AN INVESTIGATION OF FACTORS AFFECTING SUSTAINABILITY OF ROPE PUMPS: A CASE STUDY FOR SELECTED TRADITIONAL AUTHORITIES IN RUMPHI DISTRICT, MALAWI

JACOB CHING'ANYI MKANDAWIRE

A THESIS SUBMITTED TO THE FACULTY OF ENVIRONMENTAL SCIENCES, DEPARTMENT OF AGRI-SCIENCES IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN TRANSFORMATIVE COMMUNITY DEVELOPMENT

MZUZU UNIVERSITY

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DECLARATION

I hereby declare that this thesis titled, "An investigation of factors affecting sustainability of rope pumps: a case study for Rumphi District" has been written by me and is a record of my research work. All citations, references, and borrowed ideas have been duly acknowledged. It is being submitted in fulfilment of the requirements for the award of the degree of Master of Science (MSc) In Transformative Community Development of the Mzuzu University. None of the present work has been submitted previously for any degree or examination in any other University.

________________________________ ________________________________

Jacob Ching'anyi Mkandawire Date

CERTIFICATE OF APPROVAL

The undersigned certify that this thesis is a result of the author's own work, and that to the best of our knowledge, it has not been submitted for any other academic qualification within the Mzuzu University or elsewhere. The thesis is acceptable in form and content, and that satisfactory knowledge of the field covered by thesis was demonstrated by the candidate through an oral examination held on 20 June 2019.

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Dr. Mavuto Tembo

ABSTRACT

The Malawi Government has a set of recommended hand pumps as an approach to increase access to potable water, especially in rural areas. Although these approved pumps have contributed in the scaling up of rural water access, some low-cost technologies have also been, unofficially part of the water supply solution. Amongst these is the rope pump, which has been installed on 48 community shallow wells in Rumphi District.

This study was conducted to determine water quality, functionality rate and consumer satisfaction of 48 rope pumps in rural Rumphi District. Interviews were conducted, through questionnaires, to establish water users' perceptions of best practices, guidelines to contribute to the sustainability of the rope pump and their satisfaction with the pump.

The study found that cumulatively, (23/48; 48%) rope pumps were non -functional due to different reasons. On water quality, the study found most (22/24; 92%) pumps had water suitable for drinking based on the national Standards for thermotolerant coliforms (MBS, 2005, MS 733). Less than half (11/24; 46%) of the pumps had water suitable for drinking based on the more stringent World Health Organization guidelines for thermotolerant coliforms. Two pumps had water not suitable for human consumption (>200 CFU /100ml), and many (15/24; 63%) pumps supplied water with turbidity of <5 Jackson turbidity units. The pH ranged from 5.9 to 7.3 with no pump exceeding the national standard. In terms of user responses, forty three percent (204/472; 43%) reported that the rope pumps provided uninterrupted service since installation, hence satisfied.

The study recommends enhanced capacity building for water committees and siting water points away from potential contaminants. Best practices like responding based on demand, establishment of spare parts supply chain and improved governance should be included in future programming.

DEDICATION

This work is dedicated to the entire Ching'anyi family, my dear wife Lily and our Mphembuzgo who kept me in prayers throughout the academic journey till the dream has come to reality.

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LIST OF ABBREVIATIONS AND ACRONYMS

CFU	Colony Forming Units
CLTS	Community Led Total Sanitation
DRA	Demand Responsive Approach
DSIP	District Sector Investment Plan
JTU	Jackson Turbidity Units
MBS	Malawi Bureau of Standards
NTU	Nephelometric Turbidity Units
PPM	Parts Per Million
RWSN	Rural Water Supply Network
SDGs	Sustainable Development Goals
TA	Traditional Authority
TNTC	Too Numerous To Count
USD	United States Dollar
VLOM	Village Level Operation and Maintenance
WASH	Water Sanitation and Hygiene
WHO	World Health Organization
WSP	Water Sanitation Programs

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Water and sanitation are amongst vital elements which lead to improved public health, spur economic development and reduce poverty (Brocklehurst, 2011). Yet, in the year 2015, 2.1 billion people still did not use an improved source of drinking water (WHO, 2017). In Malawi, coverage of improved water supply is currently at 84% (Malawi Government, 2014-2024). This means that there is still a deficiency in accessibility to safe water in some communities, especially rural areas. Water sources which provide safe water include protected shallow wells, boreholes; taps supplied through gravity and motorized water supply schemes. However, there are some practices which, if implemented, can make unsafe water potable for human consumption (Fewtrell, 2005). These practices include water treatment with chlorine, filtration or boiling water to kill infectious bacteria before drinking (Mwabi et al., 2011). In areas where improved water supply has not yet reached, it is encouraged that water treatment should be done routinely, although water treatment is mostly influenced by outbreak of water borne diseases for instance, cholera and diarrhea (Zin et al., 2013). Water treatment can be done at both household and facility level. According to Lantagne and Yates (2018), treatment for stored water at household level should still be done to improve quality.

In Africa, during the water decade which was declared by the United Nations, most countries concentrated on the provision of water through deep wells and tap water supplied through gravity water schemes. This was the case since these water facilities provide water of good quality as long as the sources are not contaminated or closer to contaminants. According to Fattahi (2011) the satisfaction community gets from an entity results into sustainability.

Sustainability of water points is also possible if community members take part in the management of their water supply points.

In Malawi, there have been several water supply projects through which groundwater technologies have been used, such as, the Mzimba West Water Project in which a total of five hundred boreholes were drilled. Other recent projects using groundwater technologies include the Sustainable Rural Water and Sanitation for Improved Livelihood and the WASH Challenge Projects in Rumphi District (Malawi Government, 2014-2024).

Afridev, Malda and Climax are the only approved hand pumps in Malawi. Afridev pumps have the capacity to lift water from as deep as 50m or more, while Malda pump is suitable for shallow wells (Malawi Government, 2016). Although approved, the Climax pump is mostly being used for deep water and institutional water supply. The Pump is losing popularity for rural water supply due to its complexity (Njalam'mano, 2007). This pump is especially being phased out because it does not meet the requirements of village level operation and maintenance initiatives which advocates for pumps that are easily managed by community members and whose spare parts are affordably priced (Matamula, 2008).

Other technologies which are used for groundwater extraction in Malawi include Mark 5, Malda and Naira pumps. These technologies are more suitable for shallow water points when compared to the depths that can be reached by Afridev pumps (Colaru et al., 2012). The existence of these pumps has also been compromised by limited spare parts and supply chains to support functionality of these pumps, especially for Naira and Mark 5 because they are currently categorized less optimal designs (Getachew & Baumann, 2010). To some extent, Malda pump spare parts are available, especially in rural areas where non-governmental organizations have undertaken initiatives to use the pump.

Though focus of the ministry responsible for water affairs has been on the approved pumps, low cost technologies are becoming increasingly important to sustainable rural water supply (Holm, 2017). Amongst the low-cost groundwater extraction technologies gaining popularity is the rope pump (Harvey & Drouin, 2006; Coloru et al., 2012; Annemarieke, 2016; Holm et al., 2017). This pump has a long history with its first working principles developed in China some two thousand years ago but has continued to be introduced in several countries for water for household use, human consumption and agricultural production (Holtslag, 2009). According to Coloru et al. (2012), in Zimbabwe the rope pump was introduced for small scale irrigation but in the Latin American country of Nicaragua, the rope pump was introduced for drinking water supply (Albert, 2000). In Nicaragua, rope pumps have become a preferred option which contributes to availability of rural water supply (Parry-Jones et al., 2001). In Malawi the pump has also been used in some areas such as in Rumphi District, though there are no existing studies in Malawi to determine quality of water as per national and World Health Organization (WHO) standards (MBS, 2006; WHO, 2011).

Even though new technologies have been introduced in several areas through different initiatives, there is little that has been done to integrate sustainability in management of these water facilities (Whaley & Cleaver, 2016). Integration of sustainability in water facilities management was initiated through the agenda 21 of the United Nations. Although the SDGs have been very crucial in encouraging nations to mobilize resources for investing in the water sector through rapid construction of new water facilities, little attention has been paid towards investing to sustain the already existing water infrastructure which also cost a lot to be made. The promotion of investing in construction of new water facilities through the sustainable development goals has contributed in undermining functional sustainability because less emphasis has been made towards encouraging nations to consider integrating sustainability issues in the water infrastructure programming.

In Malawi, the government is currently integrating sustainability issues in water programs through introduction of technologies which can be wholly managed by the local members of the community through introduction of the village level operation and maintenance (VLOM) initiative (Matamula, 2008). This initiative aims at building capacity of community members to manage, operate and repair their water facilities (Malawi Government, 2005). The Village Level Operation and Maintenance initiative is supported by the community based management training which promotes community participation and empowerment in water points management (Matamula, 2008). Community empowerment is an area of focus in a bottom up approach and also embraced in the Decentralization Policy of 1998. Decentralization provides an environment in which community members demand what they feel should be included into their development endeavor through a participatory planning processes (Malawi Government, 1998). The community based management process also enhances the element of community resources mobilization and contributions towards operation and maintenance which has proved very efficient in contributing to sustainability of water points in many countries (Matamula, 2008). The process of water user empowerment is also in line with the Malawi Government (2005) which advocates for integrated water resources management through building capacity of water user groups and empowering the water point committees. The Government of Malawi (2005) also advocates for private sector involvement in water resources management and development.

Currently a sustainability mechanism which is being advocated in the water sector is the Water Users Associations which is a management tool for the Gravity Water Supply Schemes (Malawi Government, 2008). Through the Water Users Association, communities who benefit from a water supply scheme are sensitized, mobilized, then empowered to manage their own water supply entity with minimal outside support activities from government staff members. The mobilization process is championed by extension workers from the government and partners providing water supply services to the community (Malawi Government, 2010). The empowerment process of Water Users Association is done through a stepped up approach, which is a process where communities are taken through several trainings relevant to management of water supply facility.

In all the sustainability mechanisms being initiated, the government aims at saving resources through sustaining the already available water supply facilities rather than solely by investing in new initiatives. This is being done in a decentralized way so that the community members are involved in all the project activities including decision making (Leclerc et al., 2016).

1.2 Problem statement

The Malawi Government and water, sanitation and hygiene partners are key in the implementation of water projects in Malawi. These entities aim at improving safe water accessibility to the community members and contribute toward attainment of SDG number six of the United Nations. Mostly, water programs are implemented using hand pumps for rural water supply. The approved pumps include Afridev, Malda and Climax pump (Malawi Government, 2016). Though focus is on the approved pumps, low-cost water supply technologies are becoming an important solution to sustainable rural water supply (Holm et al., 2017). Notably amongst the low-cost technologies is the rope pump which is increasingly becoming a reliable, affordable and efficient source of water for small communities and individual families. For instance, in Rumphi District a water project using the rope pump was implemented with 1611 beneficiaries mostly located in hard to reach areas with limited or no alternative sources of safe drinking water. Despite such efforts and investment in the sector at District level through provision of rope pumps, the functionality status over time of the water points is not known more than one year post-construction. In addition to that, user' satisfaction about the pump in the Malawian context has not yet been established (Carter et al., 2010). Moreover, water quality of rope pumps in Malawi has not been determined and compared to national and WHO standards despite being a requirement before human consumption (Malawi Government, 2005). The untested water may be hazardous to community members specifically for the contaminated water which may cause water borne diseases which are prone in some locations within the study area. What communities feel should be included as best practices in rope pumps management and sustainability in their respective areas has also not been established.

1.3 Study objectives

1.3.1. Main objective

The main objective of the study was to investigate factors affecting sustainability of 48 rope pumps in Traditional Authorities Mwalweni, Mwamlowe, Mwankhunikira, Chisovya, Mwahenga and Kachulu in Rumphi District.

1.3.2 Specific objectives

The study specifically was aimed to:

- Establish functionality rate of the 48 rope pumps
- To establish consumer satisfaction of the 48 rope pumps

- Determine water quality for samples collected from 48 rope pumps and evaluate them in terms of their conformity to Malawi Bureau of Standards and World Health Organization drinking water quality standards

- Identify best practices for sustainability of rope pumps based on the link between participatory planning and community empowerment.

1.3.3 Research questions

- Are the rope pumps still functional one year post construction?
- Is the rope pump user satisfied with the pump?
- Is water quality from rope pumps potable based on MBS and WHO drinking water quality specifications?
- What could be the best practices for sustainability of the rope pumps for rural water supply in Malawi?

1.4 Justification of the study

Determining whether community members are consuming safe water meeting national and WHO guidelines from the rope pump supply is vital. This study will come up with issues on water quality, functionality, user satisfaction and best practices to be included in future programming concerning the rope pump. It is expected that the findings will be used by policy makers to consider the rope pump technology as a sustainable rural water supply technology especially for the small communities in rural and hard to reach areas where mechanically drilled boreholes cannot be possible. The District council through the study will be able to include rope pump issues in the District Sector Investment Plan as the status of the rope pumps will be known few years post construction. The District council will also be able to include water quality programs, especially if the results will indicate poor water quality for these pumps which are currently in use. Another important aspect is that there have been limited studies on rope pump water quality and compared to limited available global studies. Academically, the study will be able to expose and recommend some areas which may need further investigations.

1.5 Ethical consideration

Authorization to conduct the study was sought from Rumphi District Council, the local village authorities in which the study communities are located and from the National Commission for Science and Technology was provided prior to field data collection. Questionnaires, Observational field checklist written consent and water quality results are in Appendixes A, B, C, D and E.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter discusses an overview of global groundwater extraction technologies, and description and application of the rope pump and elements which may contribute to user satisfaction. It then examines issues of best practices and guidelines to improve sustainability of the rope pump based on a link between participatory planning and community empowerment. Due to scarcity of the literature specifically for the rope pump; literature is based mostly on models used in boreholes management which also applies in the management of low cost technologies like rope pumps and others.

2.2 Overview of water technologies

Fresh water resources can be categorized into two types; groundwater and surface water. Surface water includes a network of river systems and lakes which cover 20% of the total surface area in Malawi (Nangoma, 2007), including Lake Malawi, Shire river and others. Groundwater is another type of water which lies beneath the earth surface. Water lifting technologies are used as a mechanism to lift water from groundwater to a point where the drawer can easily access the water. There are several water lifting technologies, Yannopoulos et al. (2015) describes the rope and bucket system as one of the very first water lifting technologies.

In the past decade, hand pumps have been one of the major technologies for groundwater extraction for both human consumption and agricultural production (Yonnopoulos et al., 2015). Hand pump are both manually and mechanically drilled but operated by hand, some could be as shallow as 20 meters but others are deeper. Examples of hand pumps include Afridev and rope pumps (Holm et al., 2017). Although some projects in which groundwater extraction was done using hand pumps have failed, there is evidence that many rural communities are and will continue to rely on hand pumps for the extraction of groundwater for both human consumption and agricultural production.

2.3 Rope pump description and application

According to Albert (2000), the rope pump (Figure 1) has been around for 2,000 years. The pump is made of a fly wheel through which the rope passes into the well. Blackman (2000) stated that the pumping mechanism of the rope pump depends on the rope which is fitted

Figure 1: Rope pump at Vyeyo in Rumphi District

within a wheel. As pumping is done water is lifted through and each piston traps a column of water inside to a higher height up to the outlet above the ground surface. The rope pump can be installed on both shallow and deep wells. The introduction of the rope pump in Africa and Latin America during the 1980s was as a result of several water programs which used the pump as a self-supply option for community members (Blackman, 2000). A technological change in the rope pump system happened in 1984 where there were some improvements in the parts of the pump, specifically a rubber washer was made by incorporating molds (Albert, 2000). This innovation made Nicaragua the world's forerunning producer of the rope pumps, where it was known as the Liberator (Coloru et al., 2012; Alberts & Zee, 2003). Since its global introduction, the pump has been introduced for household water supply in several countries including in Nicaragua, Ghana, Zimbabwe and Madagascar (Sutton & Gomme, 2009).

2.4 Functionality of rope pumps

Each type of a water point has already set standards which determine its functionality level. Functional water point is the one which is able to produce water of expected amounts. According to operation of a conventional Afridev pump, a fully functional pump is supposed to produce 0.25 liters of water per second which translates to 15 liters per minute. Functionality of a water point can be compromised by different factors including worn out parts and water table amongst others. According to Matamula (2008), functionality could be enhanced with community members' participation as encouraged by the community based management approach in the rural water supply sector.

Another aspect which contributes to enhanced functionality of water points is the creation of a vibrant operation and maintenance within the areas framework. Also of importance is the establishment of a vibrant spare parts supply chain within the area.

2.5 User satisfaction

Water facility users feel satisfied if the water point serves according to their expectation. According to Fattahi et al. (2011) satisfaction can be obtained if the water produced from a water point is of enough quantity, is of good quality, amount of user fees is affordable by users and with persistent water supply. Apart from the mentioned factors which contribute to user satisfaction some include that the pump spare parts are easily accessible because they are locally found, which contributes to reduction of breakage time and that the pump can be easily repaired by local community members as long as they have gone through adequate community based management training as per requirement in rural water supply (Malawi Government, 2005).

Users who are deceived by the service received are disgruntled, they end up losing interest in that service, and they mostly portray a negative image about that service to other people who would be willing to have that service in near future (Khan, 2012). It is of prime consideration for service/product providers to emphasize on quality of product and services (Kumar, 2018). There is a linkage between the way something looks, value and the possibility of consumers demanding for it (Khan, 2012). Holm et al. (2017) state that in Rumphi, 96% (78/81) rope pump were satisfied with the pump due to its simplicity to repair. This was during a study where communities were being assessed on their technology choices. Sustainability in this context refers to water point which is able to provide water of good quality and quantity since installation. The water should be of recommended standards and the entity itself should be one which can be managed by the local community members. The issue of sustainability is also linked with the environment. Specifically for water supply, environment plays an important role as it can be the source of contamination and also a contributing factor to sustainable water supply.

Rope pumps have been installed on shallow wells since there capacity should not be overestimated (Annemarieke, 2016). According to Atine (2014), rope pump users in Uganda expressed satisfaction with the pump due to its affordability, as around the year 2011, the rope pump was pegged at around USD 240 which was at around 60,000 Uganda Shillings. On the other hand the water quality aspect was another element which satisfied rope pump users in Gulu District in Uganda (Atine, 2014). Hughes et al. (2004) expressed that rope pump users in Kenya were mostly satisfied due to the impact as there was a reduction in cases of typhoid after the rope pumps were introduced in Eldoret District in Kenya. Of course there was an argument that the introduction of rope pump could not be the sole attributor to the reduction of the outbreak as the disease is caused by several factors (Hughes et al., 2004).

The rope pump has a reported lower maintenance cost than the conventional piston pump. A study in Ghana showed that the average maintenance cost of a rope pump was USD$40 per year, including depreciation and replacement cost (Blackman, 2000). This was in comparison to the Naira AF85 which had more than twice maintenance cost of the rope pump (Blackman, 2000). There are arguments against the pump, especially on the operation of the pumps, which others have urged can lead to susceptibility to biological contamination when compared to the conventional Afridev pump. The arguments are based on the pumping mechanism whereby the rope is exposed to the outside environment and the outside environment could lead to contamination (Colaru et al., 2012). Also there are aesthetic arguments, as according to its basic looks and operation, the pump is deemed not very reliable as some of its continued operation depends on some very basic things like a rope (Sutton & Gomme, 2009). Sutton and Gomme (2009) also emphasize that the variability and quality of the manufacturing is also another argument against the rope pump. This could be the reason why most nations have not taken on-board the rope pump technology in their programs. In most scenarios, the government is responsible for regulating and controlling quality of the goods being manufactured in a country but this has not been the case with rope pumps since for many countries there are no formal guidelines or regulation by governments in the production of rope pumps. In this case, quality control in the production of rope pump is left in the hands of producers, Non-Governmental Organizations and/or donors (Sutton & Gomme, 2009). This status quo results also in manufacturers of these rope pumps having different designs, hence potentially compromising the pump. In Ghana only 20% of the pumps installed worked in a World Bank Project because there were inadequate quality checks on the manufacturers of the pump and in some instances the produced pumps were of poor quality (Holtslag, 2009). In addition to the operation, aesthetics and manufacturing arguments provided above, the rope pump has a lower capacity in terms of its production quantities as it is capable of serving only about 120 people compared to 250 people for the Afridev hand pump. In Malawi, a water point (borehole) is drilled where it can be used by up to 250 people and a shallow well up to 150 people. A communal tap supplies up to 120 people (Malawi Government, 2015). This can pose a challenge if a rope pump project is being implemented in a highly populated area, for example, in rural market centers. Also, although the rope pump has capacity to support irrigation activities, there have been some assertions that it lacks capacity of such activities. The rope pump can only support small irrigation services (Carlos & Perez, 2004). While planners and developers of irrigation schemes are incorporating other equally important things in the design of these schemes, for instance, sanitary facilities, dip tanks and even flush toilets within the area to improve hygiene and sanitation through adaptive livelihood approach, such a complex undertaking cannot be achieved through a rope pump supported irrigation scheme due to its inadequate capacity (Van Koppen et al., 2006).

2.6 Best practices to sustain the rope pump based on the link between participatory planning and community empowerment

A sustained water supply is a service that does not breakdown regularly, able to produce enough water for the community members, and in case it gets broken down it can be easily fixed by local water users (Dayar et al., 2000). Sustainability is directly linked to communities because they have the responsibility of taking care of their water facility which has been provided (Ceasar et al., 2015). A sustained service is one where the community has the ability to maintain it without relaying wholly on outside intervention (Jimenez et al, 2017). Carter et al. (2010), in a more action-oriented assertion, defined sustainability as continued provision of water by a utility through evolving and adaptive mechanisms. An example could be responding to community demands for water and sanitation services rather than just imposing an initiative on the community members. Despite the efforts by the United Nations, it is worth mentioning that there is high prevalence of non-functional water points (Bordalo & Bordalo, 2007) and this result in seeing in many African countries an operational failure rate of between 35%-40% (Jemenez et al., 2017). Whaley and Cleaver (2016) state that functionality does not only indicate what portion of the water points are functional, or not, but can also serve as a proxy for sustainability.

Evidence to show that sustainability is a challenge in the water, sanitation and hygiene sector includes a local example in Rumphi District where non-functionality rate of water points is at 35% (Rumphi District Council, 2015). At the core of this failure rate are that these programs have overwhelmingly focused on coverage while other dimensions of quality and continuity of supply have largely been overlooked while on the other hand community based management is inadequately enhanced in the process of project implementation.

2.6.1 Demand responsive approach

Sustainability is linked to having a desire to have something, as one can sustain something they desire (Mugge et al., 2007). Demand is also associated with community making an informed choice (Mugge et al., 2007), and that communities are able to prioritize a service which they demanded as it was already made known to the communities during the process of making an informed choice (Dayal et al., 2000). Demand for water services is the basis for understanding the situation in which the community members are, in terms of water services. Usually, the communities that demand for these services are those that are most in need of the services. This is done through a demand responsive approach which responds to community needs and what they will be able to take care of through locally mobilized resources (Chambers, 1994; Ramaswami et al., 2007).

The supply driven approach, also referred to as a welfare approach is when community members don't participate in choosing an initiative. The entire process of choosing a community project is in the hands of centralized set up (Naiga et al., 2012). Demand responsive approach in water supply advocates for service providers to respond to community needs for water since if a water system has been imposed on the people the end result is that there is no organized management system. In most cases, there are no spare parts for that particular water point, and the end result is that the water point is not sustainable. Supply driven approaches favor those who have a strong financial muscle, with those in decision making positions like politicians likely to receive the services (Sugden & Jenkins, 2006). If there is no community demand for a water facility, communities take a passive role in caring for and sustaining of these water utilities. Supply demand can, for example, be associated with government or donor identifying suitable projects without community taking part in the process. Whereas, community demand for water and sanitation has proved to be a very effective tool for success, for example, if the communities are made aware of the available products they can demand for such a product. In several occasions, awareness creation about the availability of a service leads to creation of demand. Evidence has shown that if project planners do not consider the nature of consumer demand, the performances of those projects are generally poor. Imposing projects on communities through a top down approach kills community desire to own the initiatives, for instance, had it been that the rope pumps were imposed on the community members, participation in the construction process would have been compromised (Parry-Jones, 1999). WSP (2001) observed that there are several principles of demand responsive approach which include that of informed choice which emanates from the communities themselves identifying their needs and ranking the needs to ensure the felt need is addressed first. After the actual need identification, there is that element of planning for intervention, where the community should be able to identify a solution for its need. Solutions can include consulting relevant service provider basing on the need. However, in principle, demand responsive approach can be achieved if there is total community engagement in the entire process but could be compromised if these communities do not have necessary capacity to take care of the water points on their own (Harvey & Reed, 2006).

Participatory rural appraisal process leads to communities to identify their needs hence they demand for interventions. This has so far led to scaling up of sanitation coverage in Malawi through the community led total sanitation (CLTS). The CLTS program is a process through which awareness is created among community members on sanitation issues which result into community members taking action in order to improve their sanitation status (Fewtrell et al., 2005). Currently, ninety four traditional authorities in Malawi have been declared Open Defecation Free (ODF) using the CLTS approach. In Rumphi, 10 of the 11 Traditional Authorities are Open Defecation Free. The ODF traditional authorities include

Mwankhunikira, Mwalweni, Chisovya, Mwamlowe, Kachulu, Katumbi, Zolokere, Mwahenga, Chapinduka and Njikula.

2.6.2 Community based management of water supply services

Community management is in line with the Decentralization Policy (1998), though it is a challenge to be implemented by local councils in Malawi due to under staffing and inadequate financial resources. Central management of water systems, where management and repair are in the hands of government has been replaced with decentralized community management to empower communities (Harvey & Reeds, 2006). But of late the concept of community management has been advocated through creation of local operation and maintenance systems. Vibrant and operational management structures contribute towards sustainable water systems like conventional pumps, rope pumps in several countries, for instance, Nicaragua (Alberts, 2004). The role of water point committees, local area mechanics and local leadership is to make sure that the pump is operational, well cared for, has well developed and functional management plans and also has finances for operation and repairs (Lockwood & Smits, 2011). For a system to work, it depends not only on the physical infrastructure but also on the availability of functional water point committees, local development committees and associations (Whaley & Cleaver, 2016). Dynamic operation and maintenance also include establishment of the spare parts supply chain, performing surveillance on the activities and working with stakeholders for ongoing technical back stopping, training and support.

Community empowerment is based on the notion that people should be able to stand on their own, be focused, and be able to explore other ways which could assist them in sustaining a water facility. In the rural water supply sector, the starting point for all the above accessions to be successful is the introduction of hand pumps for the community members. These pumps are easy to maintain and the actual maintenance is ably done by village caretakers, requiring few tools and minimal skills, manufactured locally so that the spare parts should be easily accessed and at an affordable cost (Etongo et al., 2018). The availability of maintenance materials should be supported with accessible spare parts supply chain, defined as a well-coordinated, vibrant network of spare parts in a particular area where the pump is located. This is usually done by a network of small business people living in the area since supply chain can be established in any situation regardless of the technology being used as long as users have agreed to establish such an important entity (Mentzer et al., 2001). There is need to enhance water systems performance with improved technological methodologies which supports the element of information sharing once the water point is broken down. One of the elements to improve response to broken water points is through the establishment of a surveillance response paradigm where data is used to give rapid feedback for a particular scenario, such as when a system has stopped functioning or when something needs to be attended to (Thomas et al., 2012). An example to illustrate how a response paradigm works is that of traffic lights that work dependently on the availability of traffic (Thomas & Koehler et al., 2015). In the water sector, the system is now being used to give feedback to the service providers in cases where the water point is malfunctioning (Nagel et al., 2015; Thomas & Koehler, 2015; Thomas et al., 2015).

Local councils are mandated to sensitize the communities on why they need to pay for the water services (Malawi Government, 2005). In many areas payments for water supply services are not consistent because of the sentiment that water is life and a gift, rather than emphasizing on a functional cost which needs to be attached to water supply so that it should be sustained (Malawi Government, 2005). In practice, payment mechanisms for water supply facilities are mostly not done and in most cases the amounts are far less compared to the capital investment and the required resources for maintenance. However, it has been observed that most water users have a problem to attach a cost to water services, even when there is need. Although some communities do not understand the importance of paying for water services, several studies have established that in systems where communities pay, the systems are sustainable. The resources which are mobilized at a water facility level are used for purchasing of spare parts which are used during preventive maintenances. It is encouraged that water point management committees should have readily available finances and spare parts so that if a system is broken it should be fixed within a short period of time (Kalulu et al., 2012).

Community Based Management has some limiting aspects in cases where community members cannot fully support their water supply services. It is evident that some local structures do not still have full capacity to manage their water points without some linkages with external service provider (Harvey & Reed, 2004). In reality, there is still reliance on external service providers, for instance, some entities would be able to provide assistance financially while others would choose to support through the provision of skills and actual building of capacity of water users through trainings. The most commonly used method is the provision of skills, through technical cooperation instead of cash (Lockwood & Smith, 2011). Sources of financial support are usually from local government, government agencies and development partners. Some of the support which is rendered by the services providers includes major maintenance. Institutional organizations of user groups are also important for financial sustainability (Koestler et al., 2014).

2.6.3 Spare parts supply chain

One of the important elements contributing to the sustainability of hand pumps is the strength and availability of the spare parts supply chain. The process of taking care of the spares from the production point to the outlets up to the end user is what is regarded as supply chain.

Supply chain even takes care of the transmission process from the point of manufacturing to the user or consumer. According to RWSN (2009), 25% of the water points in Democratic Republic of Congo were not functional primarily due to an ineffective spare parts supply chain. Similarly, a recent study in Eastern Congo, concluded that no spare parts supply chain exists in that area hence high level of non-functionality of water points (Koestler et al., 2014). In Malawi, functionality of rope pumps is compromised by unavailability of spare parts supply chain and non-existence of funds for repairs at water point level (Holm et al., 2017). There is need to establish a spare parts supply within the geographic network where the pumps are. Supply chain is regarded as the mechanism through which spare parts are distributed through an established network within an area. This could be done using the available outlets, for instance, if in an area shops are available, they can be used as out lets for supplying the available spare parts. Aspects which need to be considered in supply chain management include level of functionality, being well organized and coordinated, involvement of other stakeholders and unity among all the involved entities.

Entrepreneurs in the supply chain management of water facilities and services should be vibrant as the entire management and selling of spare parts depends on them. In this case they should focus their service on the available customers who own the water points in their respective catchment areas. Business people in the supply chain should be able to be strategic, be procedural in doing their under takings, be visionary as they need to consider technological changes and be customer focused since they cannot survive without the customer.

As the community members in the water supply services will be engaged in spare parts supply chain process, there are several elements which they should look at including the initial identification of the spare parts supplier. There is need to exercise prudence in selection of suppliers within the hand pump supply chain. This could be possible through having qualified procurement officers, though it is very difficult to find these qualified personnel in rural areas (Tuckwood & Mankenzie, 2012). Having the right suppliers will result into having goods of good quality within agreed time (Pazhani et al., 2015). Bidders' selection is tricky since there are several modalities which must be followed to reach a point where you can have the right supplier in place in rural areas (Karsak & Dursun, 2015). Tuckwood & Mackenzie (2012) noted that product quality, on timely service delivery and performance history are significant criteria in supplier selection. Proper supplier selection will result into the reduction of optional charges, improved returns in terms of profits and improving quality of the product (Abdollahi et al., 2015). Despite the many positive contributions which a vibrant spare parts supply chain inputs towards the sustainability of water supply services, overcoming the risks associated with poor management becomes a challenge. Supply chain risk management in water supply is explained as exploring issues that could affect the operation of the management system of the supply chain (Wieland, 2013). Some of the internal risks within the water supply chain system include equipment malfunctioning, planning, risk in demand, or which spare parts the supply entity cannot practically supply due to large quantities of the supplies needed as highlighted by Thomas et al. (2013).

The duty of those who have been put in the management positions is making sure that the rope pumps are sustainable in a particular area. This could be possible if there is a vibrant spare parts supply chain so that those spare parts should be readily available to support the Operation and Maintenance system and any broken-down time status is reduced. Supply chain risk includes anything which can compromise the success of the supply chain process from supplier to user (Shashak & Goldsby, 2009). To increase the effectiveness of the supply chain we need to put in strategies that could reduce the uncertainties. According to

Punniyamoorth et al. (2013), reducing supply chain uncertainties leads to enhanced supply chain performance. The results of an enhanced spare parts supply chain as far as water supply systems are concerned have resulted into positive developments, which include better functionality rates of the water points.

2.6.4 Governance

Governance has been used broadly as an umbrella concept as it can be widely applied on different developments. Governance is one of the aspects linked to operation, management and maintenance of rope pumps and other technologies (Tortajada, 2010). Through improved governance, participation by the communities is enhanced due to the formal management structures and informal undertakings including participation through local resources contributions. Some of governance structures in rope pump management which contribute to vibrancy of water points management include the water point committees and the piloted Central Tariff Management Unit, specifically in the area under study. Apart from participation, transparency and accountability are some of the key fundamental elements of good governance. For instance, a water point considered well positioned, as far as good governance is concerned, needs to be transparent and accountable to the users and the members who contribute resources for running of that particular water point. Some of the important governance structures in water supply include the water point committees which have a role of managing all water point issues (O & M), resources mobilization, preparation of facility management plans and making sure that the water point surrounding is being kept clean, among several roles. The local leadership has also a role in assisting the water point committee in mobilizing communities on a specific issue, for instance, resources mobilization and problems solving like when there are conflicts. The local council is there for policy guidance, implementation and monitoring and evaluation.

2.7 Water quality

Another important element that affects user satisfaction of water supply services includes quality of water delivered to the users. Quality of water is one of the critical elements as far as public health is concerned (Haylamichael et al., 2012). The presence of fecal coliforms in water is an indicator of poor quality of that water and contamination from fecal matter of warm-blooded animals or humans (Ibemenuga et al., 2014).

The Malawi Bureau of Standards has guidelines for drinking water on physical, chemical and taste (MBS, 2005, MS 733), Table 1. The Malawi Government guidelines emphasize on performing analysis of water before the communities starts using it. Limited existing studies have been done on the water quality from the rope pump, including in Uganda where the results of the all tested 29 wells that were tested met government standards for drinking water (Atine, 2014). In Tanzania, it was found that if a rope pump is well installed and partially covered it produces water of similar quality to that of a conventional pump (Atine, 2014).

Table 1: Shallow well and borehole water quality guidelines by the Malawi Bureau of Standards (2005, MS 733)

Parameter	Maximum Permissible level (mg/L)
Aluminum as Al	0.5
Antimony as Sb	0.005
Arsenic as As	0.05
Barium as Ba	0.7
Borate as B	5
Cadmium as Cd	0.01
Chromium as Cr	0.01
Cyanide as Cn	0.07
Copper as Cu	2
Fluoride as F	6
Iron as Fe	3
Lead as Pb	0.05
Manganese as Mn	1.5
Nitrate as NO_3	45
Selenium as Se	0.01
Sulphate as $S0^{2-}$	800
Zinc as Zn	15

Physical characteristics are observed in water which contributes to the community members not being satisfied with that particular state of water. Table 2 provides recommended levels of physical characteristics of water.

Table 2: Physical characteristics of the water guidelines of the MBS (2005, MS 733)

Characteristic	Unit of measurement	Maximum possible levels
Color	NTU	50
Turbidity	JTU	25
pH Value	-	6.0-9.5
Calcium	mg/l Ca	250
Chloride	mg/l Cl	750
Magnesium	mg/l Mg	200
Sulfate	mg/l SO_4	800
Sodium	mg/l Na	500

Water points should be located on the upper side of sanitation facilities (Malawi Government, 2013) to prevent microbial contamination and prevent water point from being source of diseases (Bordalo & Bordalo, 2007). In summary, though the model used in operation and management of the rope pump is borrowed from the management of other rural water supply facilities like boreholes, it has been noted that if the said best practices are applied accordingly, sustainability of the rope pumps can be enhanced. An example could be community based management aspect which is being applied on pumps which can be managed through VLOM of which the rope pump can be one of them due to its non-complicity.

The rope pump due to its design is ably serving communities who live in areas where the mechanical rigs cannot access. The rope pumps contribute towards the attainment of sustainable development goal number 6 which aims at having water for all. All the sustainability sentiments could be possible if the discussed best practices are put in place and used.

2.8 Conceptual Framework

Sustainable development has been defined as development which does not destroy the environment. Specifically to rural water supply, according to Hylamichael (2012), sustainable water supply is the one which is able to deliver the expected services to the community members for a period of time. The expected services of that particular entity should be of recommended quality, quantity, accessibility, affordability. Malawi Government (2015) emphasizes on the need of providing water of recommended standards to community members. This national recommendation on water quality is enforced by guidelines in the MBS, 2015, S733.

Community participation is one of the sustainability pillar as the involvement of the community in a particular development initiative lead to the community taking part in decision making and this create the sense of ownership which leads to sustainability. User participation could be through contributing to factors that could lead to improved implementation of community based programs. According to Etongo et al. (2018) communities participate through being members of committees, through contributions towards an undertaking in cash or kind. Sustainability of water systems is also enhanced if the facility provided was demanded for. The demand responsive approach responds to what the communities demanded from the service provider.

Availability of capacity amongst community members through trainings in community based water points management is also an important element as far as sustainability of water points is concerned. The community capacity in O & M should be supported with vibrant spare parts supply chain and a working area mechanics network.

It is also important to use systems which are user friendly, which are within the government recommended VLOM initiative. The initiative advocates for pumps which are easy to repair.

The environment plays a role in the provision of sustainable water supply. It is of importance to keep the environment in a state that can make it continue to be a source of sustainable safe water supply.

The elements discussed will be the ones to be considered in this study as the study will be looking at water quality, consumers' feedback and relevant information from communities which could improve future rope pump program implementation.

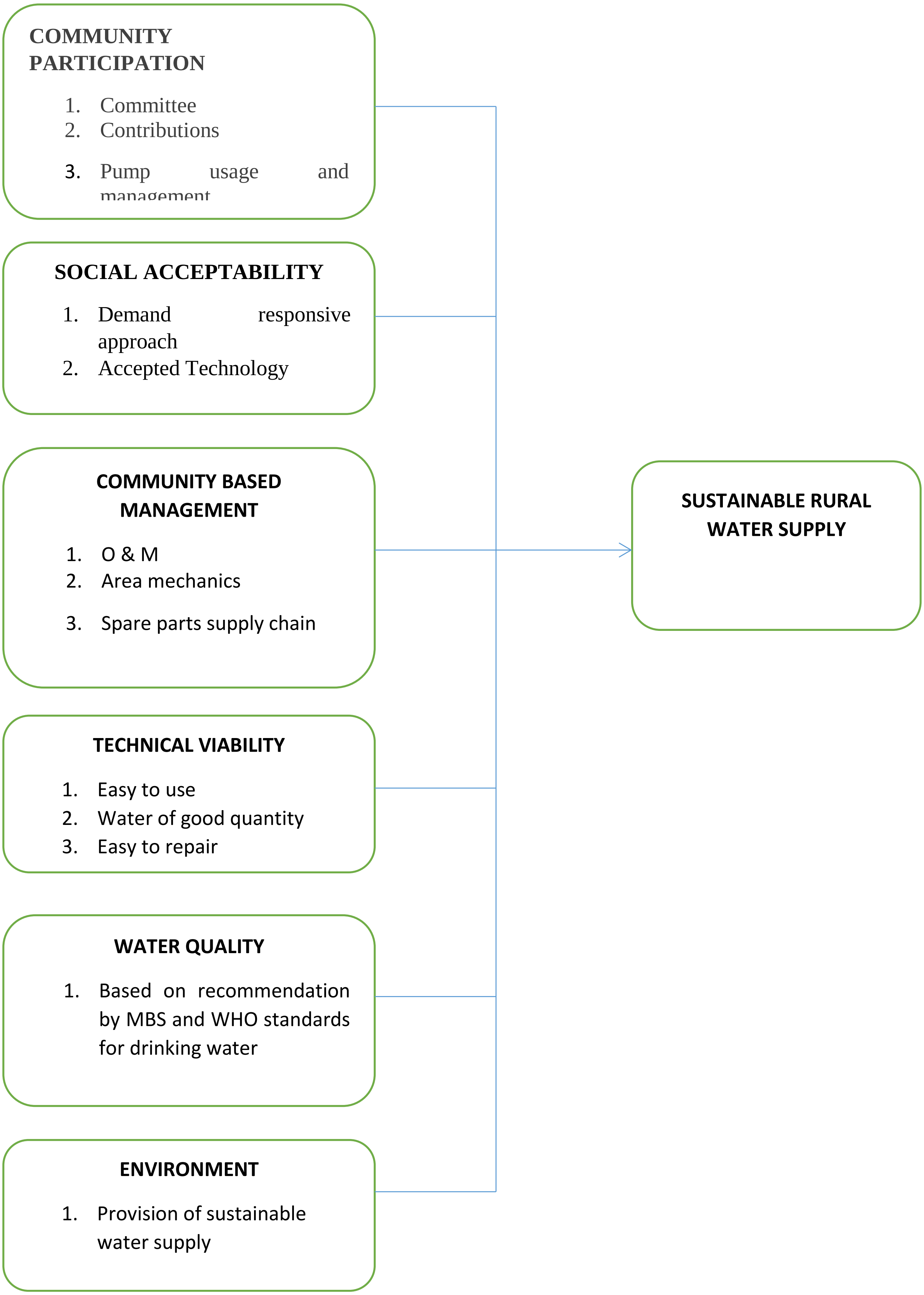

Figure 2: Conceptual framework

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

The study was conducted in the rural areas of Rumphi District from December 2017 to May 2018. The District covers 6640 km^2, of which 4594 km^2 is covered by land while 2046 km^2 is covered by lake area as a major source of surface water, that is, apart from the perennial rivers of Rumphi, Luviri, Lura, Tchetchetche and North Rukuru. The District has a population of 229,161, of which 112,652 are males and 116,509 are females (Malawi Government, 2018). The study area consisted of six traditional authorities of Mwamlowe, Mwalweni, Mwankhunikira, Chisovya, Mwahenga and Kachulu (Table 3). Traditional authorities Kachulu, Mwahenga and Chisovya are located in the northern part of Rumphi District with farming as their major economic activity. Traditional Authority Mwankhunikira is located in the central part of the District with farming as their major economic activity. TA Mwamlowe is located to the eastern part of the District bordering with Lake Malawi. Fishing is the main source of income in Mwamlowe. TA Mwalweni is located within the northern and eastern part of the District with both farming and fishing as their major activities. Mostly the areas lack paved roads and are far from major towns.

Rumphi District has a total of 442 villages, of which in 48 pumps were installed under a previous development projects. Due to the terrain of water points location making access not possible for traditional heavy water drilling rigs, the sites had no or limited alternative sources of water making the installed rope pumps an innovative solution.

3.1.1 The people

Rumphi District has several tribes but the District is dominated by the Tumbukas who originated from Tanzania and made their settlement in the District. Under the Tumbukas there are the Phokas and the Hengas. Tumbuka is spoken by 95% of the people, while the remaining 5% is shared among minority tribes of Lambia, Chewa and Yao. The District has one paramount chief in the name of Chikulamayembe who is regarded as the most senior chief among the Tumbuka (Rumphi District Council, 2016).

The majority of the people in the District follow patrilineal system of marriage whereby women live with their husbands.

3.1.2 Socio economics

Mostly the District depends on farming and fishing as their economic activities. The parts which are located in the north and western part of the District depend on farming as their source of income and maize as their source of food. Mwamlowe and part of Mwalweni largely depends on fishing and production of cassava as their source of food.

3.1.3 Roads and bridges

The District has one main road passing through from Mzuzu to Karonga. Other roads within the District includes the Njakwa to Livingstonia which connects the Rumphi boma to Chitimba a trading center along the tar marked main road to Karonga. The District has several bridges which mostly do not stand during the rainy season. The bridges which do not mostly stand the rains are mostly located in the rural areas of the District.

3.2 Research design

According to Ngwiri et al. (2016) research design constitutes ways for collecting, measuring and analyzing of data. In other ways it's the master plan for the study with specifics on procedures for collecting and analyzing of data. The researcher used a survey method of data collection from the population. Data was collected from rope pump users, and working water points through water samples.

Table 3: Distribution of improved water sources by TA in study area by population

TA Name	Number of AFRIDEV pumps	Number of taps through gravity fed systems	Number of protected shallow wells	TA Population
Mwamlowe	5	163	4	4224
Mwalweni	62	469	27	13632
Mwankhunikira	119	82	5	12537
Chisovya	30	147	0	4620
Kachulu	18	134	4	6094
Mwahenga	36	143	7	9747

Source: Rumphi District Council, 2018 and Malawi Population and Housing Census, 2018.

The researcher gathered information on pumps functionality, water quality and respondents' feedback in terms of experiences, opinion, experiences and feelings on the rope pump. In this survey, combinations of both qualitative and quantitative approaches were used. Quantitative survey approach was used in water quality determination for 24 wells which were functional at the time of the survey. Qualitative survey approach was used to establish the satisfactory levels of the communities using the rope pump in all the 48 rope pumps. The parameters for data analysis were those of water quality, functionality and rope pump users' feedback.

3.3 Sampling framework and methods

Though all the 48 pumps were included in the study, water samples were only possible to be collected from 24 of 25 functional pumps. One functional pump was skipped because it could not be initially found though it was located later in the study. During the second visit a user survey was conducted targeting the forty eight water points in the targeted area. Total number of rope pumps users for the 48 pumps were 1611 of which 480 users (30%) constituted the user sample which according to Mugenda & Mugenda (2003) is adequate for a descriptive study.

3.4 Data collection

Data collected included water sample collection and analysis for microbiological and chemical quality, water point checklist of surrounding area of each rope pump which was visited in the study (both functional and non-functional), and a user satisfaction feedback from the rope pump users at all the 48 rope pump sites.

3.4.1 Water sample collection

Water samples were collected from the 24 rope pumps using standard methods of water collection. The samples were collected in duplicates using whirl pack bags. Water samples which were collected for microbiological analyses were collected in whirl pack bags with a preservative of sodium thiosulphate to offset any residual chlorine in the samples while samples for chemical analysis were collected in whirl pack bags without a preservative.

3.4.2 Microbiological data collection

The microbiological analyses involved determination of thermotolerant coliform bacteria which was used as an indicator for fecal contamination. The Wagtech Potatest® Membrane Filtration Unit was used at 44°C as per manufacturer recommendation and 100ml samples were incubated for 18 hours. One blank equipment was analyzed daily as quality control for each day's operation using boiled and cooled water, and each equipment blank was 0 CFU /100 ml. Analysis of the samples was done within 8 hours of sample collection at a centrally located laboratory set-up within the study District, Rumphi.

3.4.3 Chemical data

A chemical analysis included determination of parameters like pH, turbidity and total hardness and was done on site at the time of the visit to the pump.

3.4.3.1 Determination of pH

Determination of pH was done using the Wagtech Pocket pH meter. Calibration of the pH meters was done using standard buffer solutions of pH 7 and pH 4 at room temperature (25°). Rinsing of the pH meters was done prior to and after analysis using deionized water. A small volume of the water sample was drawn using the protective cap of the pH meter then the pH meter electrode was inserted to take measurements.

3.4.3.2 Turbidity determination

Turbidity of the water was determined using the Jackson turbidity tubes. Proper rinsing of the tubes was done to ensure that the tubes were clean before each analysis. Water samples were gradually added into the tubes until the cross which is at the base of the tube disappeared. The reading was made from the level of the sample against the scale which is on the tube. Results were recorded in Jackson Turbidity Units (JTU).

3.4.3.3 Determination of Total Hardness

Total hardness was determined using Hach Water Quality Test Strips. A small volume of a water sample was drawn in a beaker, and then a test strip was dipped in the sample for few seconds and was left on a clean surface for 1 minute before reading results. Readings were taken by comparing the color change of the dipped test strip against the colors on the Hach water quality test strip bottle. Results were recorded in mg/L (ppm).

Table 4: Water quality data collection instruments

Materials	Frequency
Wagtech membrane with Lauryl Sulphate Broth	24
Wagtech Pocket pH	24
Wagtech Pocket Sensor	24
Wagtech Jackson Turbidity Tubes	24
Water Quality Test Strings	48 (per parameter)

3.5 Water point surrounding status

In order to come up with the condition of the water point surrounding status a checklist was administered at all the 48 rope pump sites. Site observations were done particularly to check if there were sanitation related issues which could compromise the quality of water. Of much interest was to check on the general surrounding of the water points and availability of waste disposal sites within the 30 meters of water point surrounding. The checklist was also used to collect data on water point performance, for instances if a particular water point was able to produce water as per national standards. GPS data which were collected on each surveyed water point was used to produce a map.

3.6 User satisfaction and community contributions towards best practices

For the user feedback interviews were conducted at all the forty eight water points. Through interviews the researcher probed the respondents which resulted into having more information relating to satisfaction with the rope pump and best practices which could contribute to sustainability of the rope pumps. Questionnaires in Open Data Kit were used to collect information. The respondents were rope pump users in the 48 pump sites. Specifically, the questionnaires were used to collect data from 472 rope pump users at 48 rope pump sites.

3.7 Data analysis

Water quality data were analyzed using R Project 3.3.2 and further compared to National (MBS, 2005) and international (WHO) drinking water standards. Statistical analysis for user feedback and functionality was done using Excel. Results were mostly reported in percentages and frequencies.

CHAPTER 4: RESULTS

4.1 Functionality

A functional rope pump (Figure 3) was regarded as one which was able to produce water at the time of the visit regardless of having technical problems which may compromise its full functionality. Out of the 48 rope pumps 25 (52%) were functional and 23 (48%) were not functional in the six study TAs. Mwahenga had the highest number of non-functional pumps with TA Chisovya having the lowest (Figure 3)

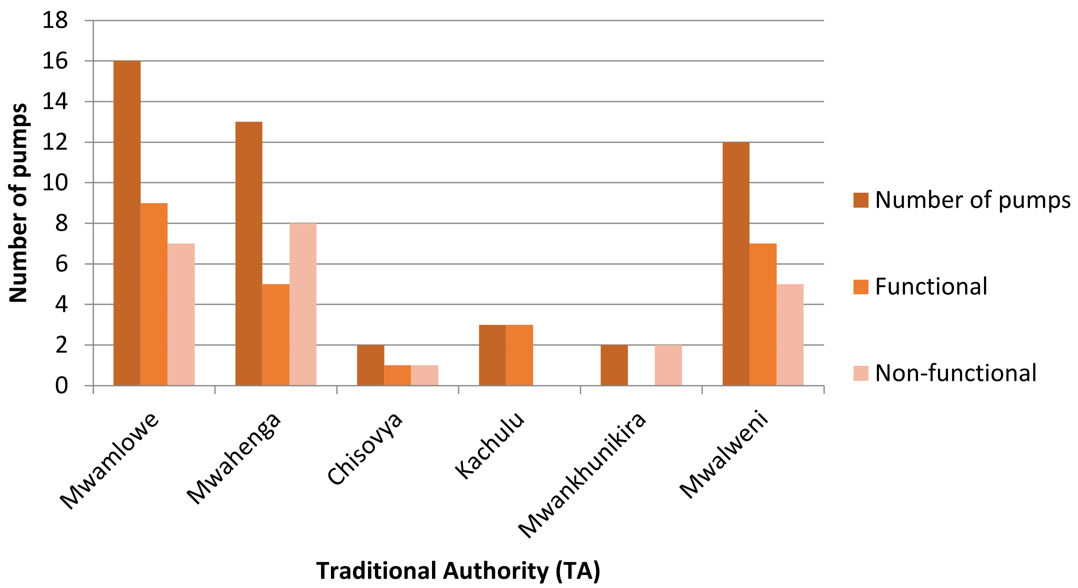

Figure 3: Rope pumps functionality in Traditional Authorities Mwamlowe, Mwahenga, Chisovya, Kachulu, Mwankhunikira and Mwalweni

4.1.1 Technical issues affecting rope pumps functionality

Functionality of rope pumps was compromised by several technical factors (Figure 3), non-functionality of (13/23; 57%) rope pumps was due to disjointed rope, (3/23; 13%) pumps due to low water table, other (3/23; 13%) for worn out pumps. (4/23; 17%) rope pumps were nonfunctional due to broken pipes and pipe stuck in pump holes both at 8.5 % respectively.

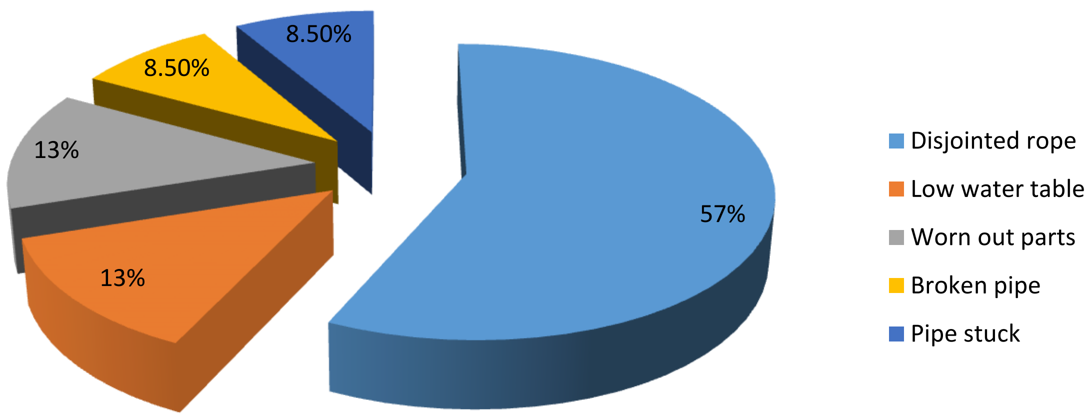

Figure 3: Technical reasons for pump non-functionality

4.1.2 Social issues affecting rope pumps functionality

Social reasons also contributed to non-functionality including non-availability of spare parts supply chain within the area, non-effectiveness of the area mechanics only (13/23; 57%) pumps out of 23 broken pumps were assisted by the localized mechanics and inadequate follow ups by extension workers. (2/23; 9%) sites out of 23 reported of being ever visited by government extension worker, who have a role of providing for instance on proper operation and maintenance procedures. Poor management structure also contributed to non-functionality status, as these wells were under a central tariff management unit which was responsible for all administrative issues involving the pumps.

4.2 Community satisfaction with rope pump

The study sort responses from uses regarding their satisfaction with the rope pump and findings are is shown in Figure 5.

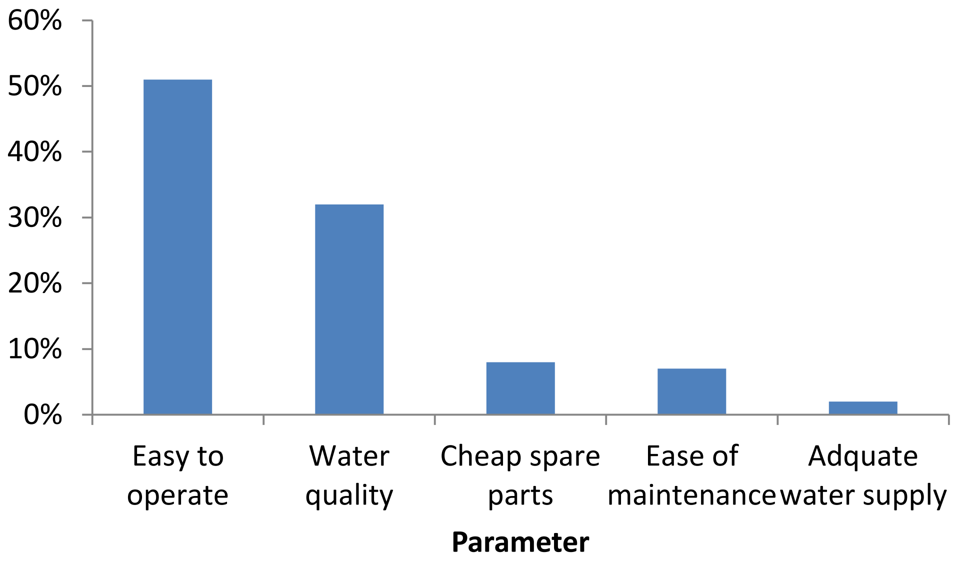

Figure 5: Attributes to rope pump user's satisfaction

In water supply, user satisfaction is usually felt post construction. Forty-three percent (204 / 472; 43%) of water users reported that they were satisfied with the rope pump. The satisfied rope pump users had various reasons for their satisfaction. (103/204; 51%) were satisfied because the pump was easy to operate, (15/204; 7%) were satisfied because the pump was easy to maintain. Cheap spare parts was an attribute of satisfaction for (16/204; 8%) of rope pump users while (4/204;2%) users were satisfied due to adequate water supply by the rope pump.32% rope pump users were satisfied due to satisfactory water quality. Yet, variation was reported by users within the same community on functionality at (32/48; 67%) pumps, indicating possible usage or other secondary sources of water other than the rope pump understudy by some users at some times. When asked, what their alternative source were when the rope pump was not functioning, most users (319/472; 68%) reported using unprotected water source such as river, lake or open well. Of the 472 rope pumps users, (268/472; 57%) users expressed dissatisfaction with the pump.

The study also found reasons for dissatisfaction (Figure 6) among 268 rope pump users.

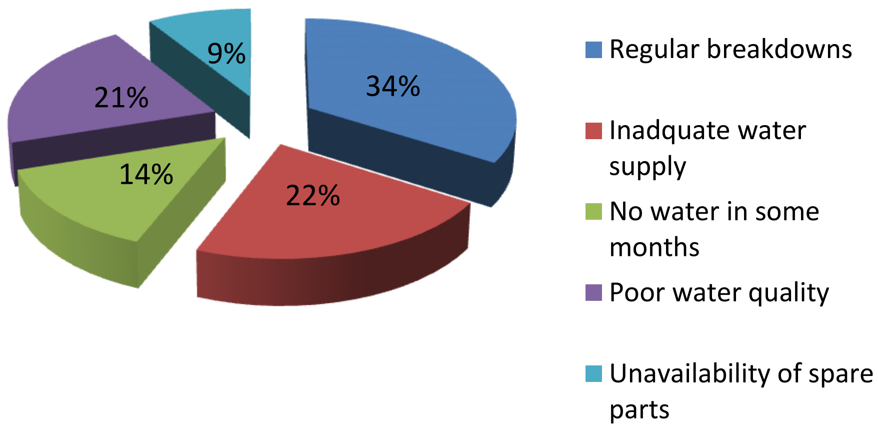

Figure 6: Attributes to rope pump users' dissatisfaction

Of the 472 respondents, 268 respondents were dissatisfied with the rope pump due to the reasons that this pump was regularly having breakdown (92/268; 34%). The (59/268; 22%) were not satisfied due to the fact that the pump had in adequate water supply. The other reasons for dissatisfaction were (37/268;14%) due to the pump not producing water in some month (September, October and November), Poor water quality (55/268; 21%) and unavailability of spare parts according to (25/268; 9%) of the respondents.

4.3 Management of water points

Management of water point was in the hands of water point committees for each pump. Women are encouraged by the local government to participate in development activities, take part in decision making processes and in leadership positions as they are regarded as prime water users. Of the total 48 rope pumps, (27/48; 56%) had female chairpersons. Out of 25 functional water points (16; 64%) water points were female led whilst 9 had male chair persons. Out of the twenty three non-functional water points, (11/23; 48%) were chaired by female whilst (12; 52%) had their male counterparts though with no significant difference as there was one pump which made the results different. To determine if there is a variation between the gender of the water committee chair and the three pump status groups (nonfunctional, had water and sustainable), a Fisher's Exact Test showed no differences (p=0.1599).

4.4 Water quality

Water samples were collected from 24 rope pumps. Water quality results from twenty- four pumps were compared to both Malawi and the World Health Organization standards for drinking water (Table 5). Most pumps (22/24; 92%) had water within the recommended local standards for thermotolerant (Malawi Bureau of Standards, 2005) and the other pumps (11 / 24; 46%) had water within the WHO recommended standards of 0 CFU /100ml. Out of all the 24 water points tested only two (8%) had two numerous to count thermotolerant coliforms surpassing both the MBS and WHO standards of 50 CFU/ 100 ml and 0 CFU/ 100 ml respectively. In terms of turbidity, according to the table below (15/24; 63%) rope pumps had water of <5 JTU while 4 pumps had water ranging from 10 to 15 JTU. In total (19/24; 79%) pumps were within the MBS requirements of turbidity levels. (5/24; 21%) water points were out of the MBS recommendations of turbidity levels. The pH for all the twenty-four water points was within the recommended levels of WHO and MBS. Another aspect which was analyzed was the total hardness. Twenty-four wells had water within recommended local standards.

Table 5: Water quality in 24 wells compared to MBS and WHO standards

Parameter	*Thermo-tolerant coliform* (colony forming units/100 ml)	Turbidity[d]	Total Hardness (mg/l as $CaCO_3$)	Total Alkalinity (mg/l as $CaCO_3$)	pH
Minimum (*n*=24)	0	<5 JTU	25	40	5.9
Mean (*n*=24)	20	40 JTU	120	80	6.5
Median (*n*=24)	1	<5 JTU	120	80	6.4
Maximum (*n*=24)	>200[c]	500 JTU	250	180	7.3
Malawi Standard [a]	50	25 NTU	800	-	6.0 to 9.5
WHO Standard [b]	0	1 NTU	-	-	-

[a] Malawi Bureau of Standards (MBS), 2005

[b] World Health Organization (WHO), 2017

[c] Result was too numerous to count, upper detection limit of method is reported.

[d]JTU = Jackson turbidity units. NTU = Nephelometric turbidity units. The two units are roughly equivalent (WHO Fact Sheet 2.33 -Turbidity measurement;

- No established value

4.4.1 Comparative pump type and water quality

The rope pump has a tightened rope passing through a rope guide wheel which is also used in the pumping process. In Malawi another rope pump type is the elephant pump which is wholly covered though. If you compare water quality data, this study had 92% of the wells with water of recommended quality within the national standards compared to 68% of the wells in the Holm et al., (2015) study. Table 6 provides more water quality comparison to other shallow wells.

Table 6: Comparative wet season shallow wells water quality

Rope pump (This study n=24	Elephant pump (Holm et al., (2015) n= 285	Indian pump (Holm et al., (2015) n=26	Malda pump (Holm et al.,(2015) n=153
92%	68%	35%	41%

Further comparisons between conventional and shallow wells in rural areas have concluded that no pump design was able to produce potable water every time of the year (Holm et al., 2015).

4.5 Best practices for rope pumps sustainability

The study also found out from the community members what they feel could be best practices which could be taken on board to improve sustainability of the rope pumps. 472 members contributed towards suggesting factors which could lead to sustainability of the rope pumps. Amongst the prime factors which communities felt important included periodic checks (159/472; 34%), comprehensive community based management training (111/472; 23%), digging wells to the required depth (89/472; 19%). The remaining (113/472; 24%) were for establishment of spare parts supply chain.

4.6 Sustainable rural water supply

Following the infrastructure checklist, user interviews and water quality samples, an assessment was made by researchers if the pumps were providing safe drinking water based on thermotolerant coliforms (Malawi Bureau of Standards, 2005), water of enough quantity and being in a working condition since installation. These parameters encompassed sustainability.

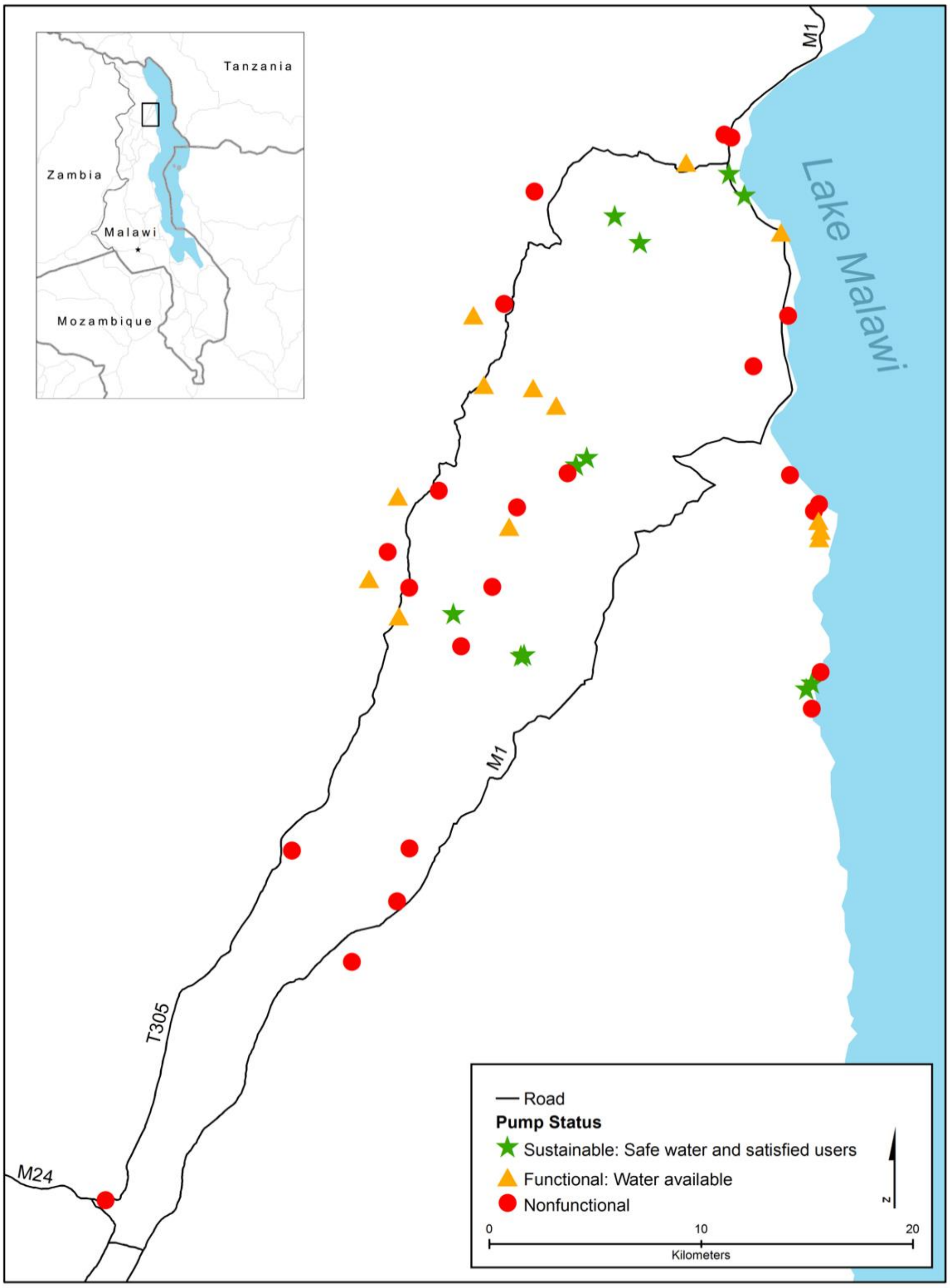

Figure 7: Map of the study area showing pump location and functionality. Inset shows location within Rumphi District in Malawi (Africa)

In this case based on the mentioned parameter, only 23% (11/48) pumps were sustainable (Figure 7). In this case a sustainable water source could lead to user satisfaction. If the users get satisfied with their water source, the result is likely to be that the water points get sustained. Importantly some of the factors that lead to rope pump sustainability includes social acceptance by the communities, availability of spare parts supply chain to support operation and maintenance, quality and quantity of water and community based management of rural water systems where communities need to be able to manage, operate and maintain their water systems (Matamula, 2008). Of the 8 pumps classified as the most rural, only two of these qualified as sustainable by our study criteria. To determine if there was a variation between the remoteness of the pump and the three pump status groups (nonfunctional, had water and sustainable), a Fisher's Exact Test showed no differences ($p=1$). This indicates that the pumps are not necessarily working better in the more remote areas. In addition, monitoring logistics of rural pumps for an investigation like this is expensive, this current study cost about USD$3000 for the 48 pumps.

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter provides a discussion of the research results and relates the results to other results from studies conducted previously.

5.2 Functionality of rope pumps

Functionality was based on the status that the pump was able to produce water at the time of the visit despite having some faults which could compromise fully functionality. Functionality of the pumps during the study time was at 52%, meaning that 48% of the pumps were not functional. While functionality of elephant pumps which is a rope pump type as well was at 69% (Holm et al., 2016).Non-functionality of the rope pumps in the study area was mostly due to disjointed rope. Similar results of disjointed rope being the most critical cause of non-functionality of rope pumps were found in a study on functionality of rope pumps in rural Malawi where 62% of the 34 rope pumps were non-functional due to rope problem (Kamanga et al., 2018). Functionality of rope pumps is mostly compromised by the status of the rope as the rope plays a major role in the uplifting of the water in the pumping system (Coloru, 2012; Holm, 2016). According to Holm et al. (2016), 61.8 %, where (n=215) pumps were not functioning due to rope problem. 18% of (n= 63) had rope slippage. Furthermore, non-functionality of pumps in the study was also due to unavailability of spare parts supply chain which made communities be unable to access the required spares. The non-availability of spare parts chain compromised functionality of rope pumps in Congo as well (Koestler, 2014). The untimely availability of spare parts results into communities abandoning the rope pump and the sustainability of the pump gets compromised as well (Matamula, 2008). It is of importance to align the spare parts supply chain to a particular service as being able to reduce the breakdown time as the spares are readily available. In a similar study that was carried out in the same area of Rumphi District, Holm et al. (2017) found that the rope management in the rope pump is a crucial determining factor for the pump functionality. This is because the pump does not function if the rope is disjointed as in the study where 61.8% were not functional, where n= 215 (Holm, 2015). Kamanga et al. (2018) in his study also found out that of the 34 non-functional rope pumps, 62% had a rope problem. In order to overcome rope problem which is very common in rope pumps, Corolu (2012) suggests that t the ropes of polypropylene would be more efficient since nylon which is stronger but due to its fineness and smoothness slips out of the hold where the pumping mechanism rests. As initiatives using the rope pump are being implemented it is vital to involve the private sector by making sure that the private sector is able to drill, construct and install the rope pumps (Annemarieke, 2016). Yet, the private sector should be oriented on WASH approaches which advocates for technologies which are affordable to the rural community members. One year post construction of the rope pumps, there was an expectation that the communities may take the initiative and have it scaled up as recommended by Malawi Government (2005) but in the study results it is clear that only one individual installed the pump for his household use. Some of the reasons that contributed to inadequate scaling up includes that some communities who had installed the same type of pumps in the previous programs experienced problems with the pump due to poor workmanship during the construction phase, this has also been assented in similar programs in Tanzania (Annemarieke, 2016). The poor workmanship compromised the working status of the rope pumps. In the course of implementation of the rope pumps initiative, it is proper to have the private sector which should assist communities through installation of the pumps and production of the spare parts as recommended by (Albert & Zee 2003). This was the case also in Kenya according to Atine (2014), where though after massive community sensitization about the rope pump, there was minimal response from community members to scale up the initiative. Since the WASH sector provides a basic service of assuring that the rural community members have access to safe drinking water, the private sector, who are mostly profit oriented, may not be mostly interested to engage into an adventure which is not profit oriented (Albert & Zee, 2003). Even though this could be the case, currently the sector is coming up with innovations that could lead to the private sector to make some gains. An example could be the financial mobilization which community members do to pay for services and goods rendered by service providers like the area mechanics and others.

The other issue which hinders the private sector from participating in WASH sector is due to their inadequate capacity as most of them have not been oriented on specific sector issues. An example could be that the private sector players are mostly not aware of what the WASH sector is involved in. The sector should think of a serious strategy which can make the private sector be interested and start participating in the sector activities as in Malawi Government (2005). Having this in mind, it is vital to align the projects being implemented to government strategy. This is important so that as projects are being implemented government staff should be able to give the necessary support. Sustainability of initiatives which have been implemented by sector partners is in the hands of community members while the government extension workers have a role of advising that particular community technically. An example could be the project in which the rope pumps were installed in Rumphi. Since the project got finished, the community has the role of making sure that the water points remain functional. It is in the view of sustaining water supply systems that the community based management of rural water supply systems came in (Malawi Government, 2005; Matamula, 2008). Through community based management, it is envisaged that ownership of the water systems is in the hands of rural community members with minimal support from technical services providers like the Ministry responsible for water affairs.

In the study area, though members of the private sector were trained, there are still some pumps which are not functional. There are several reasons which could contribute to that particular scenario. Some of the reasons include that the training might not have been well understood due to literacy levels of the participants as drilling procedures are technical in nature.

Water level plays a big role in the functionality of the water points. In this study, some water points were unable to produce water due to the fact that it was not possible for the pump system to lift water because the suction pipe would not reach the water levels of the pumps. In Holm et al. (2015) study, suction pipe was also issue compromising rope pump functionality. This status is due to several reasons which could include that drilling of the water well was not done per specified requirements for drilling.

The other reason could be poor installation of the hand pump, specifically in the installation of the piping system as according to the installation guidelines. Worn out parts was another factor compromising functionality of water points in the study. The parts that were worn out included pipes and seals which compromised full functionality of the water wells as the leakages through the pumping main system resulted in water not being able to be uplifted within the rising main pipes and seals. These said reasons have compromised functionality in other studies (Holm et al., 2015: Annemarieke, 2003).

Other reasons which compromised functionality were the conditions which could be dealt with out right; for example, a pump could have a rope being stuck within the pipe (rope not disjointed) which just required putting the rope in its normal position. These factors could have been ably dealt with outright by the user; however, community members were not aware of how to deal with these very simple issues in some cases. Management of the entire rope pumps in the study area was under a central tariff management unit which was mandated to overlook the entire management of the pumps. Some of the roles of the management unit were to identify the local mechanics and establish a vibrant spare parts supply chain. Whilst the central tariff management provided the leadership at Area Development Committee Level, water points were managed by the water point committees. Water point committees has the responsibility of making sure that communities are taking part in water points undertakings for instance contributing of resources for operation and maintenance of the water points (Malawi Government, 2005). This increases chances of sustaining the water supply facilities because community based approaches and structures are strong and represent community spirit (Carter et al., 2018). According to Malawi Government (2005), women are also encouraged to take up leadership positions and in the study (27/48; 56%) of the water committees were chaired by females. In line with making women to be in leadership positions of water managing structures, Brecht et al. (2017) found that if women take a leading role in managing water supplies, functionality of systems is generally good. Brecht et al. (2017) findings are in line with the findings from this study as functionality of women led water points were above average. Some of the reason water committees which have women in leadership role perform better include that women are the prime users of water so they are mindful that the water points they usually utilize are functional at any given time (Brecht, 2017). However, this study found that a female committee leader did not necessarily lead to a more sustainable rope and washer pump. Similarly, water point management requires some resources for operation and maintenance. These funds are mobilized at water point level mostly and water users ably contribute resources to someone they trust and usually women are trust worthy than men as found out by in Nigeria where users contributed more in water committees under female leaders.

5.3 Consumer Satisfaction

User satisfaction is usually measured post construction as the communities judge if they are satisfied with what they were expecting from the facility which was provided to them. Satisfaction in water supply usually is based on the aspects of the quantity and quality of water that the water supply facility produces (Fattahi et al., 2011; Kumar, 2018). According to Holm et al., (2017), 96% (78/81) respondents to another study in Rumphi were satisfied due to simplicity of repairing the rope pump. In Uganda Atine (2014) reported that satisfaction of the rope pump by the users was mostly due to water quality. The reduction of typhoid in Kenya contributed to the rope users' satisfaction (Hughes et al., 2004).

In this study, 204/472 users were satisfied with the rope pump. Comparatively to other studies, users in this study were satisfied because the pump is easy to operate (103/204; 51%). 15/204; 7% were satisfied due to its ease to repair. For other users 16/204; 8% were satisfied due to cheap spares whilst 32% of the respondents were satisfied due to good water quality. However, in some cases some operational and maintenance issues contribute to user satisfaction as communities often abandoned water facilities which have operational and maintenance problems. Satisfaction is linked to community need for an intervention. In most scenarios if a community has a need, they demand for that particular thing. In development undertakings, communities need to express their needy through demand. Specifically in water supply it is encouraged to use the Demand Responsive Approach where communities are required to demand for the water supply facility from the service providers, in this case, the local councils (Malawi Government, 1998). It was also noted though in this study that there were some (268/472; 57%) rope pump users who were not satisfied with the rope pump.

Some of attributes to user dissatisfaction included regular breakdowns, inadequate water and no water in some months and poor water quality for 22% of the respondents in this study.

5.4 Water quality

The quality of water was analyzed and compared to the national and international standards for drinking water. Variables for comparison included turbidity, thermotolerant coliforms, pH and total hardness. Generally the results were good as only 2 water points had water outside the national and WHO standards for drinking water. The results showed that the rope pump technology does not necessary affect the quality of water but some environmental condition. The surrounding of the water point, specifically, has an impact on the quality of the water. Similarly, Hughes et al. (2004), in a study carried out in Kenya, found that quality of water from one of the rope pumps was compromised by the surrounding with water having up to 200 CFU/100ml.In Zambia results from a regular water quality checks showed 95% samples with less than 10 CFU /100 mls compared to 34% before the introduction of the technology. This study results showed that comparatively a rope pump provides water of better quality compared to unprotected wells (Sutton, 2004). The impact of the surrounding environment on the quality of water is evident as the two wells (Kambirumbiru and Chilangalanga) which have the highest content of coliforms (TNTC) and were drilled less than thirty meters from the pit latrines. Similar result on water point proximity to possible pollutants was also reported for 7 water points which were <30 meters and were found contaminated in Ethiopia (Hylamichael, 2012). In Uganda results for water quality for all the properly sited rope pumps met the government guidelines (Atine, 2014).

The latrines near these wells were also located higher than the water points. Of these two pumps, turbidity of one of the pumps in this study was within the recommended ranges of the national standards but the other contaminated well had turbidity above both the national and international standards. Other studies in Kenya concluded that rope pump produced water of good quality with less than 10 fecal coliform units, representing 97% of water samples (Atine, 2014). This though difficult to understand for a community, as mostly communities judge the quality of water based on physical characteristics of appearance and smell and in this case one well with high amounts of thermotolerant coliforms was visually clear.

5.6 Best practices rope pumps sustainability

According to Montgomery et al. (2008), sustainability is explained as a situation where a particular entity is able to function or be able to be there for a period of time. The key elements to be considered when trying to develop sustainable water supply facility are to identify what makes that particular entity be sustainable. High social acceptance contributes to sustainability of the rope pumps. Social acceptance is linked to communities accepting the presence of a particular technology due to its benefits. The rope pump in the area under study has been well accepted (Holm et al., 2015). What needs to be done for the technology to expand is that the local manufacturer should go flat out advertising the pump so that capable families should be able to buy and install at their homes. For instance, in the area under study one family has installed a rope pump for home and commercial use after the project. The service providers should be aligning their thinking to self-supply model which can scale up the pump coverage in the area where the study was carried out. In reference to the village level operation and maintenance, which advocates for community water users to be able to take care of the water facilities, the rope pump is easy to repair as long as there has been intensive community based management training and availability of repair funds through community contributions (Kamanga et al., 2018).

Sustainability is well supported by the availability of a working supply chain. Unavailability of spare parts supply chain is one of the factors compromising sustainability of rope pumps. The rope pump spares are easily accessible, such as washers which are locally manufactured but these spares are not readily available in the area under study due to unavailability of the spare parts supply chain. Sustainable rural water supply systems provide water of recommended quality and of enough quantities to satisfy the users in a particular community. Availability of a sustainable water supply also encompasses issues like operation, repair and community resources mobilization for O & M (Matamula, 2008). The operation and maintenance aspects ensure that the facility is ably maintained by the user communities as mandated by the National Water Policy (2005) which aims at empowering user communities to be able to operate, manage and maintain their water supply facilities. Number of people at a water point is also one factor which compromise functionality of water points especially for the rope pump which is fit for small communities. A visionary thinking for communities to have sustainable, reliable and continued water supply system is through having water point at household and small communities level (Butterworth et al., 2013), also known as "Self supply". This is typically about having a water point for supplying a household. In this case, a family advances from using a communal water point to a Self-supply entity. The Self supply aspect is very common in urban areas. In rural areas of the country this aspect is still very unpopular and currently, most people are still using the communal water points for their water. By introducing water points at small community or family level, there will be reduced burden on the existing communal water points (Butterworth et al., 2013). Self supply will reduce the cost of repairing the water systems since breakages due to overuse will be reduced (Montgomery & Elimelich, 2007). Implementers who choose to implement the Self supply model need to involve the interested users at any stage of implementation. As communities and families are being supplied with water point at family and small community level, there are some inputs which the beneficiaries are supposed to contribute. This could be in case of labor, materials and the actual physical representation of the members during trainings, meetings and the operation and maintenance of the pump (Montgomery et al., 2008). Sutton (2004) suggests that Self supply could be a means of making the communal water points have reduced number of users. Due to this reduction in the number of users, the available communal water points would have reduced work load which could result to them being sustained. Self supply of an individual community or household also enables that particular entity to choose a technology of their choice and encourages progressive upgrading on their own with minimal outside support. Currently, there are several governments which are also advocating and promoting Self supply using rope pump. Countries like Ethiopia, Zambia and Uganda are now promoting low cost technologies including rope pump to scale up safe supply (Annemarieke, 2016). Self supply improves access to the water point since they are usually located within the community or households which they are serving.

Self supply through rope pumps has also been linked with economic growth. For instance communities in the study area are engaged in small scale agricultural production which is contributing to their economic growth (Rumphi District Council, 2017). There is also evidence that as people engage in economic activities there can be enhanced cooperation amongst the community since communities would be working in groups or cooperatives or even share the marketing platform (Khammar & Sellemi, 2015). There is evidence which has specified some economic growth of particular communities and the growth is linked to the use of the rope pump. Some of the practical economic growth due to rope pump use has happened in Nicaragua (Alberts & Zee, 2003). Studies have revealed improvement in financial position among users of the rope pump (Moriarty et al., 2004).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The objective of the research was to establish factors that affect sustainability of rope pumps which are a low cost hand pumps used at community level. The factors that affected sustainability of the rope pump in the study area included unavailability of a vibrant spare parts supply chain, in adequate community based management initiatives for instance inadequate trainings, improper drilling and lack of periodic checks on the pump functionality and unavailability of area mechanics network. The researcher also found out the functionality and non-functionality status of the water points with reasons for non-functionality stipulated.

The research also looked at community feedback, in terms of satisfaction with the pump regarding its performance and functionality. It was of importance to have the user feedback so that their views about the pump should be exposed for future planning and improvements.

Generally, there were members of communities who were satisfied with the pump whilst some community members were not satisfied with the pump due to different reasons. For those in favor of the pump the reasons included, good water quality, easy to pump and maintain whilst for those who were not satisfied with the pump had issues with poor water quality and frequent breakdowns. Perception on water quality by user was mostly based on physical characteristics such as color and taste.

The research also investigated the quality of water compared to the national and the World Health Organization guidelines. Of significance, is the fact that out of all the twenty four wells, only two had their water quality above both the national standards of the MBS and the World Health Organization and both wells had pit latrines located on the upper side of the wells which was deemed as a leading factor compromising the quality of water due to groundwater movement from higher to lower points.

Mostly the water from the pump was being used for drinking, cooking and economic activities like irrigation and molding bricks. Communities are mostly dependent on these pumps because in most cases they don't have other reliable sources of water. This is a typical situation for the communities who live in rural localities that do not have an alternative protected source within reach. Most of these pumps, in this study, were installed in isolated areas where mechanized drilling equipment cannot reach due to poor road network.

One issues to be considered in future programming, communities were for improved community based initiative through comprehensive training, setting up a spare parts supply chain and area mechanics system and adherence to proper drilling requirements.

6.2 Recommendations

Considering the role which the low cost technologies play in the provision of water to rural communities in Malawi, it is recommended that the rope pump be considered as one of the viable pumps for rural water supply in the country, specifically in areas where no any other technologies could be possible. The consideration is based on the fact that most of the non-functionality reasons of the pumps were due to inadequate human capacity. It was observed that the community based management training was not adequately done for this new pump design which has affected community capacity to maintain the pumps on their own. This means that a comprehensive capacity building session in this regard is required. This capacity building initiative will be able to sort out most O & M related issues.

Secondly, establishment of a spare parts supply chain and area mechanics system in the area will be vital as the spare parts will be readily available and the area based mechanics will able to provide required services as requested by the water users.

Considering the capacity of the rope pump, the researcher recommends 'Self Supply" as a solution to avoid overloading the pump which reduces its working capabilities. Self supply would be ideal since the rope pump has a small capacity compared to conventional pumps.

Considering that water quality is a prime factor as recommended by the national and World Health Organization. A critical issue which could be duly investigated during the pump construction is the positioning of the pumps in relation to the pit latrines and other factors which may compromise water quality. For instance, within the study, in areas where we had water of poor quality above the recommended standards for drinking water, the contaminated wells were located close to pit latrines (within 30 meters).

It is also further recommended that communities should embrace the system of household water chlorination which aims at getting rid of the available defects in the water. The chlorination aspect is currently being encouraged at household level using Water Guard. It is also important to remind water users on the importance of treating and boiling water for drinking through sensitization messages.

Other technical issues that compromised functionality including poor water supply in terms of quantity may be due to several factors like, poor drilling, pump setting and installation which could be as a result of incompetent officers who were engaged to do the activities. This could have been improved through adequate engagement of the ministry responsible for water affair which would have been there to assure quality control.

In conclusion, future implementation of water supply programs through the rope pump should consider highlighted issues to make sure the aims of water services provision are achieved and benefits communities, especially the rural, hard to reach areas. Further comparative studies on water quality in dry season for the rope pump are recommended.

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Appendix A: Community questionnaire

Introduction

This study aims at finding out information from community members who use the Rope and Washer pump. The information that will be gathered will include feedback having used this technology one year post construction. This questionnaire will also look at the current functionality status of all the water points in the study area. Other areas include user satisfaction and water quality issues.

Interviewer	Community name	Date	ID

Who is the respondent (tick as applicable)

Water point committee chair

Water point committee member

Chief

Community member

Water point user

Other (Specify)

Gender of respondent (tick as applicable)

Male

Female

1. Has this Rope and Washer pump been producing water every day since its installation?

Water has been available every time

Water has been available on a number of days

Water has been available most of the time

Not producing water most of the time

2. If no why?

3. What times of the day is water not available from this Rope and Washer pump?_____

4. What months was water not available from this Rope and Washer pump? _____

5. What was the alternative source(s) used when the Rope and Washer pump was not used?

6. How long did it take to be repaired?

( ) 1 month

( ) 3 months

( ) 6 months

7. Has the water point been down for more than one day in the last 30 days (Except when you are carrying out routine checks)

Yes

No

Don't know

8. If yes, what was the problem

Broken pipe

Broken rope

Broken seals

Other __________

9. Is there a functional water point committee?

Yes

No

10. If yes, what has been its roles in sustaining the water point committee of late?

11. If no, are there any plans to make the water point committee functional?

12. What is the composition water point committee?

Number males

Number Females

13. Which gender is in leadership positions (Chair, Secretary, Treasurer?)

14. Who does the maintenance of the water point

Water point committee

Hired expert

Area mechanic

Government Extension worker

Other (Specify)

15.If it's done by the committee, has it been trained?

Yes

No

16. If yes, please specify the kind of training e.g. CBM, CLTS, PRA etc.

17. How long was the specified training?

18. Are there cash resources for O& M on hand?

Yes

No

Other (Specify)

19. If yes, what ways did you use to mobilize the available resources?

Contribution

Sale of agricultural products

Sponsor outside the community

Other (Specify)

20. Do you use this pump (Rope pump) as a source of your drinking water?

( ) No --

( ) Yes ---

21. If yes, what do you usually the water from this pump for use for?

( ) Drinking

( ) Cooking

( ) Bathing water

22. Do you use this pump (Rope pump) as a source of any other water?

( ) No --

( ) Yes ---

23. If yes, what else do you usually the water from this pump for use for?

( ) Agriculture

( ) Brick making

( ) Livestock

( ) Other)_____________

24. Are you satisfied with this pump?

Yes

No

25. What satisfies you?

If no, what makes you not satisfied? If it's a water quality issue ask for specific issues.

____

____

Water quality parameters: Turbid, salty, Smell, Other specify

26. Do you like the taste of the water? If no why Let the respondent explain why)

27. What should be done to improve performance of the Rope pump (best practices)

____

____

28. Are there reasons which can make this pump a failure in the future?

29. Do you know how much a Rope pump cost?

30. What other water supply technologies have you heard about that might work well in your community?

31. If you had an opportunity to choose amongst the technologies which technology would you have chosen and why?

Appendix B: Observational Field Checklist

This check list aims at collecting information regarding the general surrounding of each water point in the study area.

Village Name:

Traditional Authority:

GPS:

1. Is water available on the day of the visit?

   Yes

   No

   If no, how long has the well been dry?

   What's the condition of the pump during the visit

   Functional

   Partially functional

   Not functional

   No longer exists or abandoned

3. Are there any problems with the pump that require attention?

   Yes

   No

   Don't know

4. If yes, what is the problem?

   Broken pipe

Disjointed rope

Worn out parts

Civil works problem

Water quality problem

Low water flow

Other (Specify)

5. Is it possible to conduct a flow rate today for the Rope pump? (You will need a 20 liters bucket). Flow Rate Result______________ (number of 20 liters filled within a minute)

Condition of apron:

Soak away pit condition:

Any water lodging around the pump

Any pit latrine within 30m

Any pit latrine located on the upper side of the pump

Cleanliness around the pump

Does the mason look sound, with no cracks?

Does the site look generally clean?

Are the bolts and nuts over worked or missing?

Is there no visible gap or sign of leakage within the pump formation?

Is there standing water near the apron?

Comments

Appendix C: Informed Consent Form for Research investigating factors affecting sustainability of Rope pump

Introduction

I am a student from Mzuzu University. We are doing research on Investigating factors affecting sustainability of Rope and Washer pumps in Traditional Authorities Mwalweni and Mwamlowe**.** There may be some words within the consent that could not be clear. Please ask me to stop for a reexamination so that you are clear. If you have questions later, you can ask them of me through or another researcher.

Purpose of the research

The goal of this research is to investigate factors affecting sustainability of the Rope and Washer pumps in Rumphi District.

Type of Research Intervention

Your participation is sought in this research.

Participant Selection

You are asked to take part in this research because you use this type of pump**.**

Voluntary Participation

Your participation in this research is entirely voluntary. You are at liberty to participate or not according to your choice. You may skip any question and move on to the next question.

Duration

The research will take place for 12 months.

Risks

You do not have to answer any question or take part in the discussion/interview/survey if you feel the question(s) are too personal or if talking about them makes you uncomfortable.)

Reimbursements

You will not be provided with any incentive for taking part in the research.

Sharing the Results

The knowledge that we get from this research will be shared with you and your community before it is made widely available to the public. Following, we will publish the results so other interested people may learn from the research.

Who to Contact

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact: Dr. Rochelle Holm, Mzuzu University, Centre of Excellence in Water and Sanitation, P/Bag 201, Mzuzu 2, Cell: +265992159079 or +265882725730.

This proposal has been reviewed and approved by NCST, which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find about more about the IRB, contact Mr. Mike G Kachedwa, Chief Research Services Officer, Health, Social Sciences and Humanities Division, National Commission for Science and Technology, P.O. Box 30745, Capital City, Lilongwe 3, Malawi, Office Phone: +265 1 771 550/774 869.

Do you have any questions?

Part II: Certificate of Consent

I have been invited to participate in research about Rope and Washer sustainability.

I have read and understood the foregoing information, or it has been read to me. I was given a chance to ask questions about it and all the questions I asked have been fully answered. I consent voluntarily to be a participant in this study

Print Name of Participant__________________

Signature of Participant ___________________

Date ___________________________

Day/month/year

If illiterate [1]

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

[1] A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Thumb print will is required..

Print name of witness____________ Thumb print of participant

Signature of witness _____________

Date ________________________

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the research project. I confirm the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent__________________________

Date ___________________________

Day/month/year

Appendix D: Informed Consent Form for Research investigating factors affecting sustainability of Rope pump (Chitumbuka)

Mazgo yakwamba Oyamba

Ndafumila ku Mzuzu University.Ndine msambili. Tikupanga kafukufuku wakukhwaopeskana na pump ya Rope and Washer.Pala tikufumbana mafumbo apo mundapulikiske chonde nifumbani kuti nilongosoleso makola. Kweniso pala munamafumbo npo nifumbani panyake mungafumbaso wanyane awo nkhupanga nawo kafukufuku.

Chakulata cha kafukufuku

Chakulata cha kafukufuku uyu ntchakuti tikukhumba kumanya kuti kasi nivifukwa wuli ivo vikupangiska kuti ama pump aya ya Rope and Washer yalekenge kukhaliska, kweniso kasi mwawanthu imwe mukugwiriska ntchito mukukholwa nawo. Kweniso pawumalilo tifumbanenge kuti tichasizge ivo tingachita kiti ma pump aya ghalutilile kugwira ntchito.linga

Ndondomeko ya Kafukufuku wathu

Kafukufuku withu tichitenge munthowa yavidumbilano.

Kusankha kwa wakufumbika

Mwasankhika kuti mutolepo lwande chifukwa mukugwiliska ntchito pump ya Rope and Washer

Kutolapo Lwande mwakujipereka

Kutengapo mbali pa kafukufuku ameneyu ndi kwa ulere. Mutha kusankha kutengapo mbali kapena kusatengapo mbali pakafukufuku ameneyu. Mukasankha kusatengapo mbali palibe chimene chitasinthe. Muli ndi ufulu okana kuyankha funso limene simungakwanitse ndikupita ku funso lina.

Nyengo ya kafukufuku

Kafukufuku uyu watolenge mwezi khumi ya yiwili.

Chenjezgo

Mukafukufuku uyu muna wanangwa wakuzgol panyake kuleka kuzgola ivo mwawona kuti vamukhalilani makola yayi.

Malipiro

Palije icho mutilipikenge pakutolapo lwande pakafukufuku uyu.

Kupereka ivo vasangika

Ivo visangikenge pakafukufuku uu vizamuperekeka kwa imwe kweniso pazamulemebka ma buku kuti wanji wasambile.

Uyo mungayowoya naye pala muna mafumbo

Pala munavinyake vakusingo vakukhwaskana na kafukufuku uyu yowoyani na: Dr. Rochelle Holm, Mzuzu University, Centre of Excellence in Water and Sanitation, P/Bag 201, Mzuzu 2, Foni: +265992159079 kapena +265882725730.

Kafukufukuyu walikuzomerezgeka na bungwe lakuwona za sayansi na kafukufuku. Kweniso pala mukukhumba kufumba vinyake mungayowoya na Mr Mike G. Kachedwa, Chief Research Services Officer, Health, Social Sciences and Humanities Division, National Commission for Science and Technology, P/O Box 30745, Capital City, Lilongwe 3, Malawi, Foni :+2651771550/774869

Muna fumbo lililose pambele tindilutilizge kafukufukuyu?

Chigawa cha chiwiri: Kuzomelezga kutolapo lwande pa kafukufuku

Ndapempheka kuti nitolepo lwande pakafukufuku wakukwaskana na ma pump ya Rope and Washer. Nawazga ndondomeko yose ya kafukufuku uyu. Nakholwa ndipo pachifukwa ichi nazomela kutolapo lwande.

Dzina la wakutolapo…………………………………………………..

Saini ………………………………………………

Dazi…………………………………………………………………………

(Tsiku/Mwezi/Chaka)

Pala wakutolapo lwande wakulemba yayi

Ine nkhuyikila umboni kuti awa watolengepo lwande pa kafukukufu uyu. Wanguwawazgila vose vakukhwaskana na kafukufuku uyu ndipo ine nkhuchitila umboni kuti wangatolapo lwande kwambula kukakamizgika.

Dzina la kaboni……………………………………. Chidindo cha woko

Signature ya mboni………………………………..

Dazi………………………………………………..

(Tsiku/Mwezi/Chaka)

Uthenga wakufuma kwa wakupanga kafukufuku

Ine nawazga makola vakukhwaskana na kafukufuku ndipo nkhusimikizga kuti wakutolapo lwande wachita ichi pakhumbo lawo kwambula kukamizgika,mwakujipeleka kweniso mwawulele.

Saini ya wopanga kafukufuku…………………………………..

Tsiku……………………………………………………………….

(Tsiku/Mwezi/Chaka)

Appendix E: Water Quality Results for 24 wells compared to standards per 100ml

	Parameters Assessed			Standard values					
				WHO			MBS		
Name of Well	pH	Coliforms (CFU)	Turbidity (JTU)	pH	CFU	JTU	PH	CFU	JTU
Dinkhondola	6.22	7	<5	-	0	1	6.0-9.5	50	25
Mlura	6.2	1	<5	-	0	1	6.0-9.5	50	25
Mwaluvulungu	6.44	1	<5	-	0	1	6.0-9.5	50	25
Kambirumbiru	5.88	200>	10	-	0	1	6.0-9.5	50	25
Chilangalanga	6.95	200>	500	-	0	1	6.0-9.5	50	25
Mutali	6.35	2	<5	-	0	1	6.0-9.5	50	25
Mchiri	6.28	6	10	-	0	1	6.0-9.5	50	25
Zumbi	6.25	0	55	-	0	1	6.0-9.5	50	25
Mlerasambo	6.17	28	10	-	0	1	6.0-9.5	50	25
Jalavula	6.38	5	<5	-	0	1	6.0-9.5	50	25
Thawata	6.1	0	60	-	0	1	6.0-9.5	50	25
Mzuwa	6.85	0	15	-	0	1	6.0-9.5	50	25
Kalopa	6.95	4	<5	-	0	1	6.0-9.5	50	25
Mkwenjere	6.2	0	<5	-	0	1	6.0-9.5	50	25
Khaula	6.55	2	<5	-	0	1	6.0-9.5	50	25
Mpulang'oma	6.6	10	<5	-	0	1	6.0-9.5	50	25
Jendausiku	7.3	0	225	-	0	1	6.0-9.5	50	25
Kapalanya	6.25	0	<5	-	0	1	6.0-9.5	50	25
Mwenyeka	6.67	0	<5	-	0	1	6.0-9.5	50	25
Lusimbo	6.93	0	<5	-	0	1	6.0-9.5	50	25
Bigida	6.4	14	<5	-	0	1	6.0-9.5	50	25

Mwachitazi	6.8	0	<5	-	0	1	6.0-9.5	50	25
Sangazinje	6.8	0	<5	-	0	1	6.0-9.5	50	25
Kasinde	6.87	0	27	-	0	1	6.0-9.5	50	25