies between the villages (table 10). One reason is affordability, a pronounced problem amongst the residents in Masanda, Shikoye and Tebung. As constrained economies are a problem in many parts of rural Uganda, this is a factor limiting how widespread POU methods are. In the predominant majority of Abolo Yero, Ogalie and Abolo Nye the residents do not acknowledge the problem at all. Acknowledging a problem is an important step towards a solution. The problem has to be recognised for the residents to be open for a new purification technique. In some of the villages traditions were brought up as a reason to avoid treating the water. As stated by Sadik, Arineitwe-Ndemere and Ololia (2015) traditions in a community are hard to alter as they are highly valued and for any purification method to be accepted it cannot interfere with the daily routines. Fetching water from the sources is a time consuming process, the possibility for a POU method to interfere with the daily routines is a reason why it is avoided in some villages. Therefor the factor of time needs to be regarded as important as the cost of a purification system.

6.3 Reasons for contamination

According to the local residents the contamination varies between the water sources and is dependent on the surroundings and the season. Most residents chose not to comment on what is causing the water sources to get contaminated, confirming the fact that many residents does not acknowledge a contamination problem. Only in Abolo Yero the interviewees had a pronounced opinion on the source of contamination, with the majority pointing out human pollution. However, this can be questioned since the water is fetched directly from the pipes, without the surrounding water re-contaminating it. Human pollution is a problem in Shikoye as well, where activities such as washing of clothes and bikes in the river were common. Another concern, in Shikoye, is the presence of corpses, both animal and human. The polluting source differs from day to day and accumulates down stream. Those acknowledging a problem were also contributing to the action causing the problem. For example the ones washing motorcycles were complaining about the river being polluted by human activity (figure 5). A situation reminding a lot of the “tragedy of the commons” is generated as the villages upstream also contributes to the contamination, this creates the mentality in Shikoye that there is no point in changing their behaviour. Therefor these problems are hard to solve, especially since the water source in the village is a river. The first step towards a secure water and sanitation situation here is a proper water source, for example a drilled well.

In Masanda the households continuously brought up the distinct smell as a problem. Although they had no explanation of where the smell originates, the result also show a high frequency of small animals and insects in the water, which can be one contributor to the odour. Although, this can be questioned and again the knowledge gap regarding safe water is clear. The odour does not automatically suggest that the water is of less quality. In Ogalie it was also stated that small animals and insects were a problem. At the water station, there was a visible problem with the outflow (figure 8), this caused an approximately 30 cm deep puddle with bad circulation. With the construction of lids and if better outflow from the sources is achieved, the problems could decrease. In many villages the dry- and wet seasons were brought up and said to be a polluting factor, as the stations often are in a bad state, in need of reparation. Better constructions in and around the stations would help to keep occasional floods and cattle out, as well as limiting debris and loose particles to enter the water. During the wet seasons floods bring loose debris and soil particles into the water stations. During the dry seasons the water table is low and soil particles etc. are accumulated. In Tebung for example, the rain season is expressed to be a polluting source. Although, the results do not show weather there is a problem only during rain season or if there are other contaminating sources during the remaining parts of the year. Further it s not clear weather the experienced health issues are concentrated to the rain season or not.

It is hard to define if the contamination of the water origins from the water stations, the surroundings, the pipes or the actual well. Without a bacterial or chemical analysis of the water it is hard to explain if the contaminating source is based on only one factor or if is a combination of various sources.

6.4 Important considerations when evaluating the point-of-use methods

The ceramic filter has proven to be the most effective method to reduce diarrhoeal diseases (table 2). Both solar (SODIS) and coagulation/chlorination disinfection reduces 31%, which is the lowest of the examined methods. Data on the general effectiveness to reduce diarrhoeal diseases by boiling is difficult, however, there are a lot of information about the effectiveness for reducing single bacteria, viruses and pathogens. Boiled water is hard to evaluate since it usually get re-contaminated by unsecure storing, lack of hygiene and sanitation. To estimate how effective a certain purification method is there are additional parameters to consider, besides the reduction of bacterial activity.

In 5 out of 6 villages the communities themselves have to maintain their water source, this is important to have in mind when implementing a POU method (table 9). The seventh and only village where the government continuously maintain the water source is Lucisy. The use of waterguard was free of charge here, suggesting that costs applied in other villages is a limiting factor. A large number of the households in Lucisy are continuously using this method, easy access and funding of POU methods is therefore shown to be of very high importance. Analysing the needs and methods are hard since there are many variables to consider. Except from availability and affordability, other important variables are time and effort. Therefor methods such as the coagulation would be poorly accepted, since it is very time demanding.

During the study it was discovered that cultural values are vital for a successful implementation of a POU method. For an implementation to be successful it requires a lot of preparatory work for the technologies to be accepted in the everyday life. Following the results presented in table 2 biosand filter scores the highest and would consequently be considered the best method. The maintenance of this system could be a limiting factor considering the time that will be needed for cleaning the filter.

Both the ceramic filter and the free chlorine scored high in scoring system (table 2). If implanting the ceramic filter the fragility of the device is to be considered, since there is a cost applied to replace broken parts. As stated by Sobsey et al. (2008) this obstacle regarding affordability is hard and in some cases even impossible to overcome. The use of chlorine is a solution, which reaches high scores in important factors such as time consumption, maintenance and the quantity. Considering this and compering it to the use of waterguard in Lucisy, chemicals would be a suitable solution, which could be applied in all villages. Since the cost has shown to be a limiting factor, this might not be the most favourable solution after all, as it demands a continuous supply and therefor an outside source would have to provide it. With this in mind, solar disinfection (SODIS) is the one method most cost efficient and that needs the least upkeep after implementation. However, the SODIS method scores low regarding effectiveness, time consumption and how big quantities of water it purifies. It is important to consider that the solar irradiation changes throughout the year and the time needed for the purification process will be affected by this. However the easy access to PET bottles and the high irradiation rates during many parts of the year makes the SODIS method a capable solution.

The coagulation and boiling methods have shown to be effective considering both quality and quantity. The coagulation method has high costs, high time consumption and maintenance, as mentioned earlier these are essential factors for an implementation to be successful. The conclusion is therefor that the coagulation method is not to recommend for implementation in the villages. Boiling is the most widespread and accepted method of today. This method has a low cost, the ability to purify a fair quantity of water and has shown to be effective in demolishing bacteria etc. However, it is a time consuming process and the availability and sustainability of firewood is low and is therefor not the optimal solution.

To reach a safe water situation, there is more to consider than just what POU method to implement and how this is executed. For example basic sanitation is also vital, along with cleaning of the vessels used for storage, which is a key factor for keeping the treated water clean. Sometimes a reconstruction of the sewage systems, if they exist, is required as well as building a barrier around the source, to keep the hygiene and water quality high.

6.5 Recommended solutions

In Lucisy the use of waterguard is working out well and would probably be accepted in all villages if implemented and maintained in an accepted and continuous manor. This solution would be the recommended method for all villages, as it would bring a well working water station and has proven to be satisfactory in Lucisy. However, an outside upkeep is needed for the chemical system to work in the long run, therefore the two solutions more suitable for implementation are SODIS and biosand filter. These methods would only require a one-time cost, the upkeep of the systems are only occasional and are easy to manage by the local residents. The SODIS method is dependent on the irradiation, which is affecting the time factor. An implementation with the biosand filter would be most suitable in all the villages considering important factors such as the one-time cost and the capability to reach high quantity of good quality water. The successful implementation made in Cambodia proves that this method can be accepted in a community.

In villages where the main problem is flooding and cattle, constructing a stronger water station with surrounding blockage would decrease these problems. In many villages an improvement of the water collecting point would provide water of better quality, as the stations are substandard.

Regardless of which new POU method that would be introduced in a household, it is important to consider suitability to cultural values and traditions. Information and discussions within the villages have to be preformed for an implementation to be possible as acceptance increases with understanding. To reach a long-term solution efforts from the government or organisations would be required, as the villages themselves do not have the capability to build sustainable water stations or to continuously fund an implemented POU method. Less comprehensive alternatives, for example the SODIS PET-bottle solution or the biosand filter could be a temporary answer to common health issues such as diarrhoea.

The belief after preforming this study is that the analysis that should be made might be misdirected, instead of focusing on which POU method that would be most suitable, the focus should be on why those already implemented does not work in the long-run. Differences within the country, -moneywise, traditions, the standard of existing water collecting points or the experienced health effects are of high importance to reach a long-term sustainable implementation. If a more well based study were preformed, including water analyses of the chemical composition and the presence of bacteria in the water, part of the problems could be located and the appropriate purification method could be found.

What we have found is that where an implementation of a POU method has taken place it is seldom well based in the local community. The interference with the local values and traditions are too big and therefore not fully accepted. The information and knowledge gap often leads to a short-term use of the methods. Organisations, governments and researchers around the globe should continue to fill this knowledge gap between theory and practice, which this study has taken up. First when this gap between the peoples in areas exposed to bad water quality and the scientific solutions is filled, a better and safer water and sanitation situation can be reached in Uganda and possibly in other vulnerable areas worldwide.

6.6 Sources of error

The study would have gained from a test establishing the present bacteria and chemicals in the water. With unknown levels of bacteria and chemical composition, it is hard to grasp the actual situation in a wider perspective.

When analysing the fieldwork, it became clear that further questions would have been required to get a complete picture of water quality in the villages. Instead of direct communication with the interviewees, the answers were communicated through an interpreter, who sometimes asked the questions in a leading way. During the interviews it sometimes became hard to get independent answers from the households participating in the field study, as it was discovered that households tended to answer the questions similarly if overhearing an interview. Further the village representatives occasionally stood by our side during interviews. It is unclear if this affected the results, since hierarchies are pronounced in the Ugandan culture.

Another factor that could have influenced the results is that the goal of accomplishing 20 interviews was not reached in all villages. This has to be carefully considered while preforming the analysis, since the results from these villages are less diverse. Furthermore, statistics from health institutions in the districts would have provided additional information about experienced water borne diseases and provided a more profound basis for this report. An expansion of the study would widen the perspective of the rural water situation in the districts, or even further to a national level.

7. Conclusion

Recommended point-of-use method for all studied water sources is the biosand filtration method, except for the village Lucisy where an already working method is implemented. Although in many cases the long-term solution is construction of a new water station. Both implementation of the biosand filtration system and the construction of a new water station would require an outside funder. Therefor a temporary answer is the SODIS PET-bottle solution.

In the studied villages there are pronounced problems with the water quality. One of the findings from this study is that the points for collection of water often are in need for renovations and construction of a blockage around the source would solve some of the villages' water problems. For example in Shikoye, where the Manafwa River provides the water, an additional source, in form drilled well, would be required for the possibility to reach a safe water situation.

All villages have their specific requirements and therefore different solutions are needed to meet those, despite the type of water source. This means that there is no general solution for one particular type of water source national or globally, as the regional and local properties and requests need to be regarded. In order to reach a long-term solution the preparatory work is highly important to fortify a change regarding safe water treatment. In conclusion a continued study including more areas of the country would deepen the knowledge and reveal possible spatial trends regarding the influence of traditions and how to cope with these to reach a long-term implementation of a POU method.

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Appendix 1

Questionnaire

What is your name?

How old are you?

How many people are living in your household?

From which water source does your household collect water?

What type of water source is it?

For what purposes do you use your water? (Drinking/ domestic work/ irrigation/ animals)
- if not, are there any limitations?

Are you treating the water in any way to purify it?
-if not, why?
-if, what purification method is utilised and why?

How do you experience the water quality?

Have you experienced any problems with the water or had any illnesses after drinking it?

How do you feel about the water situation in the village / area?

Do you regard the water situation here as a problem?

Appendix 2

Location	District	Village	Water	Id	Sex	Age	Household	Use	Water treatment	Experienced health effects	Sickness	Comment	Content with quality
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	1	Male	44	12	Water for all purposes	None	Yes	Undefined general sickness	Tries to clean it, but no boiling	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	2	Female	59	5	Water for all purposes	None	Yes	Stomach complications	Can't afford to buy cleaner water	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	3	Female	43	15	Water for all purposes	None	Yes	Diarrhea	Water is smelly, cleaning the well does not make a difference	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	4	Male	61	7	Water for all purposes	None	Yes	Diarrhea, Typhoid	Would buy other water if possible	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	5	Male	49	16	Water for all purposes	None	Yes	Stomach complications	Can't afford fire wood	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	6	Male	16	7	Water for all purposes	None	Yes	Stomach ache	Would get other water if possible	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	7	Female	18	6	Only domestic work	None	Yes	Undefined general sickness	Drinking water from a borehole but has to pay for it	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	8	Female	50	6	Water for all purposes	None	Yes	Typhoid, Stomach ache	Water smells bad	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	9	Female	20	3	Water for all purposes	None	Yes	Stomach ache	Cant afford waterguard, water smells bad	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	10	Male	57	10	Water for all purposes	None	Yes	Typhoid, Stomach ache	Cant afford firewood, animals drink the same water	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	11	Male	44	12	Only domestic work	None	No	None	Well water contains worms, can't afford bore hole water	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	12	Female	68	2	Only domestic work	None	No	None	Well water contains worms, leaches in the water	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	13	Female	22	5	Water for all purposes	None	Yes	Stomach ache	Well water contains worms, no access to firewood	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	14	Female	85	1	Water for all purposes	Sometimes boiling	Yes	Typhoid	Boil the water sometimes	No
0°59'16"N,	Mbale	Masanda	Well	15	Female	45	6	Water	Sometimes	Yes	Stomach ache	No Comment	No

34°12'33"E								for all purposes	boiling				
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	16	Female	22	4	Water for all purposes	None	Yes	Stomach complications	Water smells bad	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	17	Female	50	1	Water for all purposes	None	Yes	Stomach ache	During dry season the water gets worse	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	18	Female	21	3	Water for all purposes	Sometimes boiling	Yes	Typhoid	The water doesn't become clean when boiled (the colour) so he don't think boiling helps	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	19	Female	50	9	Water for all purposes	None	Yes	Stomach ache	Problems with too much mud in the water during rain season	No
0°59'16"N, 34°12'33"E	Mbale	Masanda	Well	20	Female	28	8	Water for all purposes	Boiling	Yes	Fever, Stomach ache	No Comment	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	1	Male	40	8	Water for all purposes	None	Yes	Stomach ache	Borehole to far away, toilets connected to the water, washing bikes and motorcycles in the water	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	2	Male	25	1	Water for all purposes	Sometimes boiling	Yes	Stomach ache	No Comment	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	3	Male	52	8	Water for all purposes	None	Yes	Stomach ache, Diarrhea, blindness	Water gets more decomposition during dry season & is muddy during rain season, 2-3 people got blind	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	4	Male	50	5	Water for all purposes	Boiling	No	None	Rotten animals & people in the river, wash of bikes & such in it, contaminated by toilets	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	5	Male	27	9	Only domestic work	None	Yes	Diarrhea, dysentery	Drinking water from a spring, people die when they get water from the river, water is better in the early morning	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	6	Male	44	7	Water for all purposes	None	Yes	Typhoid, cholera	If you continuously drink the water you get sick	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	7	Male	20	8	Water for all purposes	None	Yes	Cholera, stomach ache	Sometimes have fire wood enough to boil	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	8	Male	51	2	Water for all purposes	None	Yes	Stomach complications	Drinks the water as it is due to tradition	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	9	Male	45	6	Water for all purposes	Sometimes boiling	Yes	Typhoid	No access to fire wood	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	10	Male	30	4	Water for all	Sometimes boiling	Yes	Stomach ache	When boiling it's alright to drink	No

								purposes					
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	11	Male	35	6	Water for all purposes	None	Yes	Stomach ache	Drinks the water as it is due to tradition	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	12	Female	40	7	Water for all purposes	Sometimes boiling	Yes	Diarrhea, Typhoid, stomach ache	Children get especially sick from the water, no access to firewood	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	13	Female	36	5	Water for all purposes	Sometimes boiling	Yes	Stomach ache, Diarrhea	No Comment	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	14	Male	40	5	Water for all purposes	None	Yes	Stomach complications	No access to fire wood	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	15	Female	44	11	Water for all purposes	None	Yes	Diarrhea	Rotten animals etc. in the river, no access to fire wood	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	16	Female	25	6	Water for all purposes	None	Yes	Typhoid, diarrhea	No Comment	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	17	Male	59	5	Water for all purposes	None	Yes	Stomach ache, Diarrhea, burping	Lost child due to typhoid, fungus in the water, drinks the water as it is due to tradition	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	18	Male	22	3	Water for all purposes	None	Yes	Cholera, stomach worms	Water contains worms, boiling the water destroys the taste	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	19	Male	26	3	Water for all purposes	None	Yes	Diarrhea, Typhoid	River is contaminated by toiles etc., no time for boiling	No
0°56'27"N, 34°16'48"E	Mbale	Shikoye	River	20	Male	52	5	Water for all purposes	None	Yes	Stomach complications	Rotten animals & people in the river, washing and bathing contaminates it too	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	1	Male	35	6	Water for all purposes	Boiling, Waterguard	No	None	Typhoid in the water, get problems when he's not boiling	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	2	Female	24	9	Only domestic work	None	No	None	Drinking water from another bore hole, water is dirty in the morning, waterguard changes the smell of the water	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	3	Female	39	10	Water for all purposes	Waterguard	Yes	Stomach complications	Water is green and dirty in the morning	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	4	Male	38	4	Water for all purposes	None	No	None	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	5	Female	40	8	Water for all purposes	Waterguard	Yes	Stomach ache	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	6	Female	37	6	Water for all purposes	Waterguard	No	None	No Comment	No

0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	7	Female	24	3	Water for all purposes	Chlorine	No	None	Can get sick by the chlorine	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	8	Female	50	4	Water for all purposes	Waterguard	No	None	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	9	Male	65	4	Water for all purposes	Waterguard, chlorine	No	None	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	10	Female	27	7	Water for all purposes	Waterguard, chlorine	Yes	Stomach ache	No Comment	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	11	Female	48	6	Water for all purposes	Waterguard	No	None	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	12	Female	70	3	Water for all purposes	None	Yes	Stomach complications	No Comment	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	13	Male	69	5	Water for all purposes	Waterguard, chlorine	Yes	Stomach ache	Water contain visible particles	No
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	14	Male	53	8	Water for all purposes	Waterguard	No	None	No Comment	Yes
0°55'59"N, 34°14'45"E	Mbale	Lucysi	Borehole	15	Male	66	2	Water for all purposes	Waterguard	Yes	Stomach ache	Water contain visible particles, don't think waterguard helps	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	1	Male	23	25	Water for all purposes	Boiling	No	None	Water dirty during rain season, sometimes dries out during dry season	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	2	Female	53	10	Water for all purposes	None	No	None	No Comment	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	3	Female	44	14	Only domestic work	None	No	None	Water dirty during rain season, can only be drunk if boiled	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	4	Female	28	15	Water for all purposes	Boiling	No	None	No Comment	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	5	Female	20	23	Water for all purposes	None	No	None	No Comment	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	6	Female	65	10	Only domestic work	None	Yes	Stomach ache, head ache	No Comment	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	7	Male	39	8	Water for all purposes	None	Yes	Typhoid	Too many use it, no time for boiling	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	8	Male	43	2	Water for all	Sometimes boiling	No	None	Tastes salty & has a whitish colour	No

								purposes					
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	9	Female	45	30	Water for all purposes	None	No	None	Snails in the water, believes boiled water gives diseases	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	10	Male	71	5	Water for all purposes	Waterguard	No	None	Uses three different water sources, only drinks from this one occasionally	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	11	Female	26	10	Only domestic work	None	No	None	Uses three different water sources, only drinks from this one occasionally	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	12	Female	60	12	Water for all purposes	None	Yes	Stomach ache	Uses three different water sources, only drinks from this one occasionally	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	13	Female	58	13	Water for all purposes	Waterguard	No	None	Uses three different water sources, only drinks from this one occasionally	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	14	Female	39	5	Water for all purposes	None	Yes	Typhoid	No Comment	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	15	Female	43	12	Water for all purposes	Boiling	No	None	Water contains worms, uses different water sources, only drinks from this one occasionally and thinks that the water needs boiling	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	16	Male	25	2	Water for all purposes	None	No	None	Uses different water sources, only drinks from this one occasionally, gets polluted during rain season	No
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	17	Male	40	-	Only drinking	None	No	None	Drinks water when passing the well	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	18	Male	30	-	Only drinking	None	No	None	Drinks water when passing the well	Yes
2°19'38"N, 32°55'52"E	Lira	Tebung	Spring well	19	Male	25	4	Water for all purposes	None	No	None	Water dirty during rain season, dries up during dry season	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	1	Male	32	7	Water for all purposes	None	Yes	Occasional undefined general sickness	No Comment	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	2	Female	18	10	Water for all purposes	None	Yes	Typhoid	No Comment	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	3	Female	30	9	Water for all purposes	None	Yes	Stomach ache, Diarrhea	Not sure she has problems because of the water	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	4	Female	36	9	Water for all purposes	None	Yes	Stomach ache	Not sure she has problems because of the water	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	5	Female	41	9	Water for all	None	Yes	Diarrhea	Water contains worms	No

								purposes					
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	6	Male	27	3	Water for all purposes	None	Yes	Typhoid, head ache	No access to fire wood	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	7	Female	21	3	Water for all purposes	None	Yes	Diarrhea, worms in stomach	When flooded the cleaner water mixes with the unclean water, thinks the water is clean	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	8	Female	40	5	Water for all purposes	Boiling, waterguard	No	None	No Comment	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	9	Male	23	1	Water for all purposes	Sometimes boiling	Yes	Stomach ache	Animals drinking the water & too many villages, low flow during dry season	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	10	Female	27	7	Water for all purposes	None	Yes	Occasional undefined general sickness	Tastes sour, red & brown worms in it, don't know if they get sick by the water	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	11	Female	20	7	Water for all purposes	Boiling	No	None	Dirty pipes, worms, lived there 3 days	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	12	Female	37	7	Water for all purposes	None	Yes	Stomach ache	Red worms	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	13	Female	17	9	Water for all purposes	None	No	None	Lived there 2 weeks	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	14	Female	16	5	Water for all purposes	None	No	None	No Comment	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	15	Female	24	4	Water for all purposes	None	No	None	No Comment	Yes
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	16	Female	24	5	Water for all purposes	None	No	None	Worms in the water	No Comment
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	17	Female	27	6	Water for all purposes	None	No	None	Looks dirty	No Comment
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	18	Female	38	5	Water for all purposes	None	Yes	Stomach ache	Water contains worms	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	19	Female	60	5	Water for all purposes	None	Yes	Stomach ache	The station is dirty	No
2°14'15"N, 32°57'49"E	Lira	Ogalie	Spring well	20	Female	27	5	Water for all purposes	None	Yes	Stomach complications	Water contain visible particles, station is dirty	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	1	Male	43	8	Water for all	Waterguard	Yes	Diarrhea, worms in	Visible worms	No

								purposes			stomach		
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	2	Female	25	5	Water for all purposes	None	Yes	Children get diarrhea	Water contains worms, too many use the source it dries up, goats drink from the source	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	3	Male	40	7	Water for all purposes	None	Yes	Children get diarrhea, typhoid, amoeba	He doctor blames the water	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	4	Female	40	5	Water for all purposes	Waterguard	Yes	Diarrhea, typhoid, amoeba	Goats in the well, kids die in the water, doctor blame the water, without waterguard they get problems	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	5	Female	33	6	Water for all purposes	None	Yes	Stomach ache, head ache, typhoid, amoeba	Animals in the water	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	6	Female	45	6	Only domestic work	None	No	None	Feels the bore hole water is better	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	7	Female	27	4	Water for all purposes	Boiling	No	None	Didn't boil 1 time & had no problem, animals in the water	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	8	Male	25	2	Water for all purposes	Sometimes boiling	Yes	Stomach complications	Water contain visible particles, no time for boiling	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	9	Female	54	9	Water for all purposes	None	Yes	Stomach complications	Contaminated during rain season by floods, no time for boiling	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	10	Female	43	4	Water for all purposes	None	Yes	Stomach ache occasionally	Don't know if the water gives the problems, muddy during rain season, assumes the water is clean	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	11	Female	65	7	Water for all purposes	None	Yes	Stomach ache occasionally, worms in stomach, Children get rashes	Worms, faeces, no time for boiling, don't like taste of waterguard	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	12	Male	32	6	Water for all purposes	Waterguard	No	None	No Comment	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	13	Female	66	10	Water for all purposes	None	Yes	Head ache, fever,	Don't know if the water gives the problems	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	14	Male	25	3	Water for all purposes	None	Yes	Stomach ache, typhoid, malaria	Assumes the water is clean	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	15	Female	17	3	Water for all	Waterguard	Yes	Stomach complications	Animals in the source	No

								purposes					
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	16	Male	78	7	Water for all purposes	None	Yes	Children get diarrhea	Dries up during dry season	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	17	Female	69	7	Water for all purposes	None	Yes	Stomach complications	No Comment	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	18	Male	59	4	Water for all purposes	None	Yes	Stomach ache, malaria	Doctor said it's unsafe water, muddy during rain season	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	19	Male	44	7	Water for all purposes	None	Yes	Stomach ache, worms in stomach	Doctor said it's unsafe water, muddy during rain season, Drinks the water as it is due to tradition	No
2°18'41"N, 32°42'29"E	Lira	Abolo Nye	water hole	20	Male	52	6	Water for all purposes	None	Yes	Stomach ache, malaria	Confused about how to boil & use waterguard together, Water dirty during rain season	No
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	1	Female	66	2	Water for all purposes	None	No	None	Assumes the water is clean	No
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	2	Female	61	4	Water for all purposes	None	No	None	Animals drink the same water	No
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	3	Female	23	4	Water for all purposes	None	Yes	Stomach ache	Assumes the water is clean, station in bad conditions with animals getting into the water	No
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	4	Female	19	10	Water for all purposes	None	Yes	Stomach ache	Assumes the water is clean	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	5	Male	25	7	Water for all purposes	None	Yes	Occasional undefined general sickness	Assumes the water is clean, don't know if the water gives the problems, the spring gets low flow in dry season	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	6	Female	33	9	Water for all purposes	None	No	None	Assumes the water is clean, too many use water source	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	7	Male	69	2	Water for all purposes	Sometimes waterguard	No	None	Don't notice any difference when using waterguard or not, animals drinking the water	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	8	Female	16	6	Water for all purposes	None	No	None	Assumes the water is clean	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	9	Male	40	7	Water for all purposes	None	No	None	Cows in the water	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	10	Female	65	7	Water for all purposes	None	No	None	Station in bad shape	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	11	Male	41	1	Water for all	None	No	None	Station in bad shape	Yes

								purposes					
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	12	Male	56	9	Water for all purposes	None	No	None	Station in bad shape, floods during rain season	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	13	Female	23	10	Water for all purposes	None	No	None	Red worms	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	14	Male	23	3	Water for all purposes	None	No	None	Brown worms in the water, station in bad shape	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	15	Male	20	3	Water for all purposes	None	No	None	Station in bad shape	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	16	Female	60	9	Only drinking	None	Yes	Occasional stomach ache	Worms in the water, gets flooded during rain season	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	17	Female	36	10	Water for all purposes	None	Yes	Typhoid, stomach ache	Assumes the water is clean, animals in the source	Yes
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	18	Female	53	6	Only drinking	None	Yes	Stomach ache	Too much work boiling the water, problem accessing the well during rain season	No
2°20'03"N, 32°41'03"E	Lira	Abolo Yero	Spring well	19	Female	27	3	Water for all purposes	None	Yes	Stomach ache, malaria	Station in bad shape	No