

**A FRAMEWORK FOR MANAGING THE FUNCTIONALITY OF HAND PUMP
RURAL WATER SUPPLY SYSTEMS IN BUMBAIRE SUB-COUNTY, BUSHENYI
DISTRICT**

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Abstract

Water is a basic need and a human right. When communities access potable water, their livelihoods improve. Groundwater is the most commonly used source of water. Communities access water from this source through hand pumps, among others. The water is accessed when they are functional. Against this backdrop, the purpose of the study was to develop a framework for managing the functionality of hand pump rural water systems in Uganda. The study was contextualized on Bumaire Sub County in Bushenyi District. The study set out to establish the causes of hand pump nonfunctionality, to design a framework for improving the maintenance of hand pumps; and to validate the designed framework and recommend it for deployment. Primary and secondary data were collected to answer objective 1 while Design Science Research was adopted to design and evaluate the framework to answer objectives 2 and 3. Water users, District Water Officials and Sub County Community Development Officer participated in the study. In total, 158 participants were involved. Questionnaires, FGD, Interviews, Experiments and Sanitary Inspection tool were used for primary data collection. Findings revealed that social, financial, technical and institutional factors were responsible for nonfunctionality of the hand pumps. A framework for closing the social, financial, technical and institutional management gaps was designed and evaluated. The evaluated framework was recommended for deployment. The study concluded that when the prescriptions of the evaluated framework are duly implemented, the maintenance of hand pumps will improve. Correspondingly, the magnitude of break-down and nonfunctionality will be minimized. The study recommends need for continuous awareness creation and active engagement of the water users, among others.

Declaration

I, **Titus Nuwamanya**, hereby declare that the work contained in this dissertation titled “*A framework for managing the functionality of Hand Pumps Based Rural Water Supply in Bumaire Sub-County, Bushenyi District, Uganda*” is an original compilation and academic work. It has never been submitted to this or any other higher education institution for any award. In building the background to the study, review of literature and methodological procedures utilized and followed, works of other scholars and authorities were incorporated. However, in due acknowledgement, the works have been duly referenced and cited following the specifications of Harvard Referencing System.



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Approval

I certify that this dissertation work titled “*A framework for managing the functionality of Hand Pumps Based Rural Water Supply in Bumbaire Sub-County, Bushenyi District, Uganda*” has been duly processed and compiled by Titus Nuwamanya and is now ready for submission to external examination.



Signed

Date: **8th April 2025**

JOB SSAZI PIUS

(Supervisor)

Dedication

My Children and my wife, thank you for comradeship and your continued encouragement. You and I are victors and await to harvest unlimited dividends! Just a matter of time.

Table of Contents

Abstract	i
Declaration	ii
Approval	iii
Dedication	iv
Table of Contents	v
List of Tables	x
List of Figures	xii
List of Appendices	xiv
List of Abbreviations and Acronyms	xv
CHAPTER ONE: GENERAL INTRODUCTION	1
1.1 Introduction	1
1.2 Background to the Study	2
1.3 Problem statement	5
1.4 Objectives	6
1.4.1 Main Objective	6
1.4.2 Specific Objectives	6
1.5 Scope of the Study	7
1.5.1 Geographical	7
1.5.2 Content	7
1.6 Justification	7
1.7 Significance of the Study	8
1.8 Conceptual framework	9
CHAPTER TWO: LITERATURE REVIEW	12
2.1 Introduction	12
2.2 Water Abstraction, Water Governance and hand pump water abstraction	12
2.2.1 Water Abstraction	12

2.2.2 Water Governance	15
2.2.3 Hand pump water abstraction	17
2.3 Rural water point sources.....	19
2.4 Functionality of hand pumps	21
2.4.1 Global perspectives on nonfunctionality of hand pump rural water supply systems	22
2.4.3 Non functionality of hand pumps in Uganda.....	26
2.5 Causes of Nonfunctionality of point water sources in rural areas	28
2.6 Strategies for effective management of functionality of point water sources in rural areas...	37
2.7 Frameworks for maintaining the functionality of point water sources in rural areas	41
2.8 Chapter Summary and emerging research gaps.....	41
CHAPTER THREE: MATERIALS AND METHODS	42
3.1 Introduction.....	42
3.2 Research Approach	43
3.2.1 The Relevance cycle.....	44
3.2.2 The Design Cycle	45
3.2.3 The Rigor Cycle	46
3.3 Research Design.....	46
3.3.1 Quantitative Methods.....	47
3.3.2 Qualitative Methods	48
3.3.3 Laboratory Tests	48
3.4 Population	50
3.5 Sampling techniques and Sample size	50
3.6 Data collection methods and instruments	51
3.6.1 Data types.....	51
3.6.2. Primary data collection methods and instruments	52
3.6.2.1 Questionnaire survey	52
3.6.2.2 In-depth interviews	53
3.6.2.3 Focus Group Discussion (FGD).....	54
3.6.2.4 Experiment data collection	55
3.6.2.4.1 Petrifilm™ Testing	56
3.6.4.2.2 Physicochemical composition.....	57

3.6.4.2.3 Colour and Odour	59
3.6.5 Sanitary Inspection of Hand pumps	59
3.6.6 Secondary Data collection Methods and Techniques	59
3.7. Data Collection Instruments	60
3.7.1 Questionnaire	60
3.7.2 Interview Guide	61
3.7.3 FGD Guide.....	61
3.7.4 Document Review Guide.....	61
3.7.5 Observation checklist.....	61
3.7.6 Laboratory Results Sheet	62
3.8 Data Quality Control.....	62
3.8.1 Validity	62
3.8.2 Reliability.....	63
3.8.3 Reliability and rigor of interviews and FGDs.....	64
3.9. Procedure of Data Collection.....	64
3.10 Data analysis	65
3.10.1 Analysis of quantitative data	65
3.10.2 Analysis of qualitative data	65
3.10.3 Analysis of Laboratory results	66
3.10.4 Designing of the Framework	67
3.11 Ethical Considerations	67
3.12 Limitations of the study	69
CHAPTER FOUR:PRESENTATION AND DISCUSSION OF FINDINGS	70
4.1 Introduction.....	70
4.2 Response Rate.....	70
4.3 Background Information.....	71
4.3.1 Description of the respondents by age-group and gender.....	72
4.3.2 Description of the respondents by marital status and leadership position	72
4.3.3 Description of the respondents by household size.....	73
4.3.4 Description of the respondents by daily water needs.....	74
4.4 Causes of nonfunctionality of hand pumps in Bumbaire Sub County, Bushenyi District.....	76

4.4.1 Water quality-related causes	77
4.4.1.1 pH.....	80
4.4.1.2 Turbidity	80
4.4.1.3 Total Dissolved Solids and Total Suspended Solids.....	80
4.4.1.4 Hardness.....	80
4.4.1.5 Calcium and Magnesium	81
4.4.1.6 Electrical Conductivity (EC).....	81
4.6.1.7. Sulphates	81
4.4.1.8 Total Alkalinity.....	81
4.4.1.9 Iron.....	82
4.4.1.10 Nitrate - Nitrogen.....	82
4.4.2 Socio-technical causes of nonfunctionality of hand pumps in Bumaire Sub County.....	83
4.4.2.1 Community-based factors leading to nonfunctionality of hand pumps	83
4.4.2.2 Technical factors leading to nonfunctionality of hand pumps.....	89
4.4.3 Financial factors leading to nonfunctionality of hand pumps.....	94
4.4.4 Institutional factors leading to nonfunctionality of hand pumps	99
4.4.5 Regression results on the significance of the causes of nonfunctionality of hand pumps.	101
4.4.6 Gaps analysis	102
4.5 Designed framework for managing the functionality of hand pumps	107
4.5.1 Design decisions considered while developing the hand pump management framework.	108
4.5.2 The designed framework.....	115
4.5.3 Key features of the hand pump maintenance framework	117
4.5.3.1 Training for local ownership.....	118
4.5.3.2 Information sharing through databases	118
4.5.3.3 Multiple monitoring	119
4.5.3.4 Funding	120
4.5.3.5 Reciprocal communication	120
4.6 Evaluated Hand pump water system maintenance framework.....	121
4. 6.1 Evaluation criteria.....	121
4.6.3 Evaluation methodology adopted	123
4.6.4 Results from evaluation survey.....	124

4.6.4.1 Data Quality Control.....	124
4.6.4.2 Survey evaluation results	125
4.6.4.2.1 Background characteristics of evaluation participants	125
4.6.4.2.2 Findings on ranking of the solutions provided by the framework.....	126
4.6.4.2.3 Findings on efficiency and usability of the framework	127
4.6.4.2.3.1 Efficiency of the framework	127
4.6.4.2.3.2 Usability of the framework	129
4.6.5 Evaluated hand pump water system maintenance framework.....	131
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS	133
5.1 Introduction.....	133
5.2 Conclusion	133
5.3 Implications of the study.....	134
5.4 Recommendations.....	134
5.5 Areas for further research	135
References.....	136
Appendices.....	154
Appendix A: Questionnaire for Water Users.....	154
Appendix B: Interview Guide for District Water Engineer/Sub County CDO.	162
Appendix C: FGD For male and Female Water users	163
Appendix D: Observation Checklist.....	164
Appendix E: Document Review Guide.....	164
Appendix F: Survey tool for evaluating framework.....	165
Appendix G: Krejcie and Morgan (1970) Table of Sample Size Determination	170
Appendix H: Experiment Results	171
Appendix I: Transmittal Letter	172

List of Tables

Table 3. 1: Population, Sample and Sampling Techniques	51
Table 3. 2: Test parameters, analytical method and instruments used in water quality testing....	58
Table 3. 3: Water quality parameters tested in the laboratory	62
Table 4. 1: Summary of response rate	71
Table 4. 2: Cross-tabulated results on age-group * Gender	72
Table 4. 3: Cross-tabulated results on marital Status * Leadership Position.....	73
Table 4.4: Household size and composition in Bumbaire Sub County	73
Table 4.5: Daily household water needs and functionality of hand pumps	75
Table 4. 6: Alternative sources of water used by households.....	76
Table 4. 7: Description of the nonfunctional handpumps in Bumbaire Sub-County.....	77
Table 4.8: Permissible values for assessing quality of drinking water	79
Table 4. 9: Community-based causes of nonfunctionality of hand pumps.....	84
Table 4. 10: Engagement of women and community leadership	87
Table 4. 11: Technical factors leading to nonfunctionality of hand pumps.....	91
Table 4. 12: Maintenance issues as causes of nonfunctionality of hand pumps.....	93
Table 4. 13: Financial factors leading to nonfunctionality of hand pumps	96
Table 4. 14: Institutional factors leading to nonfunctionality of hand pumps.....	100
Table 4. 15: Regression model results	102
Table 4.16: Existing gaps in the maintenance of hand pumps in Bumbaire sub county	103
Table 4.17: Requirements and design decisions taken in designing the framework	109

Table 4.18: Test values for validity and reliability of the evaluation questionnaire.....	124
Table 4.19: Relative importance of the solutions specified by the framework	126
Table 4.20: Views of the participants on the efficiency of the framework.....	128
Table 4.21: Views of the participants on usability of the framework.....	130

List of Figures

Figure 2. 1: Credibility attached to groundwater abstraction	14
Figure 2. 2: Hand-powered pump	18
Figure 2. 3: Importance attached to hand pump water supply system in Africa	18
Figure 2. 4: A deserted nonfunctional hand pump.....	19
Figure 2. 5 : Number of deaths by risk factor globally in 2019.....	23
Figure 2. 6: An Indian woman fetching water from a hand pump.....	24
Figure 2. 7: Number of deaths by risk factor Africa (WHO Region) in 2019.....	26
Figure 2. 8: Long queue on a borehole in Uganda.....	27
Figure 2. 9: A child drawing water from a rock fountain	27
Figure 2.10: Fetching water from an open stream	27
Figure 2. 11: Number of deaths by risk factor, Uganda in 2019	28
Figure 2. 12 : Borehole prone to breakdown because of rigidity of the pumping system	34
Figure 2. 13: Sources of faecal pollution within urban a) and rural b) settings.....	35
Figure 2. 14 : Water level measurement gear	40
Figure 3. 1: Methodology Flow Diagram	43
Figure 3. 2: Design Science Research Flow Diagram for producing artefacts.....	44
Figure 3. 3: Schematic presentation of the Research Design adopted.....	47
Figure 3. 4: Field experimental test in Bumbaire Sub County, Bushenyi District	50
Figure 3. 5: Data Flow Stream.....	60
Figure 4. 1: Does the hand pump supply meet your needs?	75

Figure 4. 2: Whether hand pumps had water quality problems.....	75
Figure 4. 3: Indicators of hand pump water quality problems	76
Figure 4. 4: Whether the households considered themselves as rightful owners	85
Figure 4. 5: Causes of limited/no participation of women	88
Figure 4. 6: Responses on party responsible for site selection of the hand pumps.....	91
Figure 4. 7: Reasons for declining to pay user fees for hand pump water.....	97
Figure 4. 8: Importance attached to paying user fees for hand pump water	97
Figure 4. 9: Extent of support needed by communities	101
Figure 4. 10: Hand pump water system maintenance framework	116
Figure 4. 11: Description of the participants in framework evaluation by gender	125
Figure 4. 12: Description of the framework evaluation.....	125
Figure 4. 13: Description of the framework evaluation respondents by level of education.....	125
Figure 4. 14: Revised framework.....	132

List of Appendices

Appendix A: Questionnaire for Water Users.....	154
Appendix B: Interview Guide for District Water Engineer/Sub County CDO.	162
Appendix C: FGD For male and Female Water users	163
Appendix D: Hand pump condition/status survey checklist.....	164
Appendix E: Document Review Guide.....	164
Appendix F: Survey tool for evaluating framework.....	165
Appendix G: Krejcie and Morgan (1970) Table of Sample Size.....	170
Appendix H: Experiment Results	171
Appendix I: Transmittal Letter	172

List of Abbreviations and Acronyms

BOD	:	Biological Oxygen Demand
CDO	:	Community Development Officer
DSR	:	Design Science Research
ENRD	:	European Network for Rural Development
EU	:	European Union
FGD	:	Focus Group Discussion
GUI	:	Graphical User Interface
ICMR	:	Indian Council of Medical Research
IWRM	:	Integrated Water Resources Management
KB	:	Knowledge Body
KIU	:	Kampala International University
LCs	:	Local Councils
LICs	:	Low Income Countries
MoES	:	Ministry of Education and Sports
MoES	:	Ministry of Education and Sports
MUST	:	Mbarara University of Science and Technology

MWE	:	Ministry of Water and Environment
n.d	:	Not Dated
NGOs	:	Non-Governmental Organizations
NW&SC	:	National Water and Sewerage Corporation
O&M	:	Operation and Maintenance
pH	:	Potential of Hydrogen
READ	:	Readying Extracting Analysing Distilling
SDG	:	Sustainable Development Goals
SPSS	:	Statistical Package for Social Sciences
SSA	:	Sub Saharan Africa
TFEU	:	Treaty on the Functioning of the European Union
TSS	:	Total Suspended Solids
UBOS	:	Uganda Bureau of Statistics
UCU	:	Uganda Christian University
UN	:	United Nations
UNC	:	University of North Carolina
UNEP	:	United Nations Environmental Programme
USEPA	:	United States Environmental Protection Agency

USPHS : United States Public Health Services

WASH : Water, Sanitation and Hygiene

WFD : Water Framework Directive

WHO : World Health Organization

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Introduction

Since the beginning of time, it has been known that water is a physiological need (Maslow & Lewis, 1987). Indeed, it is a basic need that supports different forms of life on earth. That said, the availability and accessibility of water improves human life considerably while also serving as a bedrock for development of every country (Mishra et al., 2021). Despite this, the level of scarcity of drinking water is higher. It is estimated that about 40% of the 7 billion people occupying planet earth are threatened by water scarcity (Mulei & Gachengo, 2021). The challenge is even greater in rural areas of many low-income countries (LICs) (Martinez-Santos & Renard, 2020) and yet global rural population has increased by 26 per cent between 1980 and 2020 (Carter, 2021). In fact, this percentage is anticipated to rise at a future date given the trends of drought and desertification that are threatening different ecological environments (Mulei & Gachengo, 2021). The chapter presents background information about management of rural water sources. Contextually, the concern of the study is on point water sources. Specific emphasis is on hand pumps and particularly, those in Bushenyi District. Effort is made to trace the causes of nonfunctionality of hand pump based rural water supply in the study area. In the chapter also, the problem statement is defined, purpose of the study is stated, study objectives are defined, the guiding research questions sought to be answered by the study are clarified, the scope of the study is stated, justification of the study is brought out, significance of the study is indicated, the conceptual framework is presented and lastly, a summary linking the chapter to the next one is presented.

1.2 Background to the Study

Globally, availability, accessibility and reliability of drinking water are conceived as key determinants of rural development (Marks et al., 2018). As a result, several interventions have been undertaken aimed at dotting rural areas with many water sources (Marks et al., 2018). In many countries, providing secure and affordable drinking water and sewerage services is a government monopoly (Ananda & Pawsey, 2019). Access to safe and affordable drinking water is a human basic need (Lombanya & Chileshe, 2020). Besides, accessibility and availability of water is an important component in national development (Chepyegon & Kamiya, 2018). Water is thus, a crucial and valuable global resource making its sustainable use, an important challenge of our time (Sotos Rios et al., 2018). Drinking water is a human need with a daily demand and with no real substitutes, with the scale of service delivery lending itself to a natural monopoly, which should lead to financial sustainability (Hope et al., 2021). This proposition by Hope et al. (2021) is more of a wild assumption given the current shortages of drinking water in rural environs. Hope and colleagues relay that globally, 2.1 billion people lack ‘safely managed’ drinking water, including 785 million people without ‘basic’ drinking water services, of whom four out of five live in rural areas. The magnitude of this challenge is even worse in Africa. Rural Africa lags behind global progress to provide safe drinking water to everyone despite decades of effort and billions of dollars invested in the sector (Hope et al., 2021). Though majority of the rural water-insecure live in Africa and Asia, there are also small and enduring geographies of exclusion elsewhere in the world. In Australia, Europe, and North America, this challenge disproportionately affects indigenous people and ethnic groups (Hope et al., 2021).

For all communities of the world, access sufficient and affordable water is one of the basic human rights as well as a prerequisite for improving the overall life of a society (Hassen & Omer, 2021). Water is an essential element for life and health (Gurmessa & Mekuriaw, 2019). Water is among the most essential natural pre-requisites for sustenance of plants, animals and humans. It is a basic requirement for the healthy functioning of the entire world's ecosystem (Hassen & Omer, 2022). Access to safe and sufficient water is essential to healthy living (Mekuriaw & Gurmessa, 2020). It also shapes economic and livelihood activities. Food security and income options generated in crop production, industry, domestic processing, aquaculture, livestock, recreation, navigation and transport, and electricity supply are obtained from water (Gurmessa & Mekuriaw, 2019). Thus, provision of safe and adequate water supply has far-reaching effects on health, productivity, quality of life and to ensure sustainable socioeconomic development (Gurmessa & Mekuriaw, 2019). However, one in three people or 2.2 billion people around the world lack safe drinking water and 4.2 billion people live without access to safe sanitation services (Mekuriaw & Gurmessa, 2020). The situation in rural areas is even worrisome. To improve access to safe water supply and sanitation demand, water has to be supplied where and when it is needed. However, lack of water supply and sanitation services are substantial globally (Gurmessa & Mekuriaw, 2019).

Much as sufficient, safe, continuously available drinking water is important for human health and development, one in three hand pumps in sub-Saharan Africa are nonfunctional at any given time (Klug et al., 2017). Thus, the presence of a handpump does not mean that people have access to reliable and sustainable water services (Rural Water Supply Network, 2024; Mvongo et al., 2023; Foster et al., 2019). Reliable services are rendered by functional systems. Functionality of a handpump refers to its ability to provide water to users that meets quality standards when stroked

for less than 5 rounds (Carter and Ross, 2016; IRC, 2013). A handpump where water starts flowing after more than 5 strokes is partially functional while one where water does not start flowing at all using the 5-Stroke Test is nonfunctional (Rural Water Supply Network, 2024; Mvongo et al., 2023; IRC, 2013). According to Ministry of Water and Environment, Uganda (2021), a handpump is considered to be non-functional and decommissioned by the Ministry of Water and Environment Uganda, if the water it provides no longer meets the required quality standards. In this study, a handpump was conceived to be nonfunctional both with and without flowing water as long as the water never met quality standards.

Whenever handpumps become nonfunctional, a significant number of rural communities are forced to turn back to unprotected sources due to service breakdowns of their water supply system (Beshah et al., 2016). Several studies (such as Bhandari & Grant, 2007; Budhathoki, 2019; Gurmessa & Mekuriaw, 2019; Marks et al., 2013; Smets et al., 2017) have shown that nonfunctionality of hand pumps has become a common challenge facing users in different environments. In general, the nonfunctionality of domestic water systems lies between 30 and 40% in developing countries (Smets et al., 2017). The high frequency of breakdown is typically due to the poor condition of infrastructure, limited timely system maintenance, and a lack of an institutional arrangement that supports operation and maintenance (Marks et al., 2013). Other factors affecting technical sustainability of rural water systems include system's age, use of poor materials and workmanship during construction, a lack of post-construction support (Marks et al., 2013), convenience of water-point locations (Bhandari & Grant 2007), willingness of the water users to pay for water (Gurmessa & Mekuriaw, 2019), and availability of funds for maintaining the operational effectiveness and efficiency of constructed hand pumps (Budhathoki, 2019). Further, the performance of water systems has been found to rely on system-level variables (such

as improved water services, effective institutional structures, and capable water user committees and operators). Improving the functionality of rural water points worldwide will be a major determinant in the achievement of the United Nations (UN) Sustainable Development Goal (SDG) of a safely managed drinking water source for all by 2030 (MacManus, 2021). SDG 6 reaffirms the commitment of United Nations (UN) to achieving universal and equitable access to improved drinking water and sanitation for all (Anthonj et al., 2018; Gazzeh & Abubaker, 2018).

The government of Uganda and donor agencies have always supported the construction of new water facilities and rehabilitation of existing ones. In Bushenyi District, safe water coverage is estimated at 85%, with 93% coverage reported in urban and peri-urban areas compared to 7 % in rural areas. The district has 2 water schemes and the access rates vary from sub-county to sub-county. Bushenyi District has 1,379 domestic water points which serve a population of 214,451 people with a total of 178,591 people in rural areas. Despite the coverage, there are 15 water sources that have been nonfunctional in Bushenyi District for over 5 years and are considered abandoned (MWE, 2021). Of this number, 7 are in Bumbaire Sub County which represents 47% of the abandoned water sources in the entire district. Therefore, Bumbaire Sub County has the highest number of hand pump based rural water supply installations that are nonfunctional in the entire district (Bushenyi District Water Office Report, 2021). Against this backdrop, the proposed study sought to establish the causes of the problem with an ultimate goal of designing a framework to fill the existing management and maintenance gaps.

1.3 Problem statement

Despite the efforts taken by the government of Uganda to ensure increased access to drinking water in rural areas, a big number of households still lack access. Bumbaire has a projected population

of 15,300 people with an estimated population density of 34 people/km² (Uganda Bureau of Statistics [UBoS], 2015). The sub county has the lowest functionality at 64%. For instance, out of 121 protected springs, 49 are nonfunctional. As well, of the available 19 shallow wells, 9 are non-functional while out of 21 hand pumps, 7 are nonfunctional. The sub county also has no access to piped water from NW&SC (Ministry of Water and Environment [MWE], 2021). Compared to other groundwater sources, hand pumps are the most commonly used source of water in the sub county (Bumaire Sub County Community Development Report, 2022). Thus, due to non-functionality of some hand pumps in Bumaire, there is a challenge of water scarcity. Therefore, unless an investigation is carried out to assess the gaps in the management of functionality of hand pumps, the same problems leading to nonfunctionality will continue to manifest. Wilson et al. (2016) suggested the necessity of reliable monitoring of the current rates of functionality which can only be possible through coordinated actions by actors at different levels. To realise this ultimate goal, a framework is necessary. Therefore, the purpose of this study was to develop an integrated hand pump water source management framework for enhancing the management and sustainability of hand pump rural water sources in the sub county.

1.4 Objectives

1.4.1 Main Objective

To develop a framework for managing the functionality of hand pump water systems in order to ensure a steady rural water supply in Bushenyi district.

1.4.2 Specific Objectives

The study was guided by the following specific objectives;

- i. To assess the causes of nonfunctionality of hand pumps in Bushenyi District.

- ii. To design a framework for closing gaps identified in management of functionality of hand pumps
- iii. To evaluate and recommend the designed framework for deployment.

1.5 Scope of the Study

1.5.1 Geographical

The study was carried out in Bumbaire Sub County, Bushenyi District. The district lies between the coordinates; 0° N and 0°46' S of the equator and 29°41' East and 30°30' West, with its headquarters located 340 kilometers from the capital city of Uganda, Kampala. Bumbaire Sub County is located at latitude -0°35'57.37" and longitude 30°11'3.8". The estimate terrain elevation above sea level is 1524 meters with an annual rainfall of 1500- 2000 mm and mean annual temperature ranging from 12.5°C to 30°C (Ministry of Education & Sports [MoES], 2014)

1.5.2 Content

The study was limited to causes of nonfunctionality of hand pumps. Specifically, it examined maintenance of hand pumps with the intent of establishing existing gaps. The identified gaps helped in the generation of requirements for designing a framework for improved management of functionality of hand pumps in all parts of Uganda.

1.6 Justification

Access to reliable and potable water is a human right. Without access to water, the livelihoods of the communities are put at stake. Despite this degree of importance, the functionality of hand pumps which are a main source of ground water for households in many parts of Bushenyi District, Bumbaire Sub County inclusive has continued to be a malaise for many households. For effective maintenance of hand pumps, the study provides a hypothetical argument that coordination and

communication among the stakeholders in the area provides a corrective mechanism for filling the likely existing gaps. A framework was designed and proposed by this study to close these gaps and guarantee reliable operation of hand pumps in Bumbaire Sub County in particular and Bushenyi district in general.

1.7 Significance of the Study

The accomplishment of the study could benefit the following parties;

Planners and policy makers in Ministry of Water and Environment, Finance Planning and Economic Development as well as Health and Local Government benefit from the study as it provides documented evidence of the gaps in the maintenance of the functionality of water sources. This could provide insights on designing strategies that are capable of ensuring that the voids identified by this study are duly filled.

The findings of the study are of benefit to the development partners such as World Bank and International NGOs such as World Vision and Plan International that invest substantial amounts of money in safe water and sanitation in lower local governments or communities.

The findings obtained will provide evidence and scope of nonfunctionality of hand pumps in rural areas in Uganda. This could inform the leadership of the respective communities on decisions that could be taken to reverse this trend especially those connected with improvement of the functionality of hand pumps, among others. The developed framework might become their administrative and management tool.

In building the background to the study, the exploratory studies indicated that no frameworks have been designed to address the recurrent nonfunctionality of hand pumps in Uganda's water and sewerage system. This study therefore provides insights to future researchers and scholars on correction of water and sewerage service inequalities using frameworks. Equally, the structuring of the study has provided a benchmarking point to future researchers and scholars on designing related frameworks to close gaps existing in water resources management systems.

The findings of the study help to bring to the fore the precarious situation facing rural households in Bumbaire Sub County in accessing water for domestic use. The findings are likely to attract considerable interventions from funding NGOs, District Water Office and other stakeholders biased on community development consequently leading to improvements in the maintenance of the hand pumps in the sub county.

The accomplishment of the study could improve on the prowess and proficiency of the researcher in research and research related activities such as data analysis skills, report writing and literature review skills and construction of survey tools, among others.

1.8 Conceptual framework

Figure 1.1 shows a hypothetical relationship between a set of factors as independent variables and nonfunctionality of handpumps as the dependent variable. As established from the various sources reviewed, the incidence of nonfunctionality of handpumps is influenced by community factors. These manifest in the form of absence of functional water user committees (WUCs), negative attitudes and perceptions regarding the ownership of the handpumps and limited engagement of women in the management of the systems and yet they interact with handpumps frequently, given

the gender division of labour which includes fetching of water as a core responsibility of women. Besides, technical factors such as availability and affordability of the spare parts and availability of O&M personnel in the communities influences the functionality of handpump systems since they it eases preventive maintenance. Furthermore, availability of funding is equally an important determinant of functionality of handpumps since the funds are required for sustaining O&M activities. In the same vein, in most communities, there are different institutions that play different roles in supporting and sustaining community development projects, water services inclusive. Thus, when there is collaboration between such institutions, there is synergy which results in effective maintenance of the handpumps. Any variations or loopholes in the factors impacts on the maintenance of handpumps, leading to nonfunctionality. The conceptual framework assumes a real-life situation. Characteristically, handpump systems become nonfunctional when there is frequent breakdown, considerably longtime spent pumping water, decline in community standards, deserted handpumps. For effective management of functional handpumps, the study proposed solutions. These are collated into an evaluated framework.

The moderating variables are introduced in the conceptual framework because they have an impact on the degree with which the independent variables affect the functionality of the handpump water system. For instance, positive community attitudes influence the extent to which communities engage in the handpump water projects regarding provision of security for the installations and contributing funds for effective maintenance. Equally, the literacy levels of the community members are key in enhancing the effectiveness of handpump water management activities. The reverse is true when the two factors are unfavorable. For instance, even if colossal sums of money

are spent on mobilization and sensitization campaigns, negative community attitudes water down the efforts.

Independent Variables (Causes) Dependent Variable (Non-functionality of handpumps)

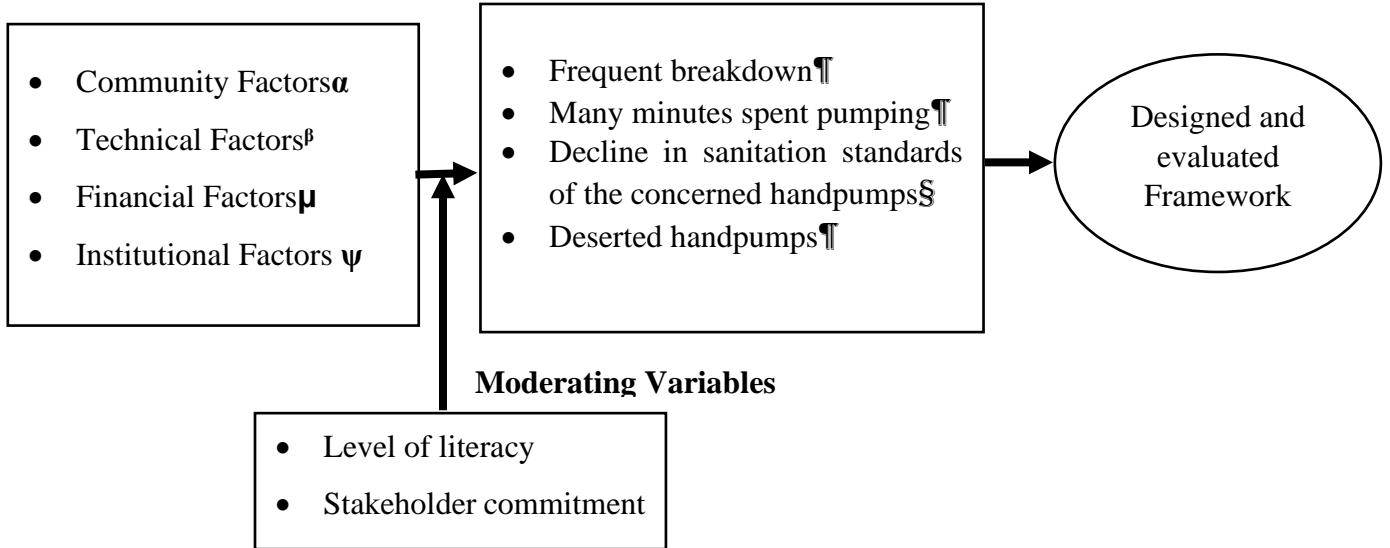


Figure 1: *Conceptual framework relating causes to nonfunctionality of handpumps*

Sources: α = Gameda et al. (2021) β = Adeenze-Kangah (2022); Lutterodt et al. (2018); Owor et al. (2019) μ = Valcourt et al.(2020) ψ = Odjegba et al.(2020), Naiga (2021); \Uparrow = Etongo et al.(2018); Kamyia et al.(2021), Foster et al.(2020); Klug et al. (2018); \S = Casey et al.(2016); Toure & Wenbiao (2020); Circle of Blue (2022).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

In this chapter, literature related to functionality and performance of hand pumps in rural water supply systems is presented. According to Thuduwege (2021) and Mauer & Veneck (2022), literature review is essential for developing a research idea, to understand what is already known about a subject and to enable a researcher to identify any knowledge gaps and how the research could contribute to further understanding of the study area. In the proposed study, a comprehensive literature review is necessary as it will help to identify knowledge gaps, to introduce a theoretical framework, to develop a conceptual framework, to discuss the findings of the study (Paul & Criado, 2020; Thuduwege, 2021). Thus, well-argued and discussed literature review helps to put findings in context (Baumeister, 2013; Winchester & Salji, 2016; Nakano & Muniz, 2018). Literature for this study has been sourced from journals, research reports and newspapers. It is reviewed under themes that were developed from the specific objectives of the study stated in Chapter 1. The actual thematic review of literature is preceded by theoretical review about water abstraction, water governance and hand pump water abstraction. This is intended to provide underpinning information on which the entire review of related literature is based.

2.2 Water Abstraction, Water Governance and hand pump water abstraction

2.2.1 Water Abstraction

Due to increasing population, globally, the demand for water has also increased proportionately (Schreiner-McGraw & Ajami, 2021). According to EnviroTech Online (2021), water is the most precious resource on our planet. It sustains different forms of life and therefore, it is not by surprise that many research studies and media reports have indicated that its demand is increasingly

enormously. This growth in water demand has led to an increase in water abstraction (Ahmed, 2021). EnvironTech Online (2021) defines abstraction as the process of extracting water from any natural source, such as a lake, aquifer, river, stream or spring. According to United Nations Environmental Programme (UNEP) (n.d), water abstraction is the process of taking water from any source, either temporarily or permanently for irrigation, industry, recreation, flood control or treatment to produce drinking water. Total annual water abstraction is presented as million cubic meters of water abstracted by all economic sectors from groundwater and surface water (European Environmental Agency, 2023). Water abstraction occurs from two sources, groundwater and surface water (Saha & Quinn, 2020). These two components form the hydrological system and are interlinked (Saha & Quinn, 2020). This study focused on hand pumps and these fall under the groundwater abstraction.

Groundwater abstraction is one of the key socio-economic development projects implemented by the governments and development partners to support and sustain livelihoods. According to Schreiner-McGraw and Ajami (2021), groundwater abstraction is one of the earliest project activities implemented by man that dates to the time of earliest human civilization. Groundwater abstraction has increased in the last five decades due to landslide developments in well drilling and pumping technology (Schreiner-McGraw & Ajami, 2021). To date, groundwater provides about 50% of all drinking water, 40% of water for agriculture irrigation, and 33% of industrial water and is supplying water for more than two billion people worldwide (Schreiner-McGraw & Ajami, 2021). For instance, in the United States, groundwater abstraction constitutes 25% of fresh water withdrawals and irrigation accounts for 65% of total groundwater withdrawals (Schreiner-McGraw & Ajami, 2021). Owing to this importance, groundwater abstraction was the theme of

the World Water Day in 2022 (See Figure 2.1). Despite this increase, there is inadequate groundwater management and absence of a monitoring plan in different environments (Ahmed, 2021). One of the indicators of the said inadequacy is that in different countries, conventional water pumps are becoming inoperative. This challenge is caused largely by declining water levels (Ahmed, 2021). The challenge is worsened by the fact that in many developing countries, groundwater governance is almost nonexistent mainly due to lack of proper institutional arrangements. While efforts have been made to support groundwater governance through formulation of rules, regulations, and policies, the major barrier to realizing the anticipated levels of governance is the lack of goodwill for enforcement (Ahmed, 2021). Though rules, regulations and policies are formalized, they are shelved in different line organizations. For this reason, they are far from being effective.



Figure 2. 1: Credibility attached to groundwater abstraction

Van der Gun (2021) reported that intensive groundwater abstraction may produce a diversity of negative side effects: declining groundwater levels; increasing cost of groundwater abstraction;

diminishing or even disappearing spring discharges and baseflows; degradation of wetlands; land subsidence; and intrusion of saline, brackish, or other low-quality water. Van der Gun (2021) also noted that to some extent, some positive side-effects may be posted such as drainage of water-logged zones, enhancing groundwater recharge and creating more storage capacity for buffering between wet and dry periods. Efforts therefore ought to be undertaken to ensure that the negative effects of groundwater abstraction are ameliorated. This need is imperative as EnvironTech Online (2021) reported that much as water is a finite resource in plentiful demand, it must be tightly regulated by the authorities to ensure that there is enough to go around. Thus, water abstraction detection and monitoring is important to ensure water management and compliance with water regulation rules and water rights (European Network for Rural Development [ENRD], 2021). Regulation is critically important because the world is facing the greatest and most complex twin challenges of water insecurity: scarcity and excess, that is while there is too much in some areas, there is also too little water in other areas (Maskey et al., 2023). This has resulted in a governance crisis (Katusiime & Schutt, 2020).

2.2.2 Water Governance

Globally, there are several legislations that have been instituted to enhance water abstraction governance (Katusiime & Schutt, 2020). The legislations are intended to ensure effective water resources management. Many countries are subscribing to Integrated Water Resources Management (IWRM) approach to achieve this goal (Global Water Partnership, 2020; Meran et al., 2021). The Integrated Water Resources Management approach aims to ensure a process that promotes the coordinated development and management of water, land, and related resources in a drainage basin to maximize economic and social welfare equitably without compromising the sustainability of vital ecosystems. The subscribing members of IWRM are mandated to establish

an enabling environment that takes the form of developing appropriate policies, strategies and legislation, institutional framework and management instruments. With such in place, the implementation of IWRM is successful (Katusiime & Schutt, 2020). To establish the enabling environment for implementing IWRM, Katusiime and Schutt (2020) noted that four water principles must be borne in mind; 1) Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment; 2) Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels; 3) Women play a central part in the provision, management and safeguarding of water; and 4) Water has an economic value in all its competing uses and should be recognized as an economic good as well as a social good.

At regional levels, legislative frameworks have been adopted to ensure that water governance is improved. For instance, in European Union, Water Framework Directive (WFD) was instituted in 2000 and aims at reducing and removing pollution and on ensuring that there is enough water to support wildlife and human needs (European Commission, 2022). WFD ensures an integrated approach to water management, respecting the integrity of whole ecosystems, including by regulating individual pollutants and setting corresponding regulatory standards. It is based on a river basin district approach to make sure that neighboring countries cooperate to manage the rivers and other bodies of water they share (European Commission, 2022). Besides WFD, Articles 191 to 193 of the Treaty on the Functioning of the European Union (TFEU) clearly state that water is not just a commercial product, but also a common good and a limited resource that needs to be protected and used in a sustainable way, in terms of both quality and quantity (Maria-Mirela & Christian, 2023). Related developments have also been noted in other regions of the world such as

Africa. For instance, according to Jasemina (2019), Africa adopted Resolution 300 in 2015 that focuses on water governance and the right to water obligations. This legislation mandates the member countries to ensure that the right to water is strictly observed for sustainable livelihoods (Jasemina, 2019). On country level, countries have policies and Acts that are focusing on regulating ground water abstraction. For instance, in Uganda, the Water Act 1997 provides for the use, protection and management of water resources and supply; provides for the constitution of water and sewerage authorities and facilitates the devolution of water supply and sewerage undertakings (Laws of Uganda, 2019).

2.2.3 Hand pump water abstraction

According to Colchester et al. (2017), the most common groundwater abstraction method is use of hand pumps. In many environments, majority of the hand pumps are hand powered (Toure & Wenbiao, 2020) (See Figure 2.2). Hand powered water pump also referred to as a manual pump or human-powered pump, is a mechanical device that is powered with human force to pump water from one place to another (Toure & Wenbiao, 2020). There are several types of hand pumps. These are: Direct Pump, Diaphragm Pump, Suction and Lift Hand Pump, Force Pump, Chain Pump and Deep Well Pump (Khan, 2022). Hand pumps have revolutionized access to safe, reliable water supplies in low-income countries, particularly in rural areas (Danert, 2022). They provide a viable alternative to contaminated surface water, open wells and unprotected springs (Danert, 2022). It is estimated that there are about one million hand pumps that supply groundwater to people in rural Africa. Groundwater is used by around 200 million rural Africans on a daily basis because it is a widely available, reliable and safe source of drinking water (Colchester et al., 2017) (See Figure 2.3).



Figure 2. 2: Hand-powered pump

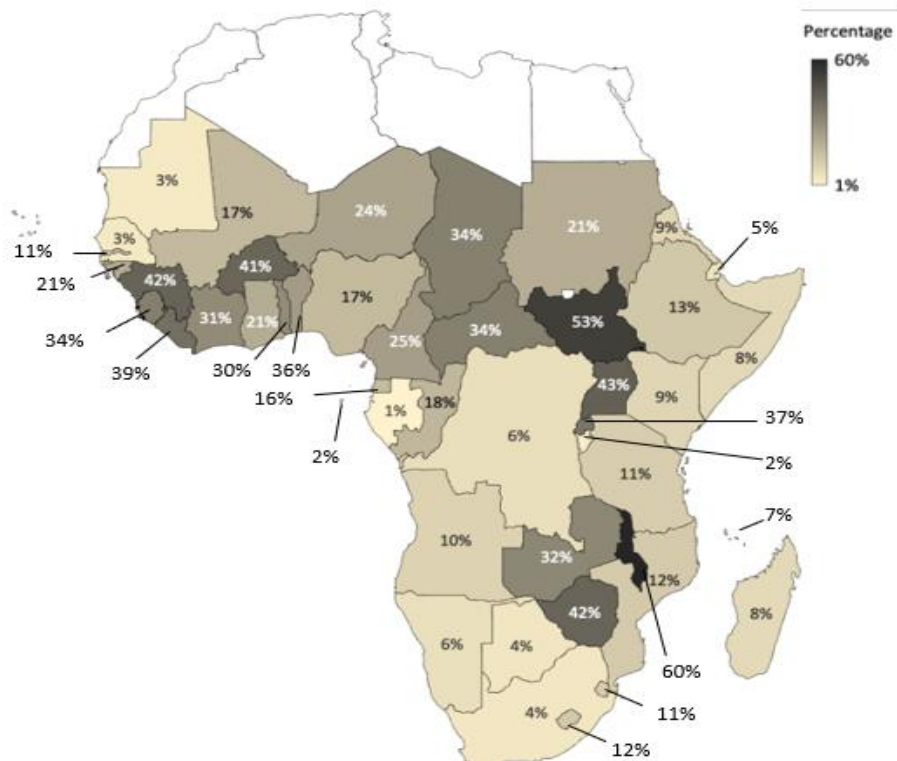


Figure 2. 3: Importance attached to hand pump water supply system in Africa

Much as hand pumps are the main water supply for rural communities across sub-Saharan Africa (Figure 2.3), studies have shown that >25 % of hand pumps become nonfunctional at any time (MacAllister et al., 2022).



Figure 2. 4: A deserted nonfunctional hand pump

2.3 Rural water point sources

Right from the onset of the SDGs in 2015, the concept of sustainability has become a common catch phrase. In the Water, Sanitation and Hygiene (WASH) sector, Goal 6 covers the strategies for realizing universal access to safe water by 2030. Granting water access therefore ranks high on the agenda of the SDGs especially due to its auxiliary contribution to other facets of socio-economic development that form part of the SDGs (Diaz-Alcaide et al., 2021). High on the agenda of meeting this goal is the implementation of integrated water resources management at all levels and capacity building for the local communities as focal strategies for enhancing the improved management of water resources (Mulei & Gachengo, 2021). In different environments, studies on the sustainability of water resources management via the prism of active community involvement has been recommended (Malima, 2021). Active involvement of the local communities is underlined by the assumption that by 2020, it was estimated that 57% of the global population would be reliant on communally managed water sources. Despite the anticipation that devolution

as a key attribute for integrated water resources management emphasizes the transfer of water management responsibilities to users (Naiga, 2021), the contribution of national governments and international donors must continue to provide the much-needed long term support of local water service delivery (Libey et al., 2020). Indeed, this intervention is necessary, appropriate, and likely more cost-effective (Libey et al., 2020) as equally professed by Adeenze-Kangah (2022) in Ghana. The funding among others is necessary for logistical support to the O&M teams (Adeenze-Kangah, 2022).

Rural water services in Sub-Saharan Africa have failures that threaten their sustainability (Jimenez et al., 2017; Mvongo et al., 2021). Sustainability of rural water projects continues to remain a challenge for both donors and the county governments with the value for investment involved being hard to realize (Muraya & Rambo, 2019) and is quite low in developing countries (Chukwuma Obeta, 2018; Dhoba, 2020; Kativhu et al., 2017; White et al., 2015). In sub-Saharan Africa the proportions of people with access to potable water supply and adequate sanitation is very low (Hassen & Omer, 2022). The infrastructure of rural water supply is often treated as a separate issue to socio-economic context (Ingram & Memon, 2020). Ensuring equitable and sustainable access to safe water continues to be one of the most pressing global challenges. Water crisis around the world has been attributed to cross-cutting governance problems such as the relationship between the state and other social actors, poor water management and coordination, inequalities between actors and value ascribed to water (Naiga, 2021).

2.4 Functionality of hand pumps

In this study, as earlier indicated, hand pumps and boreholes are used synonymously. A hand pump borehole can be defined as successful if it is able to supply water to a population of 250 people, requiring 25 litres per person per day, where pumping takes place over a 12-hour period (Barrie et al., 2012; Harvey, 2004; MacAllister et al., 2020). The term borehole failure as used here, refers to a situation in which a borehole deemed ‘successful’ at the time of drilling subsequently fails to deliver a sufficient yield of safe water throughout the year (Harvey, 2004; Kaoume et al., 2019). This does not necessarily refer to the structural failure of the borehole itself, but may occur due to a number of reasons, including depletion of groundwater levels in weathered aquifers and insufficient recharge of fractured aquifers resulting in dry boreholes. Failure may also occur as a result of: a reduction in yield; plugging of the formation around the well screen by fine particles; sand pumping due to siltation, incrustation or corrosion of casing and screens; and structural collapse of casing and screens, often as a result of corrosion due to low-pH (acidic) waters (Harvey, 2004). Over abstraction of water from the aquifer, and the ingress of pollutants may also result in borehole failure. Boreholes which are ephemeral in nature due to seasonal fluctuations in yield and water level, are also classified as failures, since although water was available directly following drilling, it is not available on a continuous basis (Harvey, 2004).

Despite the conceptualization above, the most commonly applied measures of functionality of a hand pump water system are presented in Table 2.1;

Table 2. 1: Measures of functionality of hand-pump water systems

Parameter	Description	Rating	Reference (s)
Number of strokes	5 or less	Hand pump is fully functional	Carter & Ross (2016), Truelove (2013), IRC Wash and Sanitation International (2013)
	> 5 strokes	Hand pump is partially functional	
	No flow	Hand pump is non-functional	
Status of operation	Working/Not working	A working handpump has running water when stroked. A not-working hand pump is the reverse	MWE (2010), UNICEF (2012)
	“Needs repairs,” “semi-functional,” “minimally functional,” “broken,” “missing parts,” and “seasonal,”	A hand pump that has any of these anomalies is considered to be non-functional	Truelove (2013)
Contamination	Corrosion leads to Water quality decline	Corrosion has an impact on taste, odor, and appearance of water. Corrosion can promote the growth of unpleasant iron metabolizing bacteria	Carter & Ross (2016), Casey et al. (2016)
	Pollution of ground water	This is common I urban and peri-urban areas caused by damaged septic tanks, leaks in industrial installations and fractured sewers	WHO (2013)

2.4.1 Global perspectives on nonfunctionality of hand pump rural water supply systems

In Asia, Latin America, South America and the Pacific Islands, boreholes are the main source of water for domestic use (Bundschuh et al., 2021; Martinez-Santos et al., 2020; Tran et al., 2022).

The Asia-Pacific regions are dotted with hundreds of thousands of hand pumps (Foster et al., 2020) (see Figure 2.5). Although several research studies have also been conducted to assess the functionality of the hand pumps in these countries, there is paucity of empirical evidence regarding the numbers of hand pumps that become inoperative in a year. Nonetheless, the available scanty and inconclusive findings point to the fact that there are rural water supply sustainability concerns (Foster et al., 2020). Unsafe water sources (hand pumps inclusive) have become a health hazard leading to deaths of huge numbers of people (see Figure 2.5).

Ritchie and Roser (2021) established that one-in-four people do not have access to safe drinking water with over 6 percent of the world population lacking access to an improved water source. Ritchie and Roser (2021) reported that the magnitude of the problem is greater in low-income countries where 6 percent of deaths the result of unsafe water sources. Overall, globally, unsafe water is responsible for 1.23 million deaths each year (See Figure 2.5).

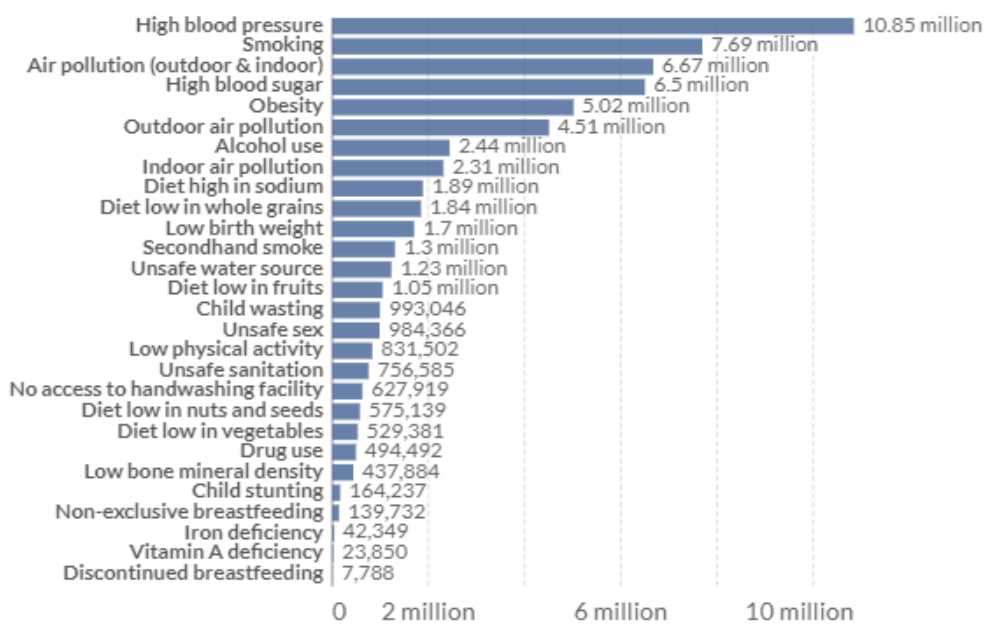


Figure 2. 5 : Number of deaths by risk factor globally in 2019

Source: Ritchie and Roser (2021)

A handful of studies have shown that hand pumps in these environments have become nonfunctional because of heavy metal contamination. For example, Bhatia et al. (2014), using the context of a marginalized village community of Khap Tola in the state of Bihar, a state in Northern India established that there were high levels of arsenic (maximum value being 397 ppb), in excess of the World Health Organization (WHO) limits of 10ppb. Analysis showed 57% of the samples from private hand pumps in the shallow aquifer zone of 15–35 m had arsenic greater than 200 ppb. Further using United States Environmental Protection Agency (USEPA) guidelines, it was calculated that children age group 5–10 years are under high risk of getting cancer. The Hazard Quotient calculated for 21 children taken for study, indicated that children may have adverse non-carcinogenic health impacts, in the future, with continued exposure (Bhatia et al., 2014). Once a community learns about the fate of consuming such water, it is plausible to infer that they will abandon it for other nearby water sources.



Figure 2.6: An Indian woman fetching water from a hand pump

2.4.2 Nonfunctionality of hand pump water sources in Africa

Fisher et al. (2015) noted that in many rural areas in Sub Saharan Africa (SSA), boreholes with hand pumps are the prominent improved water source used by over 80% of the households. Much as the total number of boreholes in Africa is unknown, rough estimates indicate that there are as many as 60,000 new hand pumps that are installed each year (Fisher et al., 2015; Schultes et al., 2022; Truslove et al., 2019). These are generally communal sources shared by multiple users within a community. Although new water source construction continues at a rapid pace, a substantial proportion of existing water sources remain nonfunctional. The challenge of ensuring that improved sources provide water of acceptable quality is also a critical one (Fisher et al., 2025; Mkandawire et al., 2020). The high rate of urbanization in Africa has increased the scarcity of water as users are outpacing the available sources (Areo et al., 2019). This has led to construction of water borehole facilities location in urban areas. At the same time, urban centres are epicenters of pollution especially from waste water, industrial effluents and municipal waste. This accounts for why Nwaiwu et al. (2020) recommended that boreholes should be sited where pollutants will not easily contaminate them.

As well, Nwaiwu and colleagues further recommended that regular water testing should be carried out to ensure the attainment of WHO guidelines always and where deviations are found, corrective actions should be undertaken. Approximately one in four hand pumps in Sub-Saharan Africa (SSA) are nonfunctional at any point in time, which in 2015 was roughly equivalent to 175,000 inoperative water points (Foster et al., 2020). This has forced most households to resort to unsafe sources leading to rapid water borne disease outbreaks and consequently, death (Foster et al., 2020). In Africa, shortage of potable water is an acute problem. Like the case globally, Ritchie and

Roser (2021) reported that deaths in Africa are also attributed to the consumption of unsafe water (Figure 2.7).

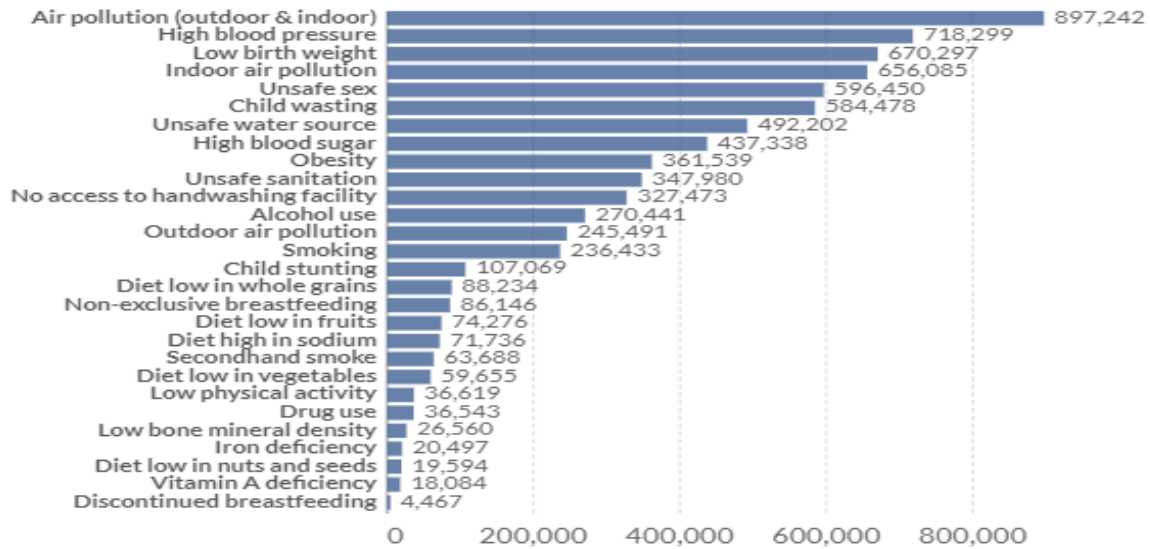


Figure 2. 7: Number of deaths by risk factor Africa (WHO Region) in 2019

Source: Ritchie and Roser (2021).

2.4.3 Non functionality of hand pumps in Uganda

Over 85% of Uganda’s 34 million people depend on rural water supply systems (Etongo et al., 2018). The current Water and Environment Sector Performance Report, 2020 reports an 84% functionality of rural water sources such as boreholes and shallow wells with a handpump (MWE, 2021). However, despite this high percentage of functionality, several households in different communities continue to be affected by shortage of safe and clean water given the high rate of breakdown of hand pumps (Etongo et al., 2018). Thus, like in other developing countries especially SSA, hand pump functionality is a big challenge in Uganda (Huston et al., 2021; Kanya et al., 2021). In agreement with these views, a study by Owor et al. (2019) noted that the main physical factors affecting functionality performance within Uganda are the poor conditions of hand pump components, and the complex aquifer resource. To note therefore, abandoned boreholes, lack of

rehabilitation activities, and loss of enthusiasm are all indicators of technical, financial, and institutional performance of community-managed water supply systems that need improvement (Etongo et al., 2018). The nonfunctionality of hand pumps strains the capacity of the existing functional hand pumps in the neighboring communities leading to long queues (see Figure 2.8) and the decision of some households to opt for other available but unsafe sources of water (See Figures 2.9 and 2.10)



Figure 2. 8: Long queue on a borehole in Uganda



Figure 2. 9: A child drawing water from a rock fountain



Figure 2. 10: Fetching water from an open stream.

Lack of access to clean water is also ranked as one of the key causes of mortality among the population in Uganda (Figure 2.11).

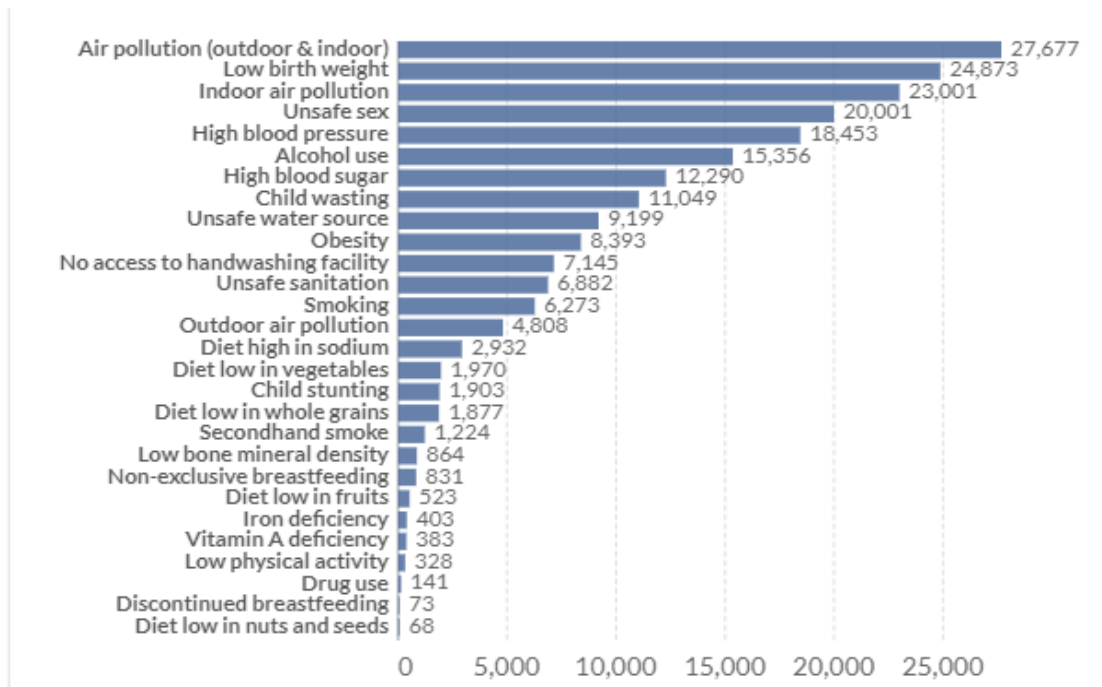


Figure 2. 11: Number of deaths by risk factor, Uganda in 2019

Source: Ritchie and Roser (2021).

2.5 Causes of Nonfunctionality of point water sources in rural areas

More supportive evidence is provided by Valcourt et al. (2020) that worldwide, most rural water supply services have consistently failed to deliver full public health impacts as intended due to a low service sustainability. The adducing evidence provided by Valcourt et al. (2020) is that the local systems composed of social, financial and environmental factors are very weak. Much as efforts have been evolved to minimise the said weaknesses, the efforts made have been myopic in a way that they are most focused on the strength and capacity of the weak factors while negating the interactions between them. This accounts for why there is continued nonfunctionality of most rural water sources despite the several interventions undertaken to achieve sustainability because the endeavors made have overlooked the inherent complexity and context-specific nature of each local system (Valcourt et al., 2020).

Much as there have been huge investments towards ensuring sustainability of water schemes in rural Africa, most schemes continue to fail (Shongwe & Dlamini, 2021). Nonfunctionality is the salient feature of the failing schemes (Shongwe & Dlamini, 2021). Hand pumps are heavily relied upon for drinking water in rural areas of low- and middle-income countries, but their operation and maintenance remain problematic (Foster et al., 2020). Approximately one in four hand pumps in sub-Saharan Africa are nonfunctional at any point in time (Foster et al., 2020). In rural sub-Saharan Africa, one in three hand pumps are nonfunctional at any time (Klug et al., 2018; Nganyanyuka et al., 2017). While there is some evidence describing factors associated with nonfunctional water systems, there is little evidence describing the categories of water system breakdowns that commonly occur. Insufficient water availability from broken down systems can force people to use unimproved water sources, which undermines the health benefits of an improved water source (Klug et al., 2018). Categorization can help to identify common reasons for water system breakdown (Klug et al., 2018). Improved monitoring instruments would enable actors to target appropriate resources to address specific breakdowns likely to rise based on system type and management characteristics in order to inform improved implementation of post-construction support for water systems in sub-Saharan Africa (Klug et al., 2018).

Several factors account for the increasing cases of nonfunctionality of water sources in SSA (Gemedda et al., 2021). These include: failure of the users to pay water service fees consequently leading to the failure to carry out the much-needed consistent operation and minor maintenance (Gemedda et al., 2021). Different from the foregoing views, several other studies have reported the causes of nonfunctionality as lack a budget source, no trained caretakers and limited access to spare parts. As well, much as the traditional top-down approach of managing water sources has

paved way for bottom-up approaches leading to the creation of user water committees, these committees are supposed to be rigorously trained so that their capacity aligns with international standards. Five dimensions that contribute to strong water service management by local citizens include technical (e.g., water technicians, spare parts), institutional (e.g., meeting frequencies, capacities of members, promotion to potential service users), social (e.g., gender composition, working relationships), environmental (e.g., drought, flooding) and financial (e.g., ability to collect water fees, cost of operation and maintenance). Gemedda et al. (2021) argued that whenever there is poor performance across these 5 dimensions, there is a high possibility that water service functionality is compromised.

Otieno (2019) established that the time taken to repair broken down water facilities is a key determinant of the functionality of water supply sources. Thus, a system is likely to be functional if it takes less time to repair compared to the base category of less than 24 hours. Besides time, Otieno (2019) also observed that affordability of water by the households equally determines the functionality since it influences sufficiency of revenues needed to respond to a break-down. These results demonstrate a cyclic relationship in which affordability increases with functionality as many more households are able to and willing to contribute towards repair costs, hence making funds available for repairs and prompt response to break-downs. In turn, functionality increases a household's willingness to pay because when the system is well maintained, it is available for use whenever need be (Otieno, 2019).

Communities use rural water systems to meet multiple water needs, regardless of system design (GC et al., 2021). Different sources of water are always available wherever people live. This is so

because, people cannot live without water, and since it does not have a substitute. Therefore, practically, people will not reside or even decide to open up homes in places where there is none (Abdullahi & Sa'idu, 2020). The foregoing presupposes that competition of water services is a challenge for now and in the near future especially in the wake of increasing population and decimation of water sources by climate change (Abdullahi & Sa'idu, 2020). Basing on this stance, there is now a growing need to ensure that sufficient quantities of good quality water are available for domestic and other uses (Abdullahi & Sa'idu, 2020).

A study by Casey et al. (2016) established that high iron concentrations is a common problem in rural water supplies across many countries in Africa and elsewhere. Although elevated concentrations of iron are not considered a particular health risk, aesthetic issues may result in a reluctance to use a water point and in severe cases, abandonment of the water point for an alternative, and oftentimes, a potentially unsafe one. Typical problems include metallic taste, discolored and turbid water following pumping, and discoloration of food and clothing (Casey et al., 2016). The World Health Organization (WHO) does not set a health-based limit for iron but states that concentrations above 0.3 mg/l impact taste and cause staining of laundry. Some national governments set limits slightly above this value for untreated rural water supplies, for example, in Uganda, a value of 1 mg/l is specified (Uganda National Bureau of Standards [UNBS], 2008). Iron is present in soil and rock formations in two forms: reduced soluble ferrous iron (Fe^{+2}) or oxidized insoluble ferric ion (Fe^{+3}). The highly soluble and colorless nature of ferrous iron can mean that, if conditions are right, groundwater can hold significant concentrations yet it appears clear and colorless. When such groundwater is pumped out and exposed to the atmosphere, oxygen will convert the ferrous iron to ferric iron, which reacts with other components in the water to form

insoluble iron hydroxides. These cause red/brown cloudiness in the water and eventually, the staining of laundry. This oxidation process can take some time, so apparently clear water can be produced at the pump, but then discolors later. A synthesis by Furey (2014) of online discussions on hand pump technology among rural water supply specialists and practitioners between 2012 and 2014 concluded that water quality, particularly related to high iron corrosion was a major issue.

Toure and Wenbiao (2020), evaluated the physicochemical and microbial qualities of hand-pump water in the rural commune of Pelengana, Mali. The parameters analyzed included: physical (temperature, pH, and turbidity), chemical (nitrate, and phosphate) and microbiological (both fecal and total coliform bacteria), using standard procedures of analysis. API 20E test was used to determine the identities of isolates. Findings were compared with the WHO permissible drinking water guidelines (or other) values. All physicochemical parameters in hand pump water samples were within the limit recommended by the WHO guideline (or other) values except for turbidity, and nitrate, whereas microbial concentrations during the rainy season were above the WHO acceptable limits. The presence of species such as *Escherichia coli*, *Salmonella* and *Klebsiella* in hand pump waters suggests that water from these sources constituted a threat to public health and was inappropriate for drinking without treatment. This results in desertion of the hitherto used hand pumps resulting in nonfunctionality. This accounts for why periodic assessment of the physicochemical and biological properties of nonfunctional hand pumps is very important. This finding therefore implies that sudden outbreak of diseases in a community that relies on hand pumped water is likely to induce them to consider using other available sources of water notwithstanding the fact that such sources might be contaminated.

Further evidence of the need for assessing the quality of water in the nonfunctional hand pumps is provided by Bekuretsion et al. (2018). Findings of their study noted that much as drinking water from hand pump-fitted borehole sources is considered as safe and suitable for human use due to a purification property of the soil, in some cases, the water from these sources can be contaminated as a result of inadequate treatment and waste disposal from humans and livestock. Their study aimed at establishing the total coliforms and *Escherichia coli* count from water samples. This was performed using membrane filtration technique. MacConkey agar media was used for both samples and isolates following standard microbiological methods. Antimicrobial susceptibility testing was carried out against seven antibiotics. Findings revealed that about 11 (15%) hand pump-fitted boreholes drinking water and 32 (42.6%) of swab samples were culture positive. The colony counts for total coliforms and *E. coli* from water samples were high. Furthermore, findings revealed that *E. coli*, *Enterobacter*, *Klebsiella*, *Citrobacter*, *Salmonella*, and *Pseudomonas* sp. were predominant isolated bacteria. *E. coli* and *Salmonella* sp. were found to be sensitive to all antibiotics and high-level resistance was revealed by *Klebsiella* sp. From this finding therefore, it is also possible to conclude that incidences of disease outbreaks in such environments where households are using water from hand pumps is likely to result in abandonment, making the pumps nonfunctional.

In West Africa, Circle of Blue (2022) reported that researchers at the University of North Carolina (UNC) while studying the physicochemical and biological properties of water drawn from hand pumps across rural regions of three West African countries of Ghana, Mali, and Niger, established that the water contained trace levels of lead. This was confirmed in 82% of the sampled hand pumps while in 9 percent of the samples, they found lead levels above World Health Organization

drinking water standards. The presence of lead in drinking water is a health hazard especially for children as it affects their neuro development (Circle of Blue, 2022).

Most hand pump water supply systems in rural Africa are drilled by private contractors or Non-Governmental Organisations (NGOs) (Alexander et al., 2015; Harvey, 2004; Odjegba et al., 2020; Sloots, 2010). In general, the operating staff from either category (private contractors and NGOs) have limited technical knowledge and equipment, and often lack basic knowledge regarding the hydrogeological conditions within which they are working. There is also often a lack of effective Government regulation or supervision (Odjegba et al., 2020). Consequently, the quality of workmanship varies considerably, as does the ability to identify, predict and mitigate possible borehole failure. The lack of technical knowhow leads to shoddy works and therefore, the deliverables do not last for long (See Figure 2.12)



Figure 2. 12 : Borehole prone to breakdown because of rigidity of the pumping system

Tapping groundwater from shallow aquifers comes with quality challenges, especially when these wells are constructed near beneficiary communities and within homes (Lutterodt et al., 2018). Hand pump water may be contaminated with microbial pathogens originating from intestinal tract

of humans and animals. In most cases, pathogens from human excreta (from pit latrines) and effluents (from on-site sanitation facilities) may therefore lead to disease outbreaks (Lutterodt et al., 2018). Therefore, monitoring and assessment of microbial quality of water from hand pumps is important since the findings can help to inform the stakeholders to devise the most plausible ways of through which they can improve the quality of water. Figure 2.13 provides an illustrative summary;

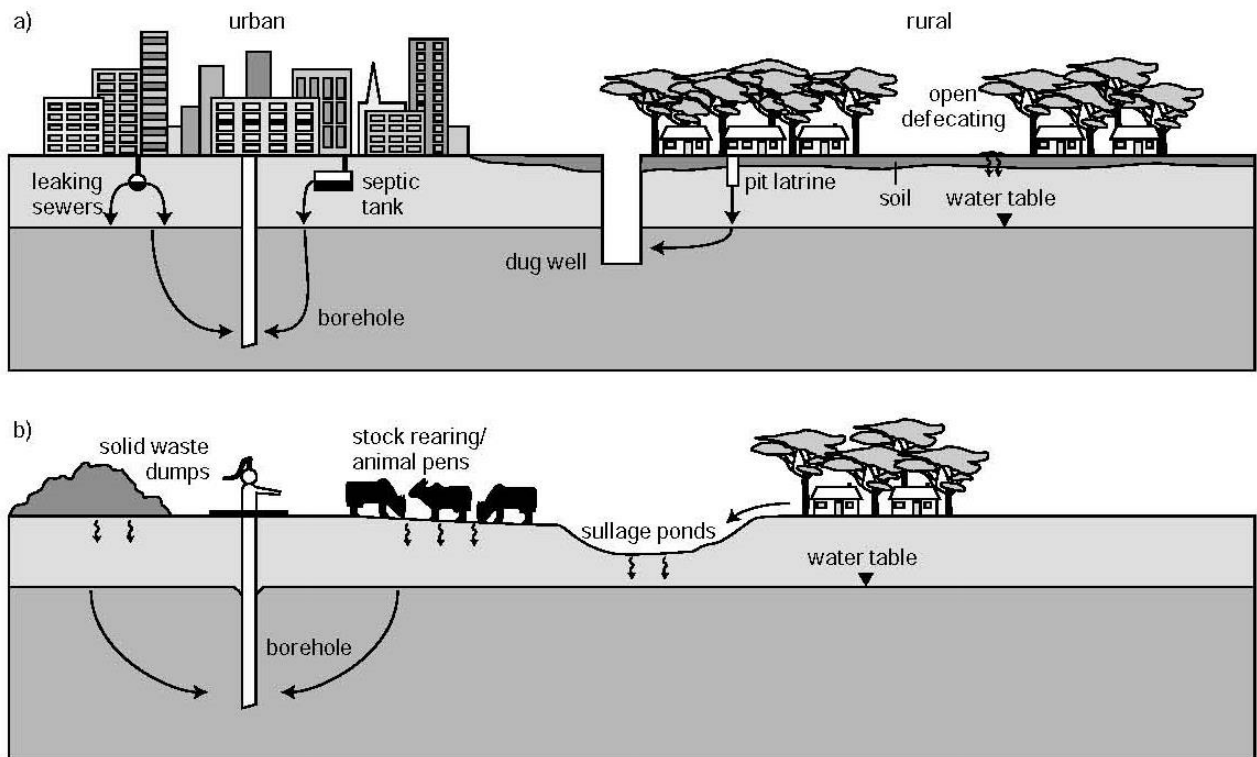


Figure 2. 13: Sources of faecal pollution within urban a) and rural b) settings (Lawrence et al., 2001)

Lawrence et al. (2001) describes the various sources of faecal pollution in different settings and the pathways of these pollutants into groundwater (Figure 2.13). This simplified representation represents a typical scenario in peri-urban areas where all of the sources of contamination coexist. However, Figure 2.13 does not show the processes of attenuation in the system that could reduce the possibility of contaminants from reaching the water table. For microorganisms in faecal and other waste materials, the main barrier to their movement into groundwater is the unsaturated zone.

Once faecal contaminants get into groundwater, there is a complex interaction with other physical, chemical and biological factors which increases on their mobility and therefore, the distance that they can possibly circulate from the source (Mesquita et al., 2013).

Islam et al. (2016) carried out a study to determine the minimum safe distance of a tube well from a pit latrine in different hydro geological conditions of Bangladesh. The study involved monitoring of 20 wells installed at three study sites (Manda, Mohanpur and Bagmara) with vertical and horizontal distances ranging from 18–47 to 2–15 m, respectively. Water samples were collected three times in three seasons and tested for faecal coliforms (FC) especially faecal streptococci (FS) as indicators of contamination. Soil samples were also collected and analysed for texture, bulk density and hydraulic conductivity following standard procedures while sediment samples were also collected to prepare lithological logs. Results revealed that when shallow aquifers at one of the three sites (Mohanpur) were overlain by 18–23-metre-thick aquitards, the groundwater in the wells was found to be contaminated with a lateral and vertical distances of 2 and 31 m, respectively. However, where the aquitard was only 9 m thick, contamination was found up to lateral and vertical distances of 4.5 and 40.5 m, respectively. The soil textures of all sites were mainly composed of loam and sandy loam. The hydraulic conductivities in the first aquifer at Manda, Mohanpur and Bagmara were 5.2–7.3, 8.2 and 1.4–15.7 m/h, respectively. Basing on these findings, Islam et al. (2016) concluded that safe distance from the tube well to the pit latrine varied from site to site depending on the horizontal and vertical distances of the tube well as well as the hydro-geological conditions of a particular area.

2.6 Strategies for effective management of functionality of point water sources in rural areas

The sustainability of rural water sources is achievable through regular maintenance. According to Lockwood (2019), maintenance of any water supply scheme prevents individual component failure, extends the useful life of such components, limits deterioration of service levels, minimizes disruptions in services, lowers the costs of sustaining access levels to water in rural areas, and ultimately ensures continued operation of the scheme over time. Different forms of maintenance are an essential part of asset management (Boulenouar & Schweitzer, 2015). These are: preventive and corrective maintenance (Akale & Kabede, 2019; Lockwood, 2019). Preventive maintenance entails regular inspection and servicing, including replacement of consumable spare parts, to preserve assets and minimize breakdowns carried out on a regular schedule according to the requirements of components of the scheme while corrective maintenance deals with repair and replacement of broken and worn-out parts to sustain reliable facilities; this category can also include what is sometimes referred to as “crisis maintenance,” which implies a catastrophic failure that requires an unplanned or emergency response to breakdowns and user complaints (Kumasi et al., 2019; Lockwood, 2019). Regular preventive and corrective maintenance cost money, and an approach based on crisis maintenance alone may appear cheaper in the short term. However, continuing crisis maintenance also called “fix on failure” (Kumasi et al., 2019) leads to frequent breakdowns, an unreliable supply, poor service levels, and a lack of user confidence, which is hard to rebuild. Therefore, it is plausible to surmise that long-term reliance on crisis maintenance may ultimately lead to complete failure of the infrastructure (Lockwood, 2019).

To circumvent the problem of nonfunctionality, Shongwe and Dlamini (2021) recommended the need for systems thinking, a practice that has the potential of enabling the policy-makers and

opinion leaders to have an inside-out analysis of the problems at hand and hence, to realise the opportunity of locating the most important interventions with potential of leveraging the desirable sustainable solutions. Shongwe and Dlamini (2021) argued a case for increased and improved performance of water schemes by emphasizing higher user satisfaction levels. Shongwe and Dlamini (2021) established that the attainment of higher levels of user satisfaction is pegged to the commitment of management of the concerned water schemes to working out modalities and mechanisms through which the water supply can be made more reliable while also creating an enabling environment that engenders active user involvement in the management and administration of the affairs connected to the management of the water resources. By doing so, the degree of ownership of the water facilities will grow manifold among the users. Much of the drinking water around the world, especially in rural SSA, is drawn from communal collection points (MacManus, 2021). However, these water points are frequently out of operation (MacManus, 2021). The functionality of rural water points is dependent on an interplay of factors including, the involvement of a paid, trained caretaker in the management of a rural water point. Other significant factors include continuous service provision, regular fee collection by a committee, and technical capacity consisting of external support response, and an operations and maintenance plan. Therefore, water point managers and water committees should seek to incorporate these factors in their short and long term plans if the sustainability of rural water points such as hand pumps is to be realized (MacManus, 2021).

In several countries, Uganda inclusive, the top-down approach in which the responsibility of water resources management rested in the hands of the state (government) has since become history (Naiga, 2021; Marije, 2017). Local management of the water systems is trending and has shown

signs of engendering sustainability (Naiga, 2021). The decision to entrust the management of the water schemes to local people is premised on the belief that when water system maintenance is locally financed, it is maintained in a condition that ensures reliable and adequate water supply, and benefits of the supply continue to be realized by all users (Kativhu et al., 2022). Consequently, it becomes sustainable (Kativhu et al., 2022). This has given rise to bottom-up approaches in which the communities are supposed to be empowered to control the management of rural water systems (Marije, 2017). David et al. (2020) noted that community management is a very insignificant in contributing to sustainability of gravity flow schemes. Among others, the communities are able to mobilize funds for repair and maintenance of water facilities much as their potentials for attracting external funding is quite low. David et al. (2020) recommended that government, through its water and sanitation departments at the district level should consider employing technical staff in water management to provide standby services to rural water communities. Equally, the study recommended the need for leadership of water resources to consider involvement of women in water management, as they are the most important users of the water facilities while to the government, NGOs and private sector, David et al. (2020) recommended the need for training the communities in fundraising, proposal writing so as to attract external funding. The funds that are obtained from this source would support the plans for achieving the sustainability of water facilities.

Ducrot (2017) observed that coordinated leadership by key committee members, and the level of village governance is very important for hand pump sustainability. Using the context of Mozambique, Ducrot (2017) established that coordinated leadership was far superior to reliance on the normative functioning of the committees. Coordinated leadership according to Ducrot

engenders collective action whose benefits *inter alia*, include the easy mobilisation of the stakeholders, mainly water users to the tune of pooling resources (such as money) for supplementary funding of the water management programmes. Ducrot (2017) conceded that leadership of the water resources ought to ensure that their coordination efforts are transparent and work towards achieving equity lest the interventions would cause community conflicts. Opacity of the operations of water resources management would become a dividing factor.

Communities where hand pumps or boreholes are the only source of water should delve into ensuring hand pump sustainability (Harvey, 2004). Hand pump sustainability, or lack of it, is rarely given significant attention in rural water supply programmes in Africa. In order to obtain detailed information as to why hand pumps are failing, thorough assessments of construction and installation are required using borehole cameras (see Figure 2.14). This is an expensive option and without strong institutional will, it is not likely to happen in most rural African contexts. Routine field data cannot provide all the answers, but they can provide indicators to the aspects of field practice which can be improved to increase sustainability.



Figure 2. 14 : Water level measurement gear

2.7 Frameworks for maintaining the functionality of point water sources in rural areas

A wide range of frameworks have been developed to measure the individual and collective capacity of factors to sustain services. According to Valcourt et al. (2020) the most important shortcoming of the developed frameworks is their assumption that when a majority of the factors have a high individual capacity, there is a correspondingly high likelihood of services being more sustainable. Conversely, if most factors had a low capacity, this would indicate a lower likelihood of service sustainability. However, this approach overlooks a fundamental concept of systems thinking; the outcome of the system (i.e., service sustainability) is not simply an aggregation of the strength of its individual factors, but the collective effect of the interactions between those factors. An enhanced understanding of how these interactions affect service sustainability is arguably as important, if not more so, than an assessment of the factors themselves (Valcourt et al., 2020). Basing on this analogy, the most viable framework should take up the views of various stakeholders. To do so, the framework should be developed and tested in a real-life situation involving the real users of the system in question (Venable, 2006).

2.8 Chapter Summary and emerging research gaps

While the studies reviewed in the above sub sections have highlighted the criticality of management of hand pumps in rural settings, the findings are mainly based on other contexts other than Uganda, hence leaving contextual gaps. Equally, most of the studies have aimed at highlighting the causes of nonfunctionality of hand pumps without providing actionable or workable solutions. This study adopted Design Science Research to fill these voids by designing a hand pump water system maintenance framework. The methodology to achieving this goal is discussed in the next chapter.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

The chapter presents the materials and methods that were used in the study to come up with a designed and evaluated framework for maintenance of the functionality of hand pumps in the study area in particular and other areas relying on hand pumps as the only or main source of water for domestic use. Generally, the chapter provides a discussion of the materials to be used in designing the framework and the methods that were adopted to select the respondents, collect data, determination of the quality of the data to be collected, procedures to be followed in analysing and reporting the findings and the steps and procedures that were followed in designing and validating the proposed framework. All these aspects were scientifically applied to enable the researcher to achieve the three objectives that informed the study. For objective (1) about the existing gaps in the management of hand pumps, both primary and secondary data were collected using questionnaires, interview guides, focus group discussions (FGDs), sanitary inspection tool and document review. The data were both qualitative and quantitative and were analyzed using descriptive means. Primary data were collected through a socio-economic survey, sanitary inspection tool and laboratory experiments. For objectives 2 and 3 which aimed at designing a framework and evaluating for deployment respectively, Design Science Research (DSR) methodology was adopted. These processes are described in details in the sections that follow. The entire methodology followed is charted in Figure 3.1. Encircled in a green ring, is the actual methodology that was followed by this study. Both primary and secondary data sources were used. The emerging data were analysed and interpreted as shall be explained later in the next sections.



Figure 3. 1: Methodology Flow Diagram

3.2 Research Approach

The study adopted DSR approach. DSR is an engineering and scientific approach from which artefacts are developed for solving problems through creative innovations that involves definition of ideas, practices, technical capabilities and products (Busse *et al.*, 2021; Puroo, 2021). In DSR, academic research objectives are more pragmatic (Dresch *et al.*, 2015) hence obliging the researcher to come up with practical solutions to address recurrent problems in a real-life situation. The adoption of DSR in this study based on the submission by Romme and Meijer (2020) that for a long time, studies based on public institutions have focused mainly on describing and explaining

how the management systems operate and yet management of these institutions is not focused at authenticity of these systems either because they are not motivated to do so or they lack experiential and expert knowledge for transforming these systems into better and efficient ones. Based on this insight, Romme and Meijer (2020) recommended the need for researchers to rethink this ‘bystander’ approach and devise interventions that are capable of changing and improving these systems. For this reason, Romme and Meijer (2020) underscored the need for adopting design science approach since it integrates retrospective research (scientific validation) and prospective research (creative design) as shown in Figure 3.2 below;

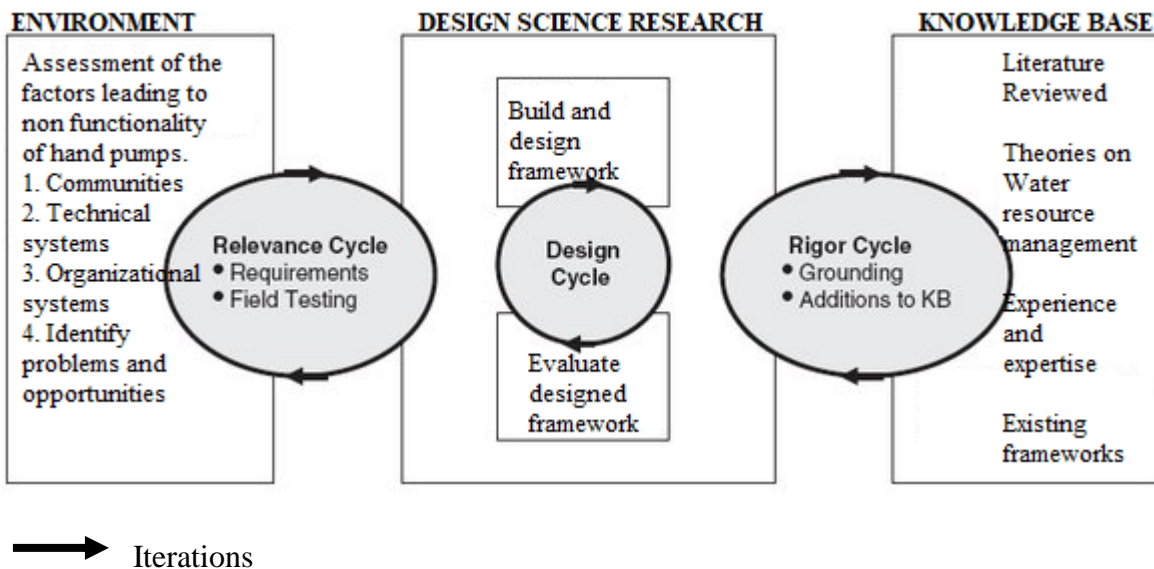


Figure 3. 2: Design Science Research Flow Diagram for producing artefacts.

3.2.1 The Relevance cycle

The relevance cycle triggers the research process within an environment that not only identifies the requirements for the research, but also defines the acceptance criteria for evaluating the results of the research process. The outputs of the research process are then returned to the environment from which it originated to be studied and evaluated (Hevner, 2007). The domain itself initiates

design research with the requirements (such as problems, opportunities) and the criteria for the evaluation of the artefact. This is followed by testing which should answer questions like what is the impact of the design artifact on the environment. Since the artefacts are not always perfect (might have some deficiencies in terms of quality), iteration is necessary (Arnold & Wade, 2017).

In this study, the relevance cycle was applied in quest for understanding the acceptance level and views of the water resource managers in Bumbaire Sub County regarding the user-friendliness and how relevant the designed framework would be. In the relevance cycle, the researcher aimed at establishing the satisfaction levels of practitioners and stakeholders regarding the applicability and usability of the designed framework. Without following this cycle, the designed framework for maintenance of the functionality of hand pumps would most likely be questioned and therefore lack impact beyond Bumbaire Sub County.

3.2.2 The Design Cycle

The design cycle is central to the design science research project. Within this cycle, the research activity iterates between the design and realization of an artefact, its evaluation, and the resulting feedback to refine the design (Hevner, 2007). Building and evaluating the artefact designed is both a product and a process. The cycle continues till the artefact is ready for field testing or till new knowledge is available for inclusion in knowledge base (Wieringa, 2014). The design cycle in this study was useful to maintain a balance between the efforts spent in designing and evaluating the designed framework. Having a strong grounded argument for the construction of the artefact without corresponding efforts to evaluate the outcome would imply that the artefact is likely to be error prone or even fail to address the purpose for which it was designed to serve. Thus, the

accomplishment of the design stage was accompanied by the last phase of evaluating the framework among the hand pump water users and leadership of Bumbaire Sub County.

3.2.3 The Rigor Cycle

The purpose of the rigor cycle is to identify prior knowledge that is relevant to the research project to ensure its innovation. It is the researcher's responsibility to ensure that the design produced is a research contribution and not conventional design based on application of established processes (Hevner *et al.*, 2004). The research rigor is dependent on the skill of the researcher in selecting and applying the appropriate theories and methods to constructing and evaluating the artefact (Hevner, 2007). In design science research, the knowledge base (KB) could be theories, methods, experiences and experts, and also existing design artefacts and processes. The rigor depends on the appropriate selection, application and evaluation of KB to build and evaluate the artifacts. The likely addition to KB could be extensions to theories and methods, new experiences and expertise, and new artifacts and processes (Arnold & Wade, 2017). In this study, existing literature about the functionality of hand pumps were identified and critically evaluated in order to establish and identify the existing gaps. This also entailed synthesis of the reports about the maintenance of hand pumps in the sub county. These reports were accessed from the District Water Office. The knowledge gaps identified formed the basis for developing a robust framework for enhancing the maintenance and the corresponding functionality of hand pump water. The outcome of the study therefore provides a solution to Uganda's challenge of maintenance of hand pumps.

3.3 Research Design

The study used a multi-method research design which involves both quantitative and qualitative methods (see Figure 3.3). This approach involves the collection and analysis of quantitative data

followed by collection and analysis of qualitative data (Schoonenboom & Johnson, 2017). This study therefore involved both quantitative and qualitative data collection and analyses.

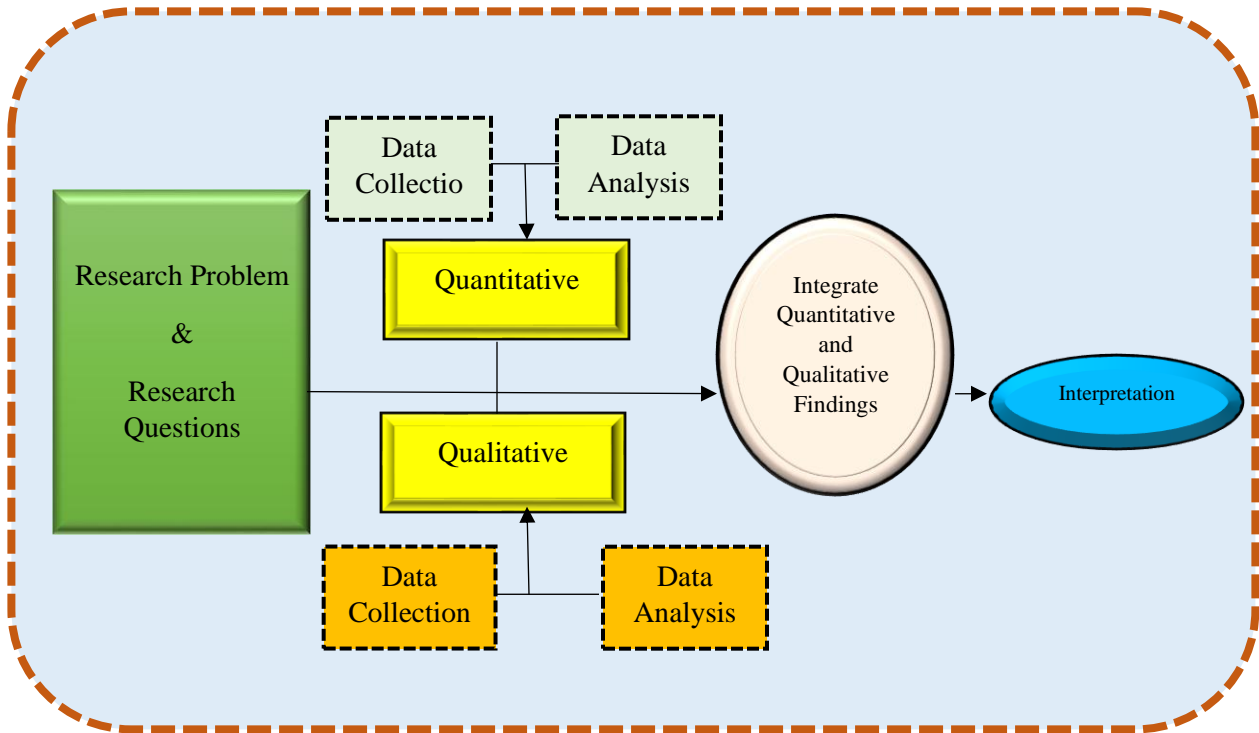


Figure 3. 3: Schematic presentation of the Research Design adopted

3.3.1 Quantitative Methods

Quantitative research is the process of collecting and analyzing numerical data (Kumar, 2019). It can be used to find patterns and averages, make predictions, test causal relationships, and generalize results to wider populations (Zikmund et al., 2012). Quantitative research is widely used in natural and social sciences: biology, chemistry, psychology, economics, sociology, marketing, etc. Quantitative research can be descriptive, experimental or causal (Guetterman, 2015). In this study, the quantitative research design adopted both descriptive and experimental methods. Descriptive data were obtained from a socio-economic survey while the experimental data were obtained through both field-based and laboratory tests and analyses.

3.3.2 Qualitative Methods

Qualitative research involves collecting and analyzing non-numerical data (e.g., text, video, or audio) to understand concepts, opinions, or experiences. It can be used to gather in-depth insights into a problem or to generate new ideas for research (Chivanga & Monyai, 2021; Gioia, 2021; Kumar, 2018; Thompson Burdine et al., 2021). Qualitative research is commonly used in humanities and social sciences, in subjects such as anthropology, sociology, education, health sciences, history, etc. (Percy, Kostere & Kostere, 2015). Unlike quantitative research in which researchers state specific hypotheses and then collect data to empirically test them, most qualitative researches employ an inductive approach in which the researcher first collects data and then derives explanations from those data. Qualitative research approach seeks to tell the story of a particular group's experiences in their own words, and is therefore focused on narratives. As such, qualitative research tends to be more exploratory in nature, seeking to provide insights into how individuals (or organizations, groups, etc.) understand aspects of their worlds (Thompson Burdine et al., 2021). Observation, FGD and interviews are the most common data collection techniques commonly used in qualitative research (Kumar, 2018). In this study, in-depth interviews and FGD were administered to collect data on lived experiences of hand pump water users in Bumbaire Sub County.

3.3.3 Laboratory Tests

International and local guidelines for quality of water were applied in the study. Only one water sample was collected from a nonfunctional hand pump that was abandoned by the community. The water sample was collected in 1.5 litre water bottles. The filled water bottle with a seal was bought from a supermarket in Bushenyi Town. It was later emptied and washed with the borehole sample water five times. This aimed at ensuring purity of the samples. The water sample was transported

in a sealed cool box to National Water and Sewerage Corporation (NW&SC) in Bushenyi Town for chemical analysis. Some of the physicochemical parameters such as temperature, pH, turbidity, hardness and alkalinity were tested on site (See Figure 3.4). The quality of water parameters were tested because they are emphasized by the Indian Council of Medical Research (ICMR), United States Public Health Services (USPHS), World Health Organization (WHO), and European Union (EU) on the international level and UNBS/NW&SC on the local scene. Thus, these helped in the determination of quality of water from one of the nonfunctional hand pumps. The field and laboratory test results helped in ascertaining whether variations in the physicochemical properties of the tested water could have been part and parcel of the reasons for abandonment of the said hand pump.



(a)



(b)

Figure 3. 4: Panels (a) and (b) show the field experimental testing in Bumbaire Sub County, Bushenyi District

3.4 Population

The study involved water users (households), District Water Engineer and Sub County Community Development Officer (SCCDO). These respondents were included in the study because they are directly involved in water use and management respectively.

3.5 Sampling techniques and Sample size

Both random and non-random sampling techniques were used in the study. The random sampling techniques employed were stratified random sampling and simple random sampling while for non-random, purposive sampling was adopted. Stratified random sampling is the type in which a researcher subdivides the entire population into parts (called stratum) in order to ensure that data on all areas of interest in a study setting are fully represented (Banning, 2021; Kumar, 2018; Nguyen et al., 2021). In this study, parishes formed strata. Within each parish, still, to accord all the subjects equal chances of participating in this study, simple random sampling was applied. Simple random sampling entails choosing a subset of individuals from a larger set with each

individual chosen randomly and entirely giving each individual, an equal chance of being selected (Illiya & Etikan, 2021). This method gives way to the sample being drawn without bias and unit by unit (Acharya et al., 2013). Lottery method involving paper tags, was used to come up with the required samples.

For non-probability sampling, the study used purposive sampling to select the District Water Engineer and the SCCDO. Alternatively known as judgmental sampling (Kumar, 2018; Staller, 2021), this technique is based on the rejection of rules of chances and enables the researcher to decide on who should participate in the study basing on the researcher’s assumption that the selected participants are knowledgeable and capable of providing informative views related to the study in question. The distribution of the sample size among respondents was made and is elaborated in Table 3.1 below.

Table 3. 1: Population, Sample and Sampling Techniques

Category	Population	Sample	Sampling Technique
Households	369	186*	Stratified, Simple random
District Water Officer	1	1	Purposive
Sub County CDO	1	1	Purposive
Total	371	188	

Source: District Water Office Strategic Plan, 2022-2025.

** Sample size determined using Krejcie and Morgan (1970)*

3.6 Data collection methods and instruments

3.6.1 Data types

Both primary and secondary data were collected. Primary data were obtained from the field through a socio-economic survey, sanitary inspection tool and laboratory experiment while secondary data were mined from existing documents and archived reports about maintenance of hand pump water sources.

3.6.2. Primary data collection methods and instruments

3.6.2.1 Questionnaire survey

Questionnaire survey method were used in this study. The selection of the questionnaire survey as a data collection method is built on the argument by Story and Tait (2019) that survey questionnaires enable collection of primary data from a big number of respondents at a very cheap cost. The questionnaire was structured. Therefore, it contained close-ended questions. The close ended questions were included to increase on response rate. The close-ended questions also enable spontaneous provision of the opinion by the respondents to the statements. As such, speedy response time per question enabled the researcher to obtain data on a broad range of issues tested by the questionnaire (Hyman & Seirra, 2016).

The questionnaire method was used to collect data from water users. The questionnaire began with a preamble that detailed the purpose of the study. The questionnaire was administered by the researcher and his research assistants. The research assistants were trained for 5 days. Their selection was also based on their ability to easily translate the questions and statements in Runyankore to the respondents. Therefore, the questionnaire was solely formatted in English and so, there was no need of any translations. Before administering the questionnaire to water users in Bumbaire Sub County, a pilot study was carried out in Kibaare Parish, still in Bumbaire Sub County. However, the communities in the parish were not involved in the actual data collection. The Sub County also faced challenges of nonfunctionality of hand pumps leading to acute scarcity of water. The pretest enhanced the face validity of the questionnaire leading to a questionnaire turnaround of 20 minutes per respondent on average. The choice of this method is informed by Tymms (2021) that the method facilitates collection of relevant data cheaply. In addition, it

enhances the collection of data that is based on the informed opinion of the respondents as they are given time to think before selecting the options measuring the statements used.

3.6.2.2 In-depth interviews

The study used in-depth face-to-face interviews to obtain data from the key informants (District Water Engineer and SCCDO). Studies (such as Deterding & Waters, 2021; Kumar, 2018; Rutakumwa et al., 2021) have argued that when using interview method, a researcher gathers data by asking questions to an individual respondent or a group in order to acquire the desired information. The key informant interviews were structured and were administered by the researcher himself. Before booking the day and time for the interviews, the researcher first made phone call appointments. On meeting the targets, a formal letter of assent from the Research Ethics Committee UCU Mukono for confidence building and assurance that they were not interviewed by a stranger or masquerader. Given the busy schedules of the key informants, preference was given for afternoon hours starting from 3:00pm. For this reason (busy schedules), the interviews lasted for 60 minutes. Since this short time required precision in capturing the dialogue, the researcher audio-taped the proceeds of the interviews. Permission was duly sought from interviewee before any voices could be recorded. To address the bias issues arising during the dialogue, I ensured that I stuck to the interview guide, which contained the key questions covering the study objectives. I minimized bias further by avoiding leading questions, while I also ensured that I listened attentively to the submissions of the key informants without any interjections. Nonetheless, at some points, I interjected if an interviewee gave a superficial explanation about a key point that was relevant to the study.

The interviews were opted for because they offer a chance for in-depth data about the study topic. Furthermore, the interviews were administered in this study because according to Kumar (2018), they afford the researcher the opportunity of rephrasing the questions in order to enable collection of quality responses. For consistency, interview guides were used to ensure that all the key data sought by the study were duly collected. According to Tavory (2020), use of an interview guide enables a researcher to have a semblance of key questions that yield key data which provides the best answers to the research questions formulated at the beginning of a research study.

3.6.2.3 Focus Group Discussion (FGD)

Qualitative data were also collected through Focus Group Discussion (FGD). Two FGDs were administered by this study, one for female and another for male. The FGDs comprised purposively selected water users. Each FGD involved 8 participants each. The FGDs were the last research field activity administered by the researcher. The motivation for handling this activity last is largely because the researcher targeted water users who expressed extensive knowledge about the functionality of hand pumps in the area. The rule of the thumb that was followed in purposive selection of FGD participants was: firstly, long stay in the parish and exhibition of extensive knowledge about the study variables compared to other participants in a given area. The participants were engaged in selecting a neutral ground from where to hold the discussion. Both FGD participants selected Winterland Inn in Bushenyi Town because of its cool ambiance. The FGDs were conducted on a Sunday in the afternoon and lasted for 90 minutes. The choice of Sunday afternoon was because it was convenient to all participants as they were off duty. Before the discussion, participants were requested to introduce themselves. The researcher followed the interlude with an introduction about the topic of discussion. The researcher moderated the FGDs while the proceeds were audiotaped by his research assistants. Permission to record the voices was

sought before actual recording began. The main reason for involving the researcher assistants was to minimize the possibility of obstructions that would arise if the researcher decided to carry out both activities by himself. Like the interviews, the FGDs followed the guide which contained key statements and questions related to the study objectives. Since all the respondents were not literate, the FGD were conducted in Runyankore.

The FGD was used in the study because of the following reasons: first, they enabled interaction between the researcher and participants which aids the production of new meanings through the hermeneutic effect of participant-to-participant interaction (Hennink & Kraiser, 2022); second, they enabled capturing of collective ideas and their underlying meanings. Further, FGDs enabled the gathering of critical information through group exchanges and snowballing of ideas. According to Sim and Water field (2019), use of FGDs provides a platform on which the respondents' contributions set off a chain of comments that enhance the quality of discussion. Fourthly, the FGDs were held with the water users. That said, the group dynamics involved in the FGDs provided the hoped synergistic effects on generation of study outcomes which would have been missed with other methods (Setia, 2017). Fifthly, FGDs generated exciting and spontaneous ideas while they also encouraged every voice to be heard.

3.6.2.4 Experiment data collection

Water quality tests were performed to obtain data on physical, microbial, and chemical properties of collected water samples to address objective 1. The detailed description of the tests is discussed below;

3.6.2.4.1 Petrifilm™ Testing

The Petrifilm™ method is straightforward. This was used for testing total coliform. Total coliform is a standard indicator organism used to show general bacterial contamination in water. *E. coli* is also used to test drinking water, but points more directly to fecal contamination (Fewtrell & Bartram, 2001). Typically, standard methods such as membrane filtration, MPN, or chromogenic media methods are used to test for total coliform and *E. coli* (Medema et al., 2003). However, due to limitations in the field it was not practical to achieve strict adherence to one of these methods. Because of these limitations, a simple, low-cost method was needed that does not require additional equipment. 3M Petrifilm™ was selected because of the simplicity of the method, low cost, and ease of transport. 3M Petrifilm™ was initially developed as a low-cost method for food safety but is considered equivalent to other commercial standard chromogenic methods for drinking water such as mColiBlue and mTEC (Vail et al., 2003; Chuang et al., 2011).

In this study, total coliform and *E. coli* were assessed in all water samples drawn from the abandoned hand pump. A 1 mL sample of water was placed on the count plate culture medium and left to incubate at 35° C for 24 hours, after which the film was read by direct count. Any total coliform or *E. coli* colony forming units (CFUs) appeared as red or blue dots respectively. The National Water and Sewerage Corporation (NW&SC) analytical laboratory in Bushenyi Town served as the incubator during testing. The total counts were estimated by determining the number of CFUs in one or more squares in the grid printed on the plate and then extrapolated to estimate the total count for the plate. I choose to do direct count up to 150 CFUs and then estimated total count if a plate had a total count higher than 150. Where it was not possible to establish an estimate because of too many CFUs, the plate was given CFU total count of 1000 to represent status as too numerous to count (TNTC). This was done to ease qualitative and quantitative analyses.

3.6.4.2.2 Physicochemical composition

This was analysed using an assortment of equipment (See Table 3.2). Water samples were collected from the nonfunctional hand pump in Kiyaga Parish. This involved applying the procedures indicated by Bartram and Balance (1996) and WHO (1997). The main physicochemical parameters measured directly in the field involved use of the WTW Photoflex Turb Set (pH and turbidity) and the Conductivity Meter AL20 CON (conductivity and temperature), while the others were analysed in the laboratory (see Table 3.2). The samples for metallic element determinations (iron, manganese, zinc, copper, lead, cadmium and chromium) were stored in 0.5 L polyethylene bottles, where concentrated nitric acid was dosed to reach a pH < 2. Also, the samples for nitrate and phosphate determinations were stored in 0.5 L polyethylene bottles, where concentrated sulphuric acid was dosed to reach a pH < 2. Finally, the samples for the other determinations (hardness, chloride, fluoride) were collected separately in 0.5 L plastic bottles. The samples were then immediately stored in ice boxes and analysed. The photometer WTW Photoflex Turb Set was used to measure hardness, chloride, nitrate, phosphate, sulphate, iron, manganese, zinc, copper, lead, cadmium and chromium (VI). Fluoride concentration was measured by the Ionometer WTW pH/ION 340i. Table 3.2 summarizes the water quality parameters, the analytical methods and the instruments used for the analyses.

Table 3. 2: Test parameters, analytical method and instruments used in water quality testing

Parameter	Analytical method	Instrument
pH	Instrumental, analyzed on site	Multi-parameter WTW, Model Photoflex Turb Set and probe Sentix 41
Temperature	Instrumental, analyzed on site	Conductivity Meter Aqualitic, Model AL20 CON
Conductivity	Instrumental, analyzed on site	Conductivity Meter Aqualitic, Model AL20 CON
Turbidity	Nephelometric method, analyzed on site	Multi-parameter WTW, Model Photoflex Turb Set
Total Dissolved Solids (TDS in ppm)	Instrumental, analyzed onsite	TDS (LR) Tester HI-98129
Hardness	Photometric method	Photometer WTW, Model Photoflex Turb Set
Chloride		
Fluoride	Potentiometric method	Ionometer WTW, model pH/ION 340i and probe F-800
Sulphate, Nitrate, Phosphate, Iron, Manganese, Zinc, Copper, Lead, Cadmium, Chromium	Photometric method	Photometer WTW, Model Photoflex Turb Set

3.6.4.2.3 Colour and Odour

Normally Colour change is not harmful unless it is associated with toxic chemicals. For the abandoned hand pump, changes in colour of water was observed mainly because of the mixing of mud during the rainy season which indicated the mixing of microbes present in the mud especially wash water from the spoil heads and areas in the uphill of the garbage collection points and pit latrines. The odour was observed because of the decay of the organic materials nearby the hand pumps. The odour and colour of all the water samples was observed with the naked eye.

3.6.5 Sanitary Inspection of Hand pumps

In addition to the survey on the socio-economic dynamics leading to nonfunctionality of hand pumps, an adapted sanitary inspection tool was used to determine likely routes of contamination (in case of any) and to estimate the risks associated with drawing water for consumption from the deserted hand pump. This method provided data for supplementing what was obtained from the other primary data collection methods discussed above to address part of objective 1.

3.6.6 Secondary Data collection Methods and Techniques

The study reviewed and analyzed several published and other non-published records at both Bumbaire Sub County and Bushenyi District Local Government Office. According Tweedie *et al.* (2020), document analysis refers to the careful consultation of documents to mine data related to the study so as to come up with detailed meaning and contextual basis of the study. The READ approach was used as recommended by Dalglish *et al.* (2020). The approach involves readying the secondary information materials (R), extracting relevant and necessary data from these information materials (E), analysing critically the data mined from these information materials (A) and distilling the meanings and presenting them as findings (D). The choice of this method of data

collection was informed by the argument of Karppinen and Moe (2019) that the outcomes from review of a cross section of documents helps to make the findings more robust. Like interviews, the researcher prepared a document review guide on which the relevant documents were listed. This ensured that none of the documents believed to contain relevant secondary data were omitted. The entire data sources are illustrated in Figure 3.5.

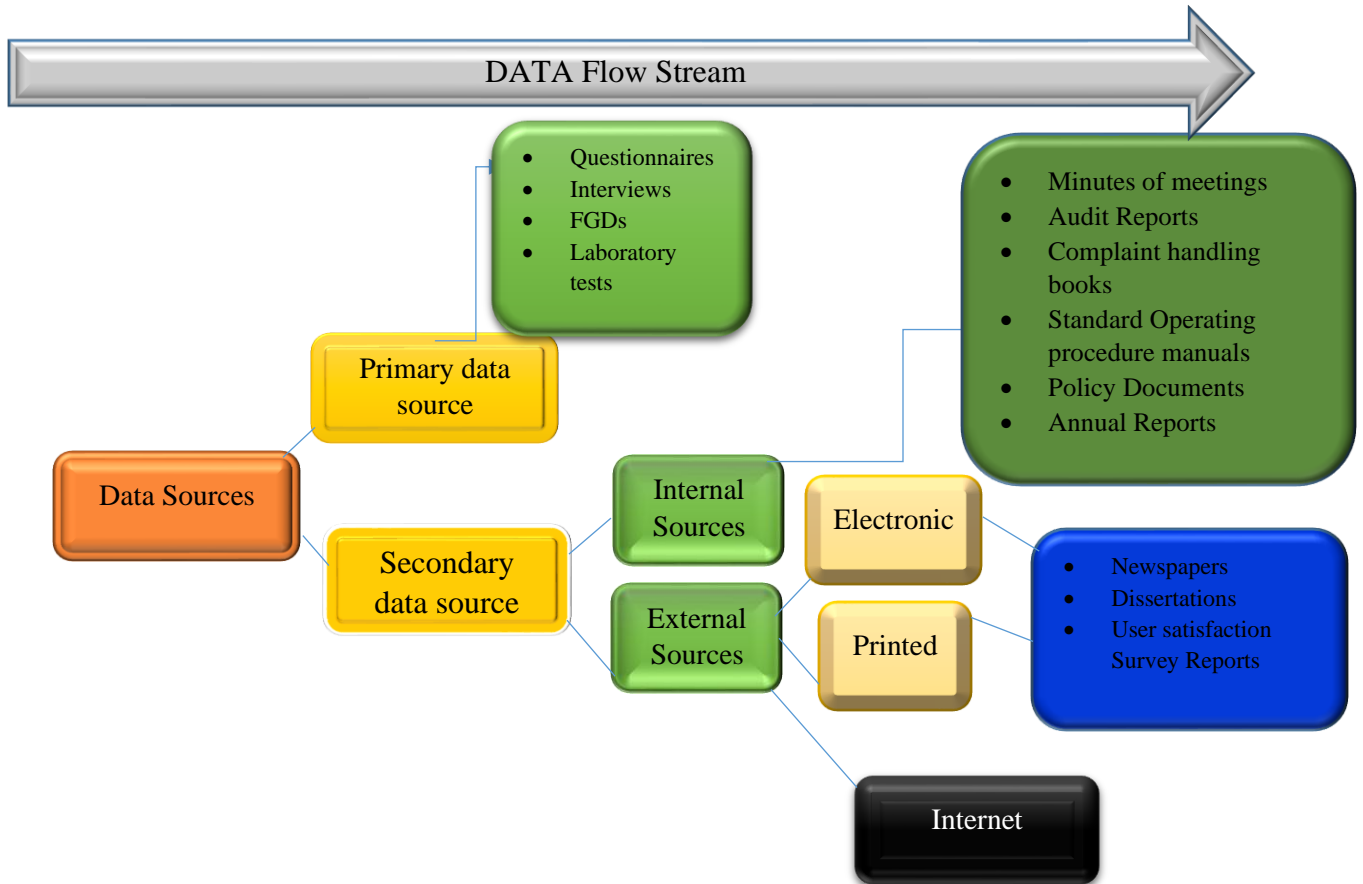


Figure 3. 5: Data Flow Stream

The secondary data that were mined from the documents that were reviewed by this study helped in corroborating the primary data. This enriched the findings that are reported in the next chapter.

3.7. Data Collection Instruments

3.7.1 Questionnaire

A questionnaire with both close ended questions and statements was administered to heads of households. Close-ended questions were included to increase response rate. The questionnaire was selected as the main data collection tool because it was cheap to administer and covered wide

geographical area; it provided a hard copy that was filed for reference purposes. The questionnaire was equally used because data were collected from a large sample in a short period of time (Kumar, 2018).

3.7.2 Interview Guide

An interview guide was used in the study to collect detailed data from key informants. The main reason for preparing an interview guide was to prevent omission of key questions that were capable of yielding vital data for this study.

3.7.3 FGD Guide

An FGD guide was used in the study to collect detailed data from the household heads who expressed a high degree of knowledge about the study variables during the period of data collection using the questionnaires. As was the case of the interview guide, the main reason for preparing an FGD guide was to prevent omission of key questions that were capable of yielding vital data for this study.

3.7.4 Document Review Guide

A list of probable sources for secondary data was compiled. The guide included the following sources: Annual Reports of Bushenyi Town Council, newspaper articles and research reports. Some of the data were integrated in the findings to make the study comprehensive and informative.

3.7.5 Observation checklist

This was used to assess the general appearance and sanitary conditions of the abandoned handpump with running water in Kiyaga parish to approximate the health risk of the hand pump

based on possible routes of contamination. It therefore served as a complimentary source of data to the water quality tests.

3.7.6 Laboratory Results Sheet

Laboratory tests were carried out on water obtained from the abandoned hand pump. A laboratory results sheet (Table 3.3) was used to record the results obtained from the various tests performed.

Table 3. 3: Water quality parameters tested in the laboratory

Water quality parameter
1. Water Appearance
2. Odour
3. Taste
4. Colour (PCU)
5. Turbidity (FTU)
6. Conductivity(μ S)
7. TDS (mg/L)
8. Total alkalinity (mg/L)
9. Iron (mg/L)
10. Nitrate (mg/L)
11. Coliform (cfu/mL)
12. E. coli (cfu/100mL)
13. pH
14. Hardness (CaCO ₃)

3.8 Data Quality Control

Two aspects of concern for the researcher regarding data quality control are: ensuring validity and determining reliability as discussed below;

3.8.1 Validity

binti Daud (2021) defines validity as the meaningfulness of research components. Validity takes different forms. It may be criterion, face, internal, content or construct (Kumar, 2018). In this study, both face and content validity were ensured. Odiya (2009) defines face validity as the ease with which the targeted respondents in a study can decode the information printed on the face of a

questionnaire without requiring the presence of the researcher for points of clarification. A researcher should therefore ensure that the instruments used in a study have face validity in order to guarantee the generation of credible and well thought responses (binti Daud, 2021). Face validity of the instruments was established by submitting the data collection instruments to my supervisor and 1 subject matter expert on water resources management. Face validity ensured that the phraseology of the questions was well structured while it also ensured that jargons and rubric were eliminated from the tool. Content validity on the other hand was emphasized by the researcher in order to ensure that there was adequate coverage of the themes developed from the study objectives. This ensured that the statements were adequate and capable of yielding comprehensive data for answering the study’s research questions. Content validity was ensured by computing the content validity index (CVI). The formula in Equation 3.1 was used (Bastilha *et al.*, 2021).

$$CVI = \frac{\text{Number of Questions judged relevant}}{\text{Total number of questions judged}} \dots\dots\dots \text{Equation 3.1}$$

$$CVI = 51/63$$

$$CVI = 0.809$$

The overall CVI was 0.809 implying that the questionnaire contained valid statements.

3.8.2 Reliability

According to Koonin (2014), reliability is the credibility or consistency of a research instrument. To test for the internal consistencies of the questionnaire items used to measure the variables, Cronbach alpha values were computed in Statistical Package for Social Sciences (SPSS). Values above 0.7 suggested reliability (Randrianarivony *et al.*, 2020). The average Cronbach Alpha obtained in this study value was 0.86, implying that the questionnaire was reliable.

3.8.3 Reliability and rigor of interviews and FGDs

Reliability is about the degree to which research can be replicated (Noble & Smith, 2015). To ensure both reliability and rigor, most of the interview and FGD questions were developed directly from the research questions. External reliability was addressed by making the questions as straightforward and understandable as possible so that any chances of the respondents misunderstanding the statements and questions was minimized. Probes were used to guide the interviewees about the gist of the interview questions asked. This enabled the researcher to obtain direct answers to the questions. The interviews were conducted in the interviewees' offices which minimized the possibility of any obstructions from interrupting the interview sessions. Furthermore, leading questions were avoided since such, mask the broad views of the respondents (Alshenqeti, 2014). As for the FGDs, a conducive place was decided upon by the researcher and the respondents to ensure that the participants were not affected by any obstructions. The FGD was administered at place that was deemed comfortable to all the participants. Winterland Inn was selected as the most convenient and noise-free place. It is located along Liberation Road in Bushenyi Town.

3.9. Procedure of Data Collection

After proposal defense, the researcher got a cover letter from the post graduate school of UCU that allowed him to proceed to the field for data collection. The letter was presented to LCs and management of Bumbaire Sub County for permission. The questionnaires were self-administered by the researcher and his assistants. This catered for illiterate respondents. Regarding face-to-face interviews, the researcher contacted key informants and provided them with a snapshot of what the study was about. Interview dates that were convenient to the respondents were scheduled,

followed by actual holding of the Interviews. Prior to administration of questionnaires and interviews, water samples were collected for experimental analysis. The researcher used NW&SC Analytical Laboratory in Bushenyi Town.

3.10 Data analysis

3.10.1 Analysis of quantitative data

Most of the variables in the research as laid down in the questionnaire are measured on ordinal scale (close ended questions) while a few were measured on nominal scale (open ended questions). All the returned questionnaires were edited and cleaned to ensure that the required data were captured. This was followed by entry of the data in the SPSS data script to facilitate easy analysis. Descriptive statistics constituting of frequencies, percentages, mean and standard deviation was used in analyzing data obtained from questionnaires. The same approach was applied in analyzing the evaluation data on the applicability, efficiency and usability of the framework for maintenance of hand pumps in the sub county.

3.10.2 Analysis of qualitative data

Qualitative analysis were performed on primary data collected using interviews and FGDs and secondary data obtained through review of relevant documents. Data from interviews and FGDs were audio-taped. The audio clips were downloaded from the voice recorder on to a laptop. This was followed by plugging headsets in the laptop audio pot. This enabled the researcher to listen to the audios. To be authentic, the researcher wrote the dialogues (for interviews) and deliberations (for FGD) sentence by sentence, word by word. The transcription of the clips for interviews and FGD lasted for 4 days. On the 5th day, the researcher typeset the written data and produced transcripts. The transcription exercise involved the researcher and his research assistants. The

transcripts were later printed to produce hardcopies that were reviewed by the researcher to ensure accuracy and completeness. The review was done hand in hand with listening to the audios one more time. After confirming that the transcripts tallied or matched the audios, data were prepared for stage three. This stage involved the analysis of the transcripts using MAXQDA22.

While in the MAXQDA22 environment or graphic user interface (GUI), the selected text in the transcribed data were dragged and dropped onto a code with a mouse. MAXQDA22 helped to create the codes automatically for every corresponding entry made. The major advantage of using MAXQDA22 is that the programme accommodates unlimited codes (Meihami & Esfandiari, 2021). Themes were generated from the coded entries. The emerging themes were validated by revisiting the interview and FGD participants. MAXQDA22 has been selected as the best analytical tool for the transcribed data largely because it is an open-source software that provides a two-month free use for analysis before one is obliged to subscribe to it. Based on the key themes and phrases, verbatim patterns were derived in accordance with the objectives of the study and used to build arguments to explain the qualitative findings.

3.10.3 Analysis of Laboratory results

The results obtained from laboratory results were analyzed and interpreted using internationally recognized permissible limits or critical points defined by the Indian Council of Medical Research (ICMR), United States Public Health Services (USPHS), World Health Organization (WHO), and European Union (EU). Locally, the permissible thresholds by UNBS and NW&SC were also used. These helped in the determination of the quality of water in the abandoned hand dug well.

3.10.4 Designing of the Framework

The framework was designed using the systems development life cycle (SDLC) model. According to McMurtrey (2013), SDLC enables the designing and development of best business and service improvement solution given its proven, tried-and-true deployment in business, industry, and government with notable landslide success (Conger, 2012). The waterfall model was adopted. According to Conger (2012), output of each phase is input to the next phase. The phases included requirements collection of analysis of the gaps to answer the what question. This corresponded with objective 1 of the study. This was followed by designing the framework to address the identified gaps and therefore to provide the answers to the how question. This corresponds with objective 2 of the study. The framework was designed using Microsoft Office Word. Lastly the designed framework was tested (for correctness), validated and recommended for implementation (transition to operation). The framework was validated by using cognitive walkthroughs with key informants. The likely deficiencies in the designed framework were ascertained by using a survey tool (See Appendix F)

3.11 Ethical Considerations

According to Brittain et al. (2020) ethical considerations refer to the protocols that a researcher must uphold in their study in order to ensure that no infringement on the rights, violation of the norms and abrogation of standard codes happens. The researcher observed a series of procedures before collecting data and in reporting the findings.

Firstly, the researcher began the process by obtaining permission from the Faculty of Engineering, Design and Technology, UCU Mukono where a letter of introduction was got. Also, permission

to conduct research in the Sub County was obtained from Bushenyi District Local Government after presenting an introductory letter from UCU, Mukono.

Secondly, the consent of the respondents was sought before they were engaged in any form of data solicitation. The researcher accorded respect everyone he meets in the field which eased the process of data collection. Also, the researcher ensured that the privacy of the informants was upheld and respected.

Thirdly, the questionnaire used in data collection was anonymous. No personal details and information such as name, telephone contact, social media profile names were included in the data collected from the respondents.

Fourthly, in reporting results, this study given its orientation in tapping qualitative data from FGDs and interviews, the researcher ensured that the views of the respondents were duly concealed. Pseudonyms were used for interviewed respondents while labels were also used to represent the submissions and contributions of the FGD participants.

Finally, to contain the challenge of presenting plagiarized information in the entire dissertation, whichever information was reported in this study attracted annotations, paraphrasing and cross matching of consenting authors in order to ensure that the views of the studies that were used as source materials for this study were not reproduced, a practice that is unethical.

3.12 Limitations of the study

The study was carried out during the planting season. The economy of Bumbaire sub-county is agrarian. Tracing the respondents was difficult. This shortcoming was minimised by targeting evening hours and Sundays when the respondents would be home. Nonetheless, A few targeted respondents were never accessed. Equally, the SCCDO and District Water Engineer were busy preparing end of Quarter 3 Reports for 2022/2023. As a result, they were hard to trace and never had adequate time to participate in the evaluation of the framework. The evaluated framework does not capture in-depth views of the key informants.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF FINDINGS

4.1 Introduction

This chapter presents the findings based on the data gathered from questionnaires, interviews, FGDs, document review and experimental analysis. The findings are presented in the gist of the three specific objectives that the study sought to achieve. These were: To assess the causes of nonfunctionality of hand pumps in Bushenyi District, To design a framework for closing the gaps identified in the management of functionality of hand pumps; and To evaluate and recommend the designed framework for deployment. Four categories of respondents took part in the study. These were: household heads (156), District Water Engineer (1) and Sub County Community Development Officer (1). The presentation of the key findings is preceded by an overview of the participation of the respondents who were targeted by the study. The next subsection therefore presents the overall response rate in the study.

4.2 Response Rate

The response rate of the respondents targeted by the study was computed. Krishnan and Poulouse (2016) define response rate as the ratio of the number of participants in relation to those that were targeted. Response rate is also conceived by Morton et al. (2012) to mean the total number of those who have participated in a study divided by the total number who were eligible. Presentation of the results on response rate was important in this study because high response rate presuppose quality of the study findings. Besides, high response rates are manifestations that the participants has keen interest on the study and for that reason, they participate in big numbers (Krishnan & Poulouse, 2016). Further evidence of the critical importance of a high response rate is provided by Dillman (2020) who reasoned that when a study has attracted a high response rate, it is implied

that the findings reported are by far robust and representative of the perceptions of their counterparts who never participated in the study. The response rate for this study were as follows;

Table 4. 1: Summary of response rate

Data collection method	Number targeted	Number accessed	Response rate
Questionnaire Survey	186	156	84%
Interviews	2	2	100%
Total	188	158	
Average response rate			92%

Source: Field Data, December 2022.

Note: Table 4.1 excludes response rate from FGD since the participants were selected from those who filled questionnaires and or participated in the interviews. Including them would have led to double counting problem and eventually discredit the study findings. The response rate for household heads was 84% while for interviews with key informants, all the targeted respondents participated, giving rise to 100% response rate. On average, the response rate was 92%. This implies that the study findings are representative of the views of the targeted respondents and can therefore be based on to draw generalizations on maintenance and functionality of hand pumps in Bumbaire Sub County. This inference is supported by Morton et al. (2012) who established that studies with a response rate below 50% of the sample yield less accurate results compared to those with response rate of 70% and above. The inference made is also in line with the findings of Krishnan and Poulouse (2016) & Matthiesen et al. (2021) that high response rates indicate greater probability that the sample was representative of the population. Generally, the high response rates indicated that majority of the respondents were interested in the study.

4.3 Background Information

The background characteristics captured by the study are cross-tabulated below;

4.3.1 Description of the respondents by age-group and gender

A cross-tabulation was computed for age-group and the gender category of the respondents. The following results were obtained'

Table 4. 2: Cross-tabulated results on age-group * Gender

Age-group		Gender		Total
		Male	Female	
19 - 27 years	Count	2	21	23
	Column %	8.3%	15.9%	14.7%
28 - 36 years	Count	14	65	79
	Column %	58.3%	49.2%	50.6%
37 - 45 years	Count	5	30	35
	Column %	20.8%	22.7%	22.4%
Over 45 years	Count	3	16	19
	Column %	12.5%	12.1%	12.2%
Total	Count	24	132	156
	Sample %	15.4%	84.6%	100.0%

Source: Field Data, December 2022.

Table 4.2 shows that most of the study participants were female aged 28-36 years (49.2%). The findings equally showed that the greater proportion of males (58.3%) belonged to the same age-group. Overall, the most dominant age group were the respondents aged between 28 – 36 years (50.6%). This finding implies that issues that have to do with hand pumps including their maintenance and functionality affected both males and females in a similar manner.

4.3.2 Description of the respondents by marital status and leadership position

A cross-tabulation was computed for marital status and leadership position of the respondents.

The following results were obtained;

Table 4. 3: Cross-tabulated results on marital Status * Leadership Position

Marital Status		<i>Do you have any leadership position in the community?</i>		
		Yes	No	Total
Married	Count	110	25	135
	Column %	86.6%	86.2%	86.5%
Widowed	Count	11	3	14
	Column %	11.2 %	10.3%	9.0%
Never Married	Count	7	0	7
	Column %	5.5%	0.0%	4.5%
Total	Count	128	28	156
	Sample %	81.4%	18.6%	100.0%
		$X^2 = 9.010$	$df = 2$	$p = .061$

Source: Field Data, December 2022.

Results in Table 4.3 showed that the majority of the respondents were married (86.6%) and at the same time, these were holding leadership positions in their respective communities. The findings further showed that there was a significant positive relationship between marital status and leadership in the communities ($X^2 = 9.010, p > 0.05$). By implication therefore, leadership positions were not determined by one's marital status and therefore, any community member qualified for any leadership position including water use management irrespective of their marital status orientations.

4.3.3 Description of the respondents by household size

The outcomes of the household size in Bumba Sub- County are shown in Table 4.4.

Table 4.4: Household size and composition in Bumba Sub County

Total N = 156 Respondents	Range	Min.	Max.	Mean	SD
Number of persons in the household	7	4	11	6.282	1.217
Number of persons engaged in any employment	3	1	4	1.949	0.726
Number of children in the household	4	1	5	2.436	0.924

Source: Field Data, December 2022.

Results in Table 4.4 show that on average, a household in Bumbaie Sub County had 6 members (Mean = 6.282). The highest number of persons in any household observed was 11. The average household size is reflective of a high dependence burden which implies that a typical household in Bumbaie Sub County is stretched regarding provision of the needs and necessities to the dependents. This observation is even manifested by the fewer number of household members that were engaged in gainful employment at the time of this study. The findings revealed that only 2 members were engaged in paid employment (Mean =1.949). An average number of 2 children was also observed in the study (Mean=2.436) and so, this is equally reflective of the high dependency burden.

4.3.4 Description of the respondents by daily water needs

The respondents were also engaged on a series of statements to establish their daily water needs. All the respondents were beneficiaries of hand pumps. As shown in Table 4.5, a typical household drew 126 litres of water from hand pumps in the area. This is equivalent to approximately 7 jerrycans of 20 litres per household. By implication, the households had a great need for water for both domestic and farming use. The communities in Bumbaie are livestock farmers with majority of the households keeping at least 2 heads of cattle. Given this attribute, the study equally established that the quantity of water drawn from the hand pumps was far less than the optimal water needed by the households. The average litres of water required by a typical household were 263 litres (Mean=262.72). This scenario is indicative of high demand for water by the households leading to stiff competition for the available hand pumps and therefore, it was established that 1 in every 5 hand pumps in each parish was functional. The rest are nonfunctional and this had become a perennial problem since 2007, with peak breakdown experienced in 2013.

Table 4.5: Daily household water needs and functionality of hand pumps

	Range	Min.	Max.	Mean	SD
Amount of water obtained from hand pumps per day	140.0	80.0	220.0	126.4	23.5
Amount of water I need per day	120.0	220.0	340.0	262.7	11.7
Is the hand pump currently functional?			1.0	1.0	
If No, when did it become nonfunctional?	12.0	2007.0	2019.0	2013.9	3.1
Frequency of its failure to render a service before shutdown	1.0	1.0	2.0	1.4	0.5
From which source does your household currently obtain drinking water?	4.0	1.0	5.0	2.7	1.1

Source: Field Data, December 2022.

Despite the high degree of need for water for domestic use, the hand pumps were not able to sustainably serve all the households. Figure 4.1 shows that the study findings revealed that majority of the respondents (91.7%) disagreed that the hand pump system in the area was able to supply water capable of meeting all their needs. Besides, the respondent household heads revealed that to a large extent, some of the hand pumps had water quality issues which equally worsened the water needs of the households (Figure 4.2). The respondents cited some of the water quality problems associated with the hand pumps such as taste and smell, among others (Figure 4.3). The majority of the respondents attributed the decline in water quality to construction problems especially cracked aprons, disinfection and water logging of the areas adjacent to the hand pumps.

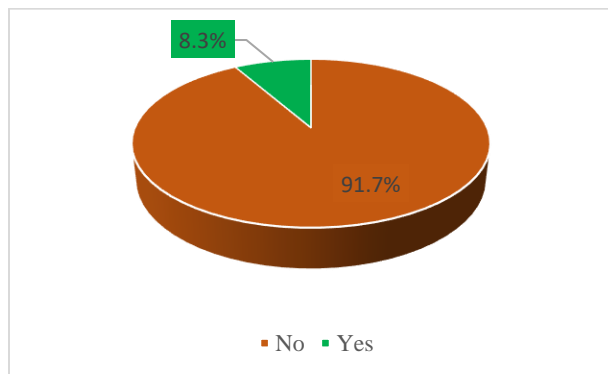


Figure 4. 1: Does the hand pump supply meet your needs?

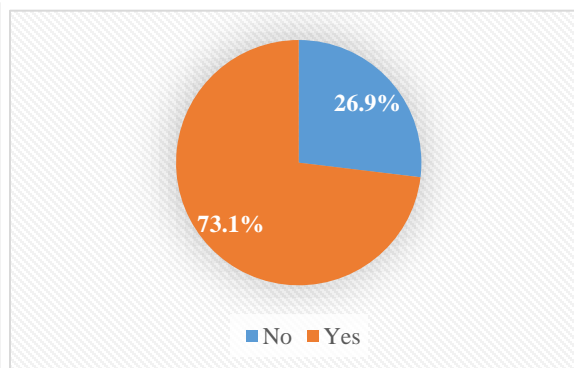


Figure 4. 2: Whether hand pumps had water quality problems

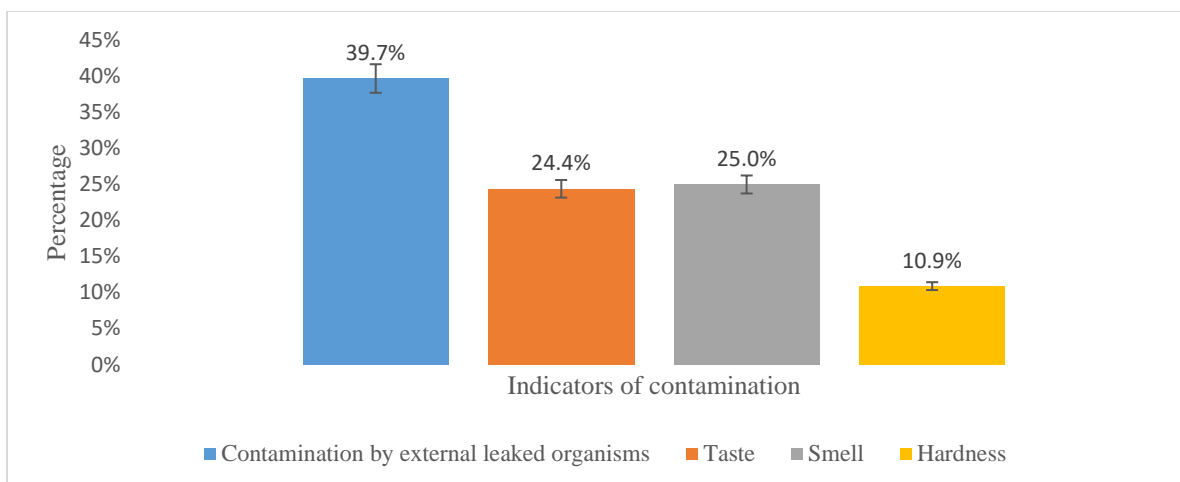


Figure 4. 3: Indicators of hand pump water quality problems

To cope with the inadequacy of the water supplied by the hand pumps and the associated water quality issues above, 3 out of every 5 households in the area were compelled to draw water from other sources, most of which are unsafe (Table 4.6). These included deserted sand and clay quarries that were permanently occupied by water, hand dug wells in the area and flowing streams with blackish-brownish water especially in areas such as Nyandozo village that are bifurcated by seasonal swamps.

Table 4. 6: Alternative sources of water used by households

	Total N = 156 Respondents	Count	Percent	Cumulative %
<i>Which alternative water sources are you using to draw water for domestic use?</i>	Using open sources	123	78.8	78.8
	Rain water harvesting	19	12.2	91.0
	Buying from vendors	14	9.0	100.0

Source: Field Data, December 2022.

4.4 Causes of nonfunctionality of hand pumps in Bumaire Sub County, Bushenyi District

Objective One (1) assessed the causes of nonfunctionality of hand pumps in Bumaire Sub County. The assessment was done from two perspectives. These were: water quality related causes and socio-technical causes as discussed below;

4.4.1 Water quality-related causes

The quality of the water was assessed to establish whether it could have been among the causes of the nonfunctionality of hand pumps in Bumbaire Sub County. The study was carried out on 7 nonfunctional handpumps in the subcounty as detailed in Table 4.4. The status of the handpumps was assessed using an observation checklist. The results obtained are shown below;

Table 4. 7: Description of the nonfunctional handpumps in Bumbaire Sub-County

Hand pump Code	Parish	Status	Availability of water
Num001	Numba	Installation vandalized, no visible sign of water	Unavailable
Numb002	Numba	Installation exists, no flowing water after 100 strokes	Unavailable
Kiya001	Kiyaga	Only apron exists. The installation was vandalized and part of the apron area covered by silt	Unavailable
Kiya003	Kiyaga	Complete installation exists. Water flowing but abandoned by the community	Available, flowing after 4 strokes
Rye001	Ryeishe	Installation uprooted by vandals; underground piping system filled with soil	Unavailable
Ruha001	Ruhaaro	Installation uprooted by vandals	Unavailable
Kain001	Kainamo	Installation cut at the base of the apron by scrap sellers	Unavailable

Source: Field Observation, 2022

Given the budget constraints for this study, water quality tests were carried out on Kiya003. The hand pump had flowing water, although it had been abandoned 3 years before this study. Samples were drawn from this hand pump to assess whether the physicochemical qualities of the water qualified it for human consumption. Besides, the biological load of the water was equally

determined by this study. The following parameters were assessed pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Hardness, Calcium, Magnesium, Chloride, Manganese, Iron, Sulphates, Nitrates and Faecal Coliforms. The laboratory tests were conducted in Bushenyi Town Council at NW&SC Laboratory (See Appendix H). The tests aimed at establishing the extent to which the water sample was either suitable or unsuitable for human consumption (cooking and drinking). The internationally and locally recognized permissible values for the drinking water were used. These were: Indian Council of Medical Research (ICMR), United States Public Health Services (USPHS), World Health Organization (WHO), and European Economic Community (EEC) now, European Union (EU) and National Water and Sewerage Corporation (NW&SC) of Uganda as shown in Table 4.10;

Table 4.8: Permissible values for assessing quality of drinking water in the abandoned hand pump

Parameter	Internationally Recommended Values				Local Permissible values	Recorded Field Result	Comment
	EU	USPS	ICMR	WHO	UNBS/ NW&SC		
pH	6.5-8.5	6.0-8.5	6.5-9.2	6.5-9.2	5.5-8.5	6.45	Acceptable
Turbidity	10 NTU		5 JTU		5.0	0.9	Acceptable
TDS	500	500	500		700	768	Exceeded
TSS		5.0			0	0.0	Acceptable
Hardness	300		300	200	500	550	Exceeded
Calcium	75	100	75	75	75	89	Exceeded
Magnesium	30	30	50	50	50	64	Exceeded
EC		300 µmho/cm			1000	1200	Exceeded
Chloride	250	250	200	200	250	6.4	Acceptable
Sulphate	150	250	200	200	200	30	Acceptable
Total Alkalinity		120 mg/l			500	40	Acceptable
Iron	0.3	0.3	0.1		<0.30	0.14	Acceptable
NO ₃ -N	45	10	20	45	50	0.07	Acceptable
E. coli (MPN/ml)		100/100ml	1/100ml	10/100ml	0	0	Acceptable

(Except pH, E. coli other parameters are in mg/l) Key: JTU= Jackson **Turbidity** Unit, NTU= Nephelometric **Turbidity** Units

Key: pH=Potential hydrogen; TDS= Total Dissolved Solids, TSS=Total Suspended Solids, BOD=Biochemical Oxygen Demand, DO=Dissolved Oxygen, EC=Electric Conductivity, COD= Chemical Oxygen Demand; NO₃-N=Nitrate-Nitrogen, MPN=Most Probable Number.

Source: Laboratory Experiment Data (December, 2022)

4.4.1.1 pH

This parameter measured the concentration of hydrogen ions in water. While pH has no direct adverse health effects. The assessment of quality of water intended to establish whether there were low values below 4.0 at any of the sites because values in that range will produce water which has a sour taste while higher values above 8.5 will produce a salt tasting water since at this rating, the water is too alkaline. The experiment results indicated that the pH lied in the acceptable range.

4.4.1.2 Turbidity

This was concerned with the transparency of the water. Turbidity results from substances present in the water. These substances are normally present in suspension form. From the experiment, turbidity was 0.9 NTU and therefore it was fit for drinking.

4.4.1.3 Total Dissolved Solids and Total Suspended Solids

A high concentration of TDS and TSS presupposes that water is saline or bears high salt content. High TDS in ground water suggests presence of Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate ions. In this study, TDS exceeded the local permissible threshold of 700 (TDS=760). This implied that the water was not fit for human consumption.

4.4.1.4 Hardness

Water hardness occurs when there is excess concentration of metallic cations of multivalent form. Hardness is usually common in ground water that is polluted with cations of Calcium, Magnesium, Strontium, Ferrous and Manganese ions. Households give up on a water source for an alternative in order to minimize the cost of soap as hard water forms a scum with soap. The alternative soapless chemicals such as detergents like OMO, NOMI and MAGIC are expensive to a rural-

based household as these have properties that form leather with hard water during washing. Results from the water sample drawn from the abandoned hand pump showed that the hardness of the water exceeded the permissible threshold of UNBS/NW&SC by 50 units.

4.4.1.5 Calcium and Magnesium

The concentration of Calcium and Magnesium exceeded the permissible thresholds and therefore, the concentrations made the water unfit for human consumption.

4.4.1.6 Electrical Conductivity (EC)

EC refers to conduction of electric current. In this study, EC was measured as the capacity of water in hand dug wells to conduct an electric current. According to WHO standards, EC is indicative of TDS. As well, it is reflective of salinity which degrades the quality of portable water. Chemically pure water does not conduct electricity. Results from all the samples indicated that EC ranged exceeded the permissible range set by UNBS/NW&SC. Therefore, it is eminent to infer that the water in the abandoned hand pump was contaminated.

4.6.1.7. Sulphates

Results in show that water from the abandoned hand pump contained concentration of sulphates that were within the acceptable permissible range.

4.4.1.8 Total Alkalinity

Alkaline water is capable of neutralizing acids. The results showed that alkalinity lied in the permissible range.

4.4.1.9 Iron

Results of the experiments indicated that iron concentration was 0.14 mg/L and therefore, it lied in the acceptable ranges of drinking water permissible at both local and international levels.

4.4.1.10 Nitrate - Nitrogen

The results revealed that Nitrate – Nitrogen content was 0.07 mg/l. The concentrations were within the permissible limit by UNBS/NW&SC. The water was less polluted with nitrate-nitrogen. Using the national reference point of 50 mg/l, the concentration also was within the acceptable range of UNBS.

4.4.1.11 *Escherichia coli (E. coli)*.

Presence of fecal indicator bacteria (*Escherichia coli*) in water samples from the abandoned hand pump was tested using membrane filtration with plating and glass wool filtration with quantitative polymerase chain reaction (PCR), respectively. In addition, sanitary inspection of surroundings of the sources was conducted to identify their vulnerability to pollution. The results indicated that the water was free of E-coli and therefore, acceptable for human consumption.

The findings especially on the parameters with values surpassing the permissible range are not unique to Uganda. A study by Toure and Wenbiao (2020) that evaluated the physicochemical and microbial qualities of handpump water in the rural commune of Pelengana, Mali established that turbidity, and nitrate, whereas microbial concentrations during the rainy season were above WHO permissible values. A related study in West African countries (Mali, Ghana and Niger) by Circle of Blue (2022) established that handpumps had lead levels that were above World Health Organization drinking water standards. The presence of lead in drinking water is a health hazard especially for children as it affects their neuro development (Circle of Blue, 2022).

4.4.2 Socio-technical causes of nonfunctionality of hand pumps in Bumbaire Sub County

This aspect assessed the contribution of social, ownership, technical, financial and institutional factors towards the nonfunctionality of hand pumps. The following results were obtained;

4.4.2.1 Community-based factors leading to nonfunctionality of hand pumps

The study assessed the contribution of the social factors towards nonfunctionality of hand pumps in Bumbaire Sub-County. Results in Table 4.8 show that majority of the respondents intimated that the biggest proportion of hand pumps (79%) in the area were constructed by Non-Governmental Organizations (NGOs). It is important to note that NGOs have been widely recognized in Uganda as is the case elsewhere in the developing countries especially for their involvement in establishing socio-economic development projects that are in tandem with the 2030 Sustainable Development Goals (SDGs). In Bumbaire, their credit in water governance and water services is remarkable. However, this study established a shortcoming about their participation in constructing hand pumps. Majority of the respondents (85.3%) revealed that the hand pump projects in the areas were not consultative. The rife evidence provided by the respondents in this matter was that they never participated actively in the development of the hand pumps.

Results from both the male and female FGDs provided confirmatory evidence that there were limited consultations made by the NGOs before constructing the hand pumps in the subcounty. The participants further reiterated that even where there was involvement, it never took place throughout the entire project life. It was revealed that an insignificant number were involved in all the phases of development. Still on the same matter, majority of those who were involved were vital persons in the community with the capacity to contribute some money to the projects as well as some local materials that were needed for the construction activities. Generally, the hand pump

projects in the Sub County were sort of an imposed developments in the communities given the fact that the majority of the community members were not engaged. Consequently, this situation had a grand effect on the maintenance of the hand pumps because of lack of community buy-in. The respondents through interviews revealed that most of the NGOs in this sector applied a Build and Transfer (BaT) strategy or approach. By implication, the subsequent activities especially those to do with maintenance were shouldered by the communities. Therefore, the failure to involve majority of the communities had a net effect on maintenance and consequently, the functionality of the hand pumps. This assertion is vindicated by the results in Figure 4.4 which showed that the majority of the respondents (83.5%) submitted that they never regarded themselves as the rightful owners of the hand pumps. This finding rhymes the observations of Malima (2021) who noted that the functionality of groundwater sources such as handpumps is greatly influenced by active community involvement. More light on community involvement is shed by Naiga (2021) who noted that integrated water resources management emphasizes the transfer of water management responsibilities to users.

Table 4. 9: Community-based causes of nonfunctionality of hand pumps

	Total N = 156 Respondents	Count	Percent	Cumulative %
<i>Who selected the site for the development of the hand pump?</i>	Community	19	12.2	12.2
	Government	5	3.2	15.4
	NGOs	123	78.8	94.2
	All in collaboration	9	5.8	100.0
<i>Did you participate in the development of the hand pump?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	No	133	85.3	85.3
	Yes	23	14.7	100.0
<i>If Yes, at which stage or phase did you participate?</i>	Total N = 23 Respondents	Count	Percent	Cumulative %
	During planning	2	8.7	8.7
	During construction	14	60.9	69.6
	Post construction	6	26.1	95.7
	All phases	1	4.3	100.0

Total N = 23 Respondents		Count	Percent	Cumulative %
<i>What was your contribution in the development of the hand pump?</i>	Labour	1	4.3	4.3
	Local materials	9	39.1	43.5
	Both labour and local material	2	8.7	52.2
	Money	2	8.7	60.9
	Both labour, money and materials	9	39.1	100.0

Source: Field Data, December 2022.

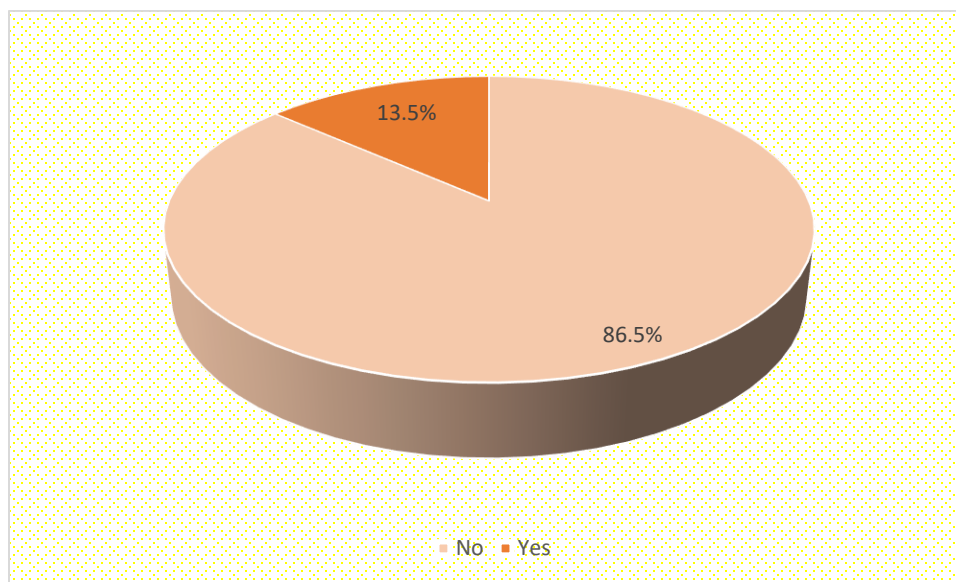


Figure 4. 4: Whether the households considered themselves as rightful owners of the hand pumps

The results from interviews with SCDO and District Water Engineer provided rhyming evidence that the majority of the community members felt that they were not the bonafide owners of the handpumps. The SCDO revealed that majority of the community members in Bumbaire were bitter with the NGOs because they have imposed development on them. The SCDO summarised the observation in the following words;

“...Many people in this sub county are confused regarding why the NGOs that have donated hand pumps in the area never consulted and engaged them right from the inception of the projects and yet other social developments in the communities observe that protocol. They give examples of violence against women and girls (VAW&G), breastfeeding, immunization, among others where NGOs have played a pivotal role using all the available community structures. They keep wondering why they were not

part and parcel of the initiation of the hand pump schemes in the areathis is quite confusing to many” (SCDO 20 November 2022).

In relation, the District Water Engineer noted that in almost all annual reports for the years 2018 to 2021, the community members benefitting from the handpumps constructed by both the District and the NGOs hardly believe that the water sources belong to them. The reason accounting for this indifference is that both the District and NGOs have sidestepped the existing community social structures and went ahead to construct the hand pumps. As a result, there is no buy in from the community and therefore, the hand pump systems are mismanaged by the communities.

The other community-based aspect assessed by the study was the level of engagement of women in the development of hand pumps. The respondents on the aspect of participation of the women in the development of hand pumps, unequivocally declined which implied that women were never engaged at any of the hand pump development phases. A number of factors were responsible for this lack of engagement, with burden of domestic chores (45.5%) and non-permitting husbands (17.0%) standing out as the most limiting factors (Table 4.9). Other limitations included religious factors, cultural beliefs, lack of interest among some women, among others (Figure 4.5). This observation serves to indicate that the nonfunctionality of the hand pumps was also predicted by the non-involvement of women and yet from the perspective of gender division of labour, women and children are the custodians of domestic chores, fetching water inclusive. They are therefore in prime position to provide important information about any challenges that they face or encounter while using the hand pumps. Such information is important as it would provide leads and insights to the operation and maintenance team about the areas that require adequate attention before they become worse.

Equally, the study assessed the degree of engagement of community leadership in the management of the hand pumps, majority of the respondents (81.4%) disagreed that at the time of constructing the hand pumps in their communities, there wasn't any established community management system to oversee the establishment and maintenance of the hand pumps (Table 4.9). Therefore, the management of the hand pump development remained a preserve of the NGOs as shown by most respondents (48.3%). As a result, the communities were by far less convinced that the leadership that never involved them did things rightly on the hand pumps (48.3%). It is therefore plausible to infer that the local people were not largely interested in the sustainability of the hand pumps and as a result, they were least concerned about protecting this water source for example against vandalism. Equally, they showed no interest in reporting to the concerned authorities or institutions about the mechanical conditions that arose from time to time. Thus, in most cases, the maintenance that was carried out on the hand pumps (if any) was not preventive, but reactive. Consequently, the operation life of the hand pumps was shortened by mismanagement of the installations by the local people.

Table 4. 10: Engagement of women and community leadership in the management of hand pumps

<i>Do women participate during water scheme development in this community?</i>		Count	Percent	Cumulative %
No		156	100.0	100.0
<i>Was there an established management system for the developed hand pump?</i>		Count	Percent	Cumulative %
Total N = 156 Respondents				
No		127	81.4	81.4
Yes		29	18.6	100.0
<i>If Yes, who managed the hand pump?</i>		Count	Percent	Cumulative %
Total N = 29 Respondents				
Water user committee		3	10.3	10.3
NGO		14	48.3	58.6

		Not sure of the management body	12	41.4	100.0
<i>Did the management body perform their duties and responsibilities adequately?</i>	Total N = 29 Respondents		Count	Percent	Cumulative %
	No		14	48.3	48.3
	Yes		15	51.7	100.0

Source: Field Data, December 2022.

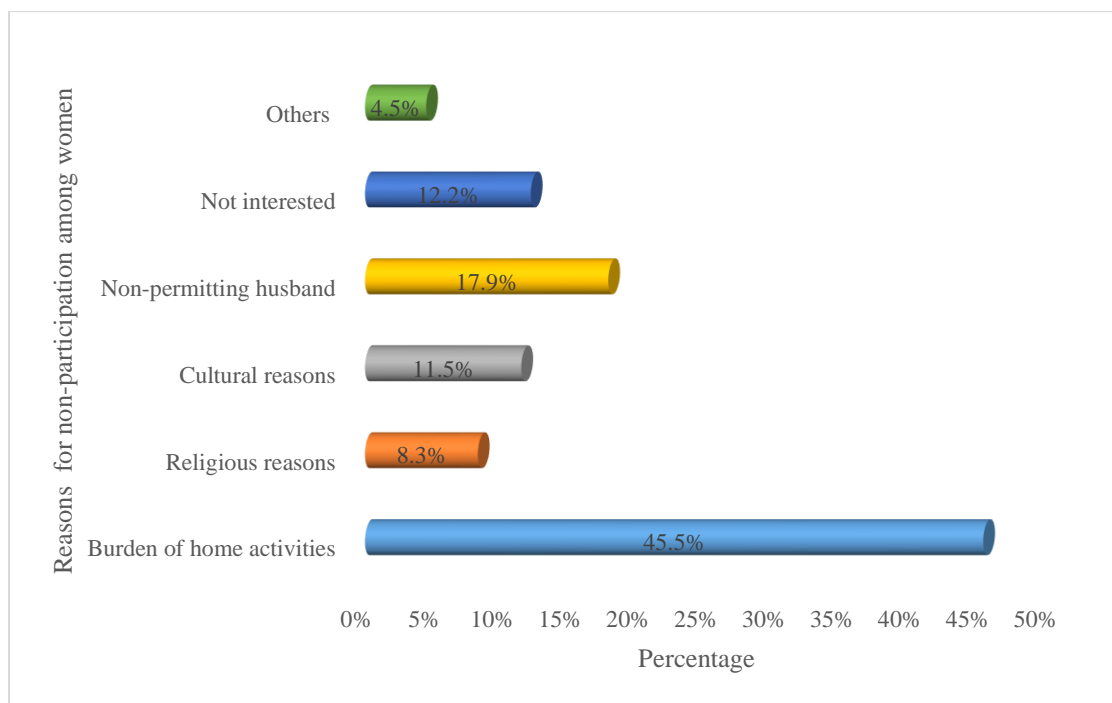


Figure 4. 5: Causes of limited/no participation of women in hand pump water system management

Majority of the participants in both male and female FGDs revealed that community engagement was under looked by the government and NGOs and yet the social dynamics within the community have a large bearing on the success and sustainability of all the projects implemented in the sub county. The FGD participants singled out the example of the Parish Development Model projects in the subcounty. They revealed that consultations were carried out before the beneficiary projects were selected and further intimated that consultations have not ceased since then. For this reason, the PDM projects were performing well putting Bumbaire in the second-best slot after Bushenyi Municipality. I validated this finding by analysing the PDM performance reports for 2022 (Quarters 3 and 4) and confirmed that Bumbaire was the second best. The point of emphasis by FGD participants was that as long as the NGOs continue to construct boreholes in the subcounty without observing the models used by Ministry of Local Government (MoLG) for PDM projects, It will be impossible to realize sustainability of the hand pumps largely because there is limited and/ or insignificant community ownership.

4.4.2.2 Technical factors leading to nonfunctionality of hand pumps

The study assessed the technical factors that could have had a bearing on the high spate of nonfunctionality of the hand pumps in Bumbaire Sub-County (Figure 4.6). In regard to the selection of the site and equipment to use for constructing the hand pumps, majority of the respondents revealed that most of the decisions were made by the NGOs (45.5%). Generally, a significant proportion of the respondents expressed ignorance in regard to how the sites for the hand pumps were selected (28.8%). These statistics implies that the communities hosting the hand pumps were largely on the receiving end and yet the key informants intimated that in almost every community in the sub county, there are some differences among the residents and mainly determined by the religious differences. Therefore, the decision by the NGOs to shy away from

such prevailing conditions had a net effect on the sustainability of the hand pumps constructed in the sub county from time to time.

The other technical aspect that was assessed by this study pertained to the quality of the hand pumps that were constructed in the communities in Bumbaire Sub County. None of the respondents rated the usability of the hand pumps to be good. Majority of the respondents (58.3%) rated the hand pumps “fair” while an equally big proportion of the sampled respondents rating them “poor.” The difficulties reported in the study included rigidity of the pumping handle which the respondents cited as being so hard to move, easy wearing and breaking of the parts of the hand pump system, flooding of the apron areas and use of poor-quality gear or materials that rusted in a short period of time. By implication therefore, the hand pumps installed in the communities were not well planned. It is therefore not by coincidence that very few of them last for more than 5 years. Actually, most respondents revealed that a few of the hand pumps that have been installed in their communities in the last two decades have functioned for more than 8 years, with many hand pumps serving the communities for less than 5 years before they malfunction. This short functional period can also be attributed to lack of technical knowhow and skillset for maintaining the hand pumps periodically. For instance, majority of the respondents (57.7%) revealed that the NGOs failed to plan for the longevity of the hand pumps by among others, failing to train the local community members about preventive maintenance of the hand pumps (Table 4.10). The findings of the study concur with Mulei and Gachengo (2021) who accredited the importance of capacity building for the local communities as one pathway for realizing the functionality of water resources, handpumps inclusive.

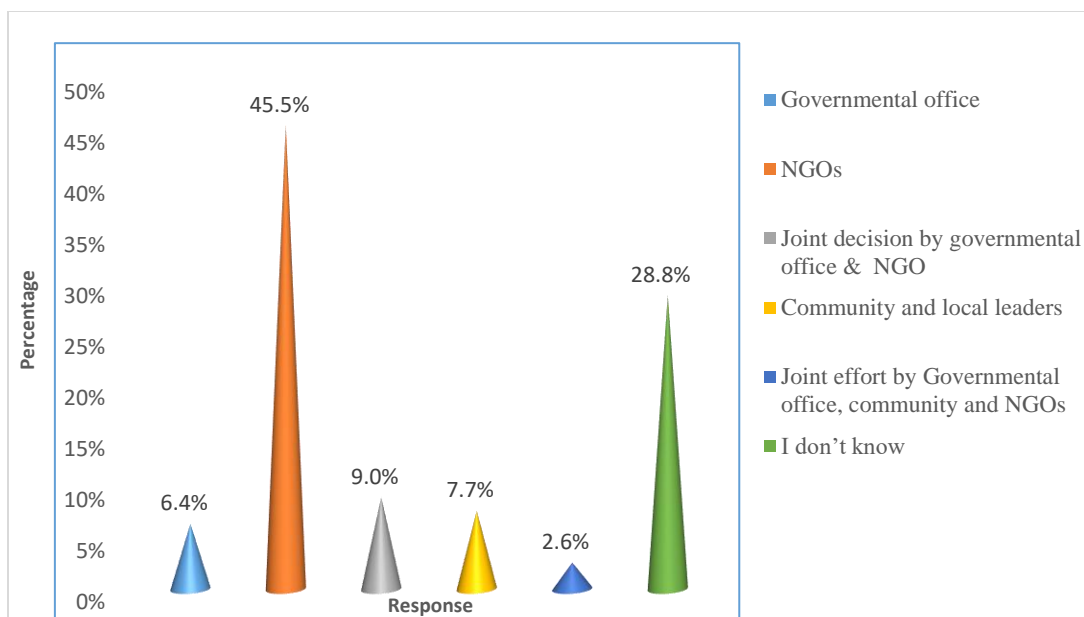


Figure 4. 6: Responses on party responsible for site selection of the hand pumps

Table 4. 11: Technical factors leading to nonfunctionality of hand pumps

	Total N = 156 Respondents	Count	Percent	Cumulative %
<i>Was a preliminary study conducted before establishing the pump?</i>	No	80	51.3	51.3
	Yes	13	8.3	59.6
	I am not sure	63	40.4	100.0
<i>What is your rating of the usability of the pump when it was still operational?</i>	Fair	91	58.3	58.3
	Poor	46	29.5	87.8
	Very poor	19	12.2	100.0
<i>Is there any training given to local technicians engaged in O&M of the hand pumps?</i>	No	90	57.7	57.7
	Yes	8	5.1	62.8
	I am not sure	58	37.2	100.0

Source: Field Data, December 2022.

A further assessment was made to establish whether the maintenance of the hand pumps was affordable. Emphasis was on the spare parts. A high proportion of the respondents disagreed (42.3%) and showed a split opinion (48.1%) regarding the availability of the spare parts for hand

pumps in Bumbarre Sub County and its environs (Table 4.11). Majority of those who agreed that the spare parts were available (53.3%) cited the government agency as the source of the spare parts with a smaller number (20%) and (26.7%) scoring purchase from the local market and donation by NGOs as the other avenues through the spare parts were obtained respectively. Majority of the respondents about the affordability of the price of the spare parts disagreed (53.3%) that the prices were pocket friendly while an equally big number were non-committal (33.3%). Therefore, one can infer that on the whole, the price for obtaining the spare parts was by far prohibitive. This finding finds support in the views of Gameda et al. (2021) who noted that lack of a budget source and limited access to spare parts are some of the causes of nonfunctionality rural handpump water systems in Africa.

Results from FGDs with both men and women confirmed the above gaps. The participants revealed that some hand pumps were non-functional largely because of technical issues. To cope with this challenge, the communities abstained from maintenance until sufficient money was collected from the users. Besides, support was sought from the government offices at the district while on some occasions, the communities mobilized themselves and approached the NGOs in the area for redemption. Practically, as noted earlier about the daily water needs of the communities, abstaining from maintenance exposed the hand pumps to costly and at times, irreparable damage, consequently leading to total breakdown and nonfunctionality. This assertion builds on the argument that water is a basic need and therefore, even when the hand pump appears in trouble, the community will still run to it for the water.

Table 4. 12: Maintenance issues as causes of nonfunctionality of hand pumps

	Total N = 156 Respondents	<i>Count</i>	<i>Percent</i>	<i>Cumulative %</i>
<i>Are spare parts for the hand pumps locally available?</i>	No	66	42.3	42.3
	Yes	15	9.6	51.9
	I am not sure	75	48.1	100.0
<i>If Yes, where do you get the spare parts from?</i>	Total N = 15 Respondents	<i>Count</i>	<i>Percent</i>	<i>Cumulative %</i>
	Purchase on market	3	20.0	20.0
	Provided by the governmental agency concerned	8	53.3	73.3
	Donated by NGOs	4	26.7	100.0
<i>Is the price of spare parts affordable at community level when needed?</i>	Total N = 15 Respondents	<i>Count</i>	<i>Percent</i>	<i>Cumulative %</i>
	No	8	53.3	53.3
	Yes	2	13.3	66.7
	I am not sure	5	33.3	100.0
<i>In case the price is not affordable, what do you do?</i>	Total N = 08 Respondents	<i>Count</i>	<i>Percent</i>	<i>Cumulative %</i>
	Abstain from <i>maintenance</i> until sufficient money is collected from users	4	50.0	50.0
	Appeal to governmental office for support	1	8.3	58.3
	Seek for NGO support	3	41.7	100.0

Source: Field Data, December 2022.

The SCCDO revealed that some of the hand pumps were nonfunctional due to lack of spare parts. This situation was summarised in the words below;

“...The hand pumps in Ryeishe and Numba are out of function because the community members could not access the spare parts within the two towns of Bushenyi and Ishaka. The SCDO revealed further that the spare parts at that time were available in Kampala and not even in nearby Mbarara city. As a result of the back-and-forth movements chasing for the same, part of the money that had been mobilized was spent on transport. Literally, after hitting a snag, the community could not afford the transport charges of obtaining the spare parts from Kampala. Consequently, the hand pumps became nonfunctional. I have reflected this challenge in the community development reports that I normally write on quarterly basis to the district...”

The submission of the SCCDO was echoed by the District Water Engineer who said that for the last 3 years or more, his office has received information from community leadership of Bumbaire Sub County that the numbers of hand pumps were decimated by break downs. One of the cross-cutting factors mentioned by the community leadership and in the application letters for support is limited access to spare parts. The District Water Engineer revealed that while they have supported the cause of the community and extended some funds to augment what was pooled by the communities, at times, this has not become automatic. The reason advanced for failure to maintain the donated hand pumps by the NGOs in the sub county was that quite often, when there is such an outcry, the district treasury does not have any contingency funds from which to draw funds to support such uncertainties. Consequently, the hand pumps become nonfunctional.

Confirmatory evidence of technical challenges facing the communities in the sub county was obtained using the Observation Checklist (Appendix D). The only nonfunctional hand pump in the area (Kiya003 in Kiyaga Parish) had three loose nuts and bolts while on the upper casing, an incompatible nut was fixed on a bolt and this caused damage to the bolt screws. This could have been possibly precipitated by lack of compatible nuts which must have compelled community leadership to improvise. This level of improvisation was dangerous as future repairs would entail breaking the entire top component, consequently leading to cost overruns.

4.4.3 Financial factors leading to nonfunctionality of hand pumps

An assessment was equally made of the influence or contribution of the financial factor towards the nonfunctionality of the hand pumps in Bumbaire Sub County. As was the case established on the foregoing aspects of social and technical factors, the study established that the NGOs contributed a lion's share of the funds that were invested in the installation of hand pumps in most

parts of the sub county (48%) followed by the community (44%). However, on both community and NGO- installed hand pumps, majority of the respondents were non-committal about whether the community contributed money for O&M. This implies that hand pump wells in the area were faced with the challenge of funding especially for O&M servicing. One of the causes of this shortage or lack of funding is the indifferent attitude of the communities. For instance, majority of the community members (80%) were opposed to the idea of paying water user fees (Figure 4.7). The water users equally cited a number of reasons why they felt paying user fees was not worth it. In their order of importance, they cited dissatisfaction with the hand pump water service (30%), water as a gift of nature that should be freely provided (24%) and lack of awareness about the importance of paying the fees (23%), among others (Figure 4.8).

The respondents however expressed that in case they were mobilized and sensitized about payment of user fees, they would easily comply. Majority reasoned that they would comply because water is a basic need and therefore, user fees would be something they would find easy to foot. As shown in Table 4.12, most users intimated that the user fees would support the regular maintenance of the hand pumps and meet other overhead costs or obligations such as paying the emoluments of the team that carry out regular patrols in order to keep the bandits and vandals away. Besides, the accumulation of the user fees would also provide a backup fund that would be used to construct a new hand pump in case the one that they are currently using broke down. The finding is in agreement with Adeenze-Kangah (2022) who established that in Ghana, handpump systems whose beneficiaries contributed user fees were functional most of the time because of preventive maintenance that was supported by the user fees. Such funds were devoted to O&M and more so,

in facilitating the teams and personnel who carried the O&M activities that kept the handpump systems in a functional mode.

Table 4. 13: Financial factors leading to nonfunctionality of hand pumps

	Total N = 156 Respondents	Count	Percent	Cumulative %
<i>Who financed the development of the hand pump?</i>	NGOs	75	48.1	48.1
	Government	8	5.1	53.2
	Community	69	44.2	97.4
	All in collaboration	4	2.6	100.0
<i>Does the community contribute money for O&M?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	No	55	35.3	35.3
	I am not sure	101	64.7	100.0
<i>Do you support the idea of paying water user fees?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	No	125	80.1	80.1
	Yes	31	19.9	100.0

Source: Field Data, December 2022.

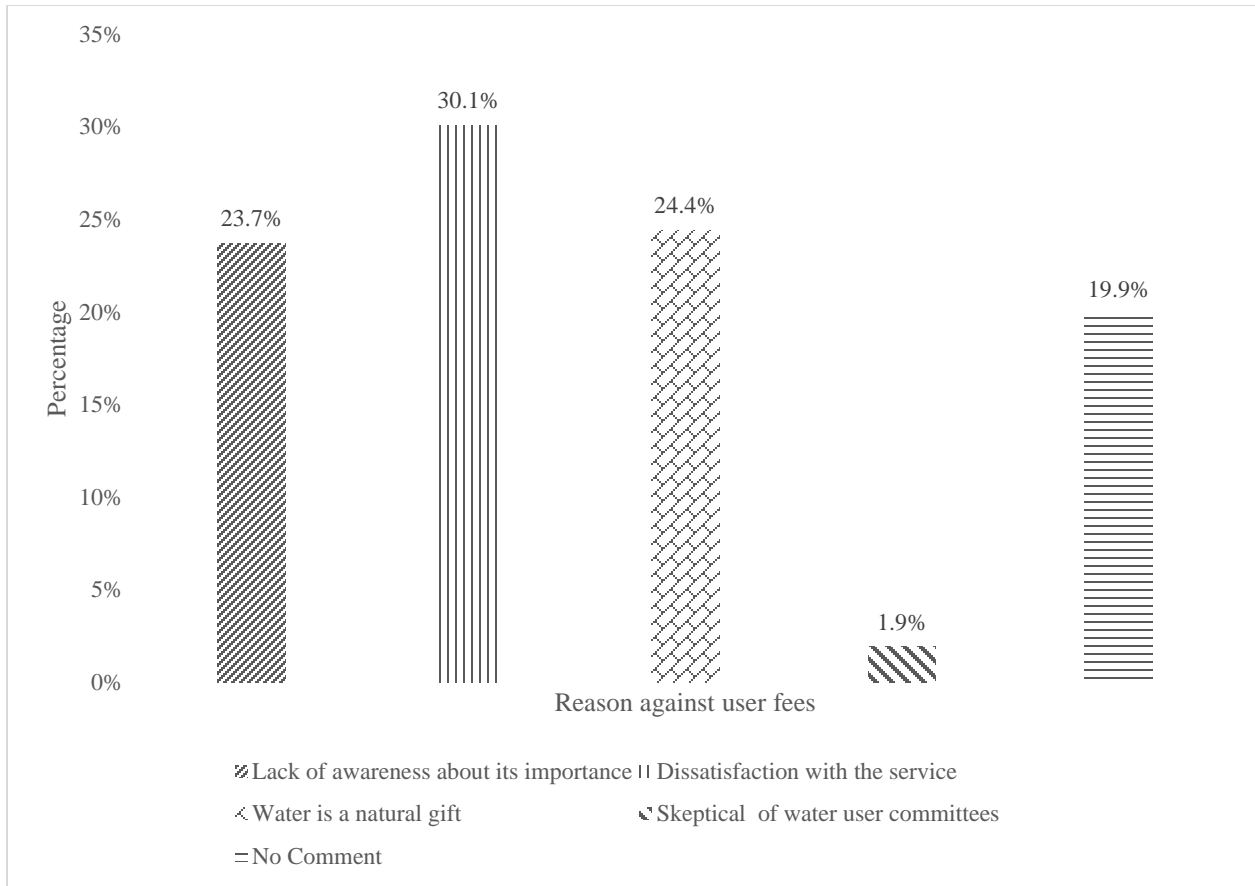


Figure 4. 7: Reasons for declining to pay user fees for hand pump water

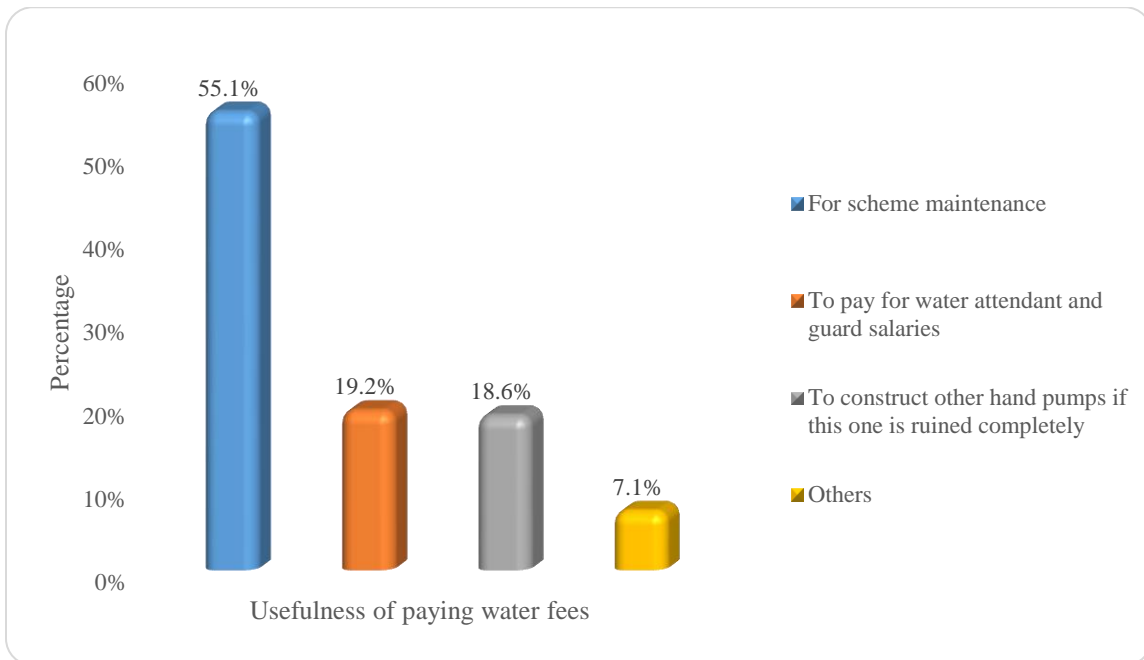


Figure 4. 8: Importance attached to paying user fees for hand pump water

The FGD participants reiterated the importance of community engagement and revealed that there are many social security schemes in the communities including youth groups, women groups and investment groups. In either group, there is pooling of money for saving and future investment. The participants indicated that the prosperity of these groups over the years provides sufficient evidence that when there is active community engagement right from the inception of the handpump projects, the collection of user fees would be very easy because water is an indispensable need. Thus, much as the members in such groups appreciate the usefulness of water to everyday life, they seem not to have bought the idea of contributing funds for sustaining the functionality of the handpumps in the subcounty.

Related issues were raised by the SCCDO and the District Water Engineer. They revealed that water is a cheap commodity and therefore, the financing of the handpump systems in the subcounty would not be a big issue. However, the communities are yet to appreciate the idea that the handpumps belong to them, given the fact that they were not fully engaged throughout the project cycle. The SCCDO went further and indicated that as long as the issue of community ownership has not been emphasised, the handpump systems can hardly be owned and maintained by the communities. This argument was reinforced in the following words;

“..., I highly believe that a grand plan needs to be worked on that can venture into deploying a group of community and rural development specialists to work with my office in mobilising and sensitizing the communities about the ways and means through which the handpump systems can be maintained....this team should include the donor NGOs and the District top leadershipsuch a broad-based team would help in shaping the attitudes and changing the perceptions of the communities regarding ownership of the water systems...I am convinced that the communities would appreciate the work done by the team and would

consider mobilising water user fees for sustaining the functionality of the handpumps in the area....I am sure this strategy would work and produce wonderful results because other related community development programmes in the sub county are using a similar approach....”

4.4.4 Institutional factors leading to nonfunctionality of hand pumps

The last set of factors assessed by this study were the institutional dynamics. Views were sought from the respondents about whether the stakeholders in the area such as district water office and NW &SC among others, carried out follow ups about the performance of the hand pumps. Majority of the respondents were not sure (53.2%) while a big proportion (46.8%) disagreed. This finding portrays that the technical stakeholders of water and sanitation in Bushenyi District never played a key role in supporting the sustainability of the hand pumps in the sub county.

Further evidence of limited institutional support was further cited by the respondents where the majority (61.5%) disagreed that in communities where hand pumps are currently governed by a water user committee, no external support for O&M has been received from the government (Table 4.13). The only external assistance was solicited by the communities from the NGOs serving in the area (66%) and more so those that have a component of Water, Sanitation and Hygiene (WASH) among the services range rendered to the communities. The respondents cited training and financial support as the key forms of assistance secured from the NGOs as well as availing of spare parts. Furthermore, the respondents cited the ways in which they ought to be assisted or supported in order to maintain the hand pumps in functional mode, including active involvement of all the community members at all stages, among others (Figure 4.9). The lack of multi-stakeholder collaboration was decried by Shongwe and Dlamini (2021) who recommended the need for systems thinking, a practice that has the potential of enabling the policy-makers and opinion leaders to have an inside-out analysis of the problems at hand and hence, to realise the

opportunity of locating the most important interventions with potential of leveraging the desirable sustainable solutions.

Table 4. 14: Institutional factors leading to nonfunctionality of hand pumps.

<i>Is there any follow-up carried out by stakeholders about the status of hand pumps?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	No	73	46.8	46.8
	I am not sure	83	53.2	100.0
<i>Does the water committee of your hand pump receive external support from government for O&M?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	No	96	61.5	61.5
	I am not sure	60	38.5	100.0
<i>Did the water committee of your hand pump receive external support from NGOs for O&M?</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	Yes	103	66.0	66.0
	I am not sure	53	34.0	100.0
<i>If yes, what kind of support does your community get from NGOs?</i>	Total N = 103 Respondents	Count	Percent	Cumulative %
	Training	57	55.0	55.0
	Materials	1	0.9	56.0
	Financial	45	44.0	100.0
	Total	103	100.0	
<i>In your opinion, what types of support are needed by the community to make the hand pump functional for a long period of time</i>	Total N = 156 Respondents	Count	Percent	Cumulative %
	Spare parts	79	50.6	50.6
	Quality construction	11	7.1	57.7
	Trained local technicians	9	5.8	63.5
	Active involvement of the community water users at all stages	10	6.4	69.9
	Other	47	30.1	100.0

Source: Field Data, December 2022.

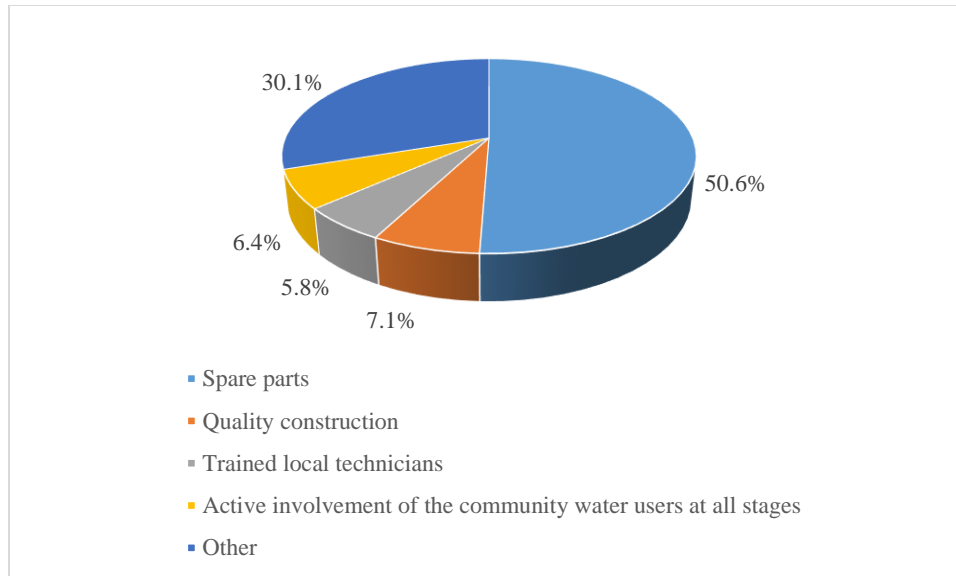


Figure 4. 9: Extent of support needed by the communities for maintaining the hand pump systems

The FGD participants revealed that intra-and inter-institutional collaborations were important for maintaining the functionality of the handpump water systems in the sub county. The participants used the referent of agricultural development projects in the communities that have succeeded over time because of collaborations between institutions. They reiterated that such templates could be benchmarked and replicated in the handpump water management system in the area. The same views were shared by the SCCDO and District Water Engineer during interviews. The duo revealed that different institutions have different strengths. When the strengths are combined, there is synergy. Such synergy would support and sustain the community initiatives for enhancing the functionality of the handpump water systems in the area.

4.4.5 Regression results on the significance of the causes of nonfunctionality of hand pumps

A multivariate model was run in SPSS using the average indices of community factors (COMMFAC), Financial factors (FINFAC), Institutional collaboration (INSTICO), Technical

factors (TECIFA) and water quality factors (WAQUAFA) to establish their significance to causing nonfunctionality of hand pumps. The results obtained are shown below;

Table 4. 15: Regression model results

Variables	Unstandardized coefficients (β)	Standard coefficients(β)	t-statistic	p-value
Nonfunctionality	.309		3.772	0.000
COMMFAC(X1)	.278	.311	3.061	0.011*
FINFAC (X2)	.232	.302	2.614	0.010*
INSTICO(X3)	.228	.299	3.066	0.011*
TECIFA(X4)	.131	.173	2.571	0.014*
WAQUAFA(X5)	.120	.132	3.088	0.003*

The resulting regression model was $Y=0.309+ 0.278X_1 + 0.232X_2 +0.228X_3 + 0.131X_4 +0.120X_5 + \varepsilon$. The model therefore suggested that community factors, financial factors and institutional collaboration were the major causes of non-functionality of the hand pumps while technical factors and water quality factors had a moderate effect.

4.4.6 Gaps analysis

Bumbaire sub-county was the problem space for this study forming the basis for designing the framework for managing the functionality of handpump water systems in the area. From the preceding field findings, gaps in the management of the functionality of the hand pump were identified by the respondents while others at large were identified by the researcher through review of existing literature at the district and through observation. The voids identified enabled the researcher to determine requirements for designing the framework for improving the management

of functionality of the hand pumps in the sub county. Table 4.14 provides a summary of the voids and the emerging requirements for designing the framework to improve the maintenance of the hand pumps.

Table 4.16: Existing gaps in the maintenance of hand pumps in Bumbaire sub county

Code	Maintenance gaps	Code	Derived requirements for framework
HPMG1	Limited involvement of the community members in the establishment of hand pumps.	DR1	Active engagement of the community members is important right from the inception of the hand pump project since they are the water users and frequently interface with the hand pump systems
HPMG2	Low community responsibility manifested by the absence of formally constituted and vibrant water user committees	DR2	The establishment of and consequent active involvement of community selected and elected water user committees is important for attitude change, information sharing and mobilisation of resources such as water user contribution for maintenance of the hand pumps
HPMG3	Build and Transfer Approach used by the NGOs is disempowering as it creates a vacuum that contracted firms use to do shoddy works	DR3	Clearances from the District Water Office and entrusting the community political and opinion leaders has potential of minimizing the magnitude of shoddy works.
HPMG4	The construction of the hand pumps and the District Water Office are not interlinked. The working procedures followed in the construction	DR4	Linkages between the donor NGOs and the District Water Office ought to be continuous than the current one-off clearances and coordination. This will enhance the sharing

Code	Maintenance gaps	Code	Derived requirements for framework
	of the long serving hand pumps are not shared between the parties.		of work procedures that will engender sustainability.
HPMG5	Indifference among community members who are unwilling to make contributions however small or affordable they are for maintenance of the hand pumps.	DR5	Engagement of the communities through the construction phases and mobilisation campaigns including periodic open forums are pathways for shaping the attitudes of the communities to support the cause for maintaining the functionality of the hand pumps.
HPMG6	Limited engagement of non-hand pump water using stakeholders such as dealers in spare parts leads to inflated charges on spare parts and O& M contracts.	DR6	Active engagement of every concerned stakeholder is necessary for enhancing integrated efforts for the sustainable management of the hand pumps.
HPMG7	Lack of local O&M personnel to respond to immediate warning signs of break-down	DR7	Training of local personnel is a tailor-made and cost-effective way of ensuring that the cost of maintaining the hand pumps is kept within acceptable and affordable limits

HPMG= Hand Pump Maintenance Gap **DR**= Derived Requirement

Source: Field Data, December 2022

Table 4.14 shows the shortcomings identified from the findings derived from the questionnaires, interviews, FGDs and review of related documents. The emerging gaps laid a foundation for identifying the design requirements for the hand pump water system maintenance framework. The practical relevance of each of the derived requirements is discussed below;

DR1: Active engagement of the community members is important right from the inception of the hand pump project since they are the water users and frequently interface with the hand pump systems.

Majority of the respondents revealed that there was laxity in the engagement and involvement of the community members right from the inception of the projects. This gap implied that there was limited community ownership and buy-in for the hand pumps. Extant evidence is further provided by the failure to engage the women and yet practically, the gender division of labor in the communities reserved the role of fetching water to women and girls. This negation therefore implied that there was a missing link in reporting and alerting the concerned authorities about the trouble that the hand pumps were soon falling into.

DR2: The establishment and active involvement of community selected and elected water user committees is important for attitude change, information sharing and mobilisation of resources such as water user contribution for maintenance of the hand pumps

The involvement of the water user committees in the management of hand pumps in the framework addresses the existing vacuum in the communities whereby despite the existence of layers of responsibility in other socioeconomic, political and cultural facets, the hand pumps have continued to become a to whom it may concern resource. Water user committees are critical in the management of shared community resources such as hand pumps for monitoring and mobilisation of the users for a common cause.

DR3: Clearances from the District Water Office and entrusting the community political and opinion leaders has potential of minimizing the magnitude of shoddy works.

In the past years, the District Water Office has always cleared the NGOs that donate the hand pumps without making follow-ups. The NGOs with expertise in water construction projects are

also limited in the area. As a result, the NGOs have always contracted third parties who eventually do shoddy work. The delegation of responsibility to community-based groups or teams is a magic bullet that will keep the contracted firms accountable consequently leading to quality deliverables.

DR4: Linkages between the donor NGOs and the District Water Office ought to be continuous than the current one-off clearances and coordination. This will enhance the sharing of models and work procedures that will engender sustainability.

Two prominent players in the establishment of the hand pumps in the area are operating as silos. This accounts for why some hand pumps have worked consecutively for years without any major breakdowns. The framework prescribes need for maintenance of close linkages so that best work practices such as models can be shared and used whenever new hand pumps are to be established in the area. The modalities under which the functioning water sources are maintained can also be documented and shared as best practices and model knowledge that can be replicated in the different communities.

DR5: Engagement of the communities through the construction phases and mobilisation campaigns including periodic open forums are pathways for shaping the attitudes of the communities to support the cause for maintaining the functionality of the hand pumps.

The derived requirement is an antidote to the existing problem of unwillingness of the community members who the water users to pay water user fees. This indifference was reported to have financial implications to the maintenance of the hand pumps, with the majority of the respondents expressing their unwillingness to pay any penny for maintaining the sources. When the engagement of the community members is prioritized, the refusal to contribute for the maintenance of the hand pumps will cease to be a serious challenge.

DR6: Active engagement of every concerned stakeholder is necessary for enhancing integrated efforts for the sustainable management of the hand pumps.

The requirement addresses the gaps existing in accessing spare parts at affordable costs. This will not only provide a means of identifying competent suppliers but will also strengthen the relations between the authorities concerned with the maintenance of the hand pumps.

DR7: Training of local personnel is a tailor-made and cost-effective way of ensuring that the cost of maintaining the hand pumps is kept within acceptable and affordable limits

The creation of a pool of locally trained personnel in O&M of hand pumps will mitigate the current challenge of lack of skilled manpower. The local trained manpower will therefore ably provide routine preventive maintenance compared to the current reactive maintenance which is expensive in both relative and absolute terms.

4.5 Designed framework for managing the nonfunctionality of hand pumps

Objective two (2) of the study sought to design a framework. The purpose of this objective was to design a framework for improving the maintenance of the hand pumps in Bumbari Sub County and specifically, minimising the nonfunctionality of the handpumps. The section presents the designed framework which integrates the solutions proposed to close the gaps existing or likely to crop up in regard to the maintenance of hand pumps in the sub county. The proposed solutions were presented in the preceding chapter as ‘derived requirements’ which are case specific in regard to addressing the major challenges and gaps identified from questionnaire, interview and FGD findings.

4.5.1 Design decisions considered while developing the hand pump management framework

The study adopted DSR methodology which obliges the scientists to make a critical analysis of the design requirements synthesized from the observed gaps so that they are able to make the best decisions to guide the designing of the framework. The decisions presented in Table 4.14 are rooted in the established knowledge body. The knowledge body underscores the viability of each of the strategies that is incorporated in the framework as a lasting solution for the existing maintenance gaps.

Table 4.17: Requirements and design decisions taken in designing the framework for maintenance of hand pumps

Code	Derived requirements for framework	Code	Decision made	Relationship between decision made and design requirement	Source of Design Decision
DR1	Active engagement of community members is important right from the inception of the hand pump project since they are the water users and frequently interface with the hand pump systems	DM1	Active engagement of community members is important for buy-in and ownership of constructed hand pumps	Engaged and positive communities will minimize the magnitude of vandalism and will report any challenges requiring attention in time before it escalates	Literature Review
DR2	The establishment of and active involvement of community selected and elected water user committees is important for attitude change, information sharing and mobilisation of resources such as water user contribution for maintenance of the hand pumps	DM1	When water user committees are fully established, they will help to weather down any form of resistance to any proposals and call for regular maintenance of hand pumps, something the communities are missing at present.	User committees will break community resistance to contributing for O&M activities, leading to regular maintenance of the hand pumps	Literature Review

Code	Derived requirements for framework	Code	Decision made	Relationship between decision made and design requirement	Source of Design Decision
DR3	Clearances from the District Water Office and entrusting the community political and opinion leaders has potential of minimizing the magnitude of shoddy works.	DM2	Delegation of responsibility by the District Water Office will serve as an empowering strategy that will keep the contractors answerable and under the careful watch of the community members	This will provide a lasting solution to the current spate of breakdown of newly constructed hand pumps due to shoddy works.	Literature Review
DR4	Linkages between the donor NGOs and the District Water Office ought to be continuous than the current one-off clearances and coordination. This will enhance the sharing of models and work procedures that will engender sustainability.	DM3	Diversity of methods and techniques does not encourage transfer of knowledge and transfer of learning and yet these are vital for improved performance of projects	The recurrent hiccups of breakdown of hand pumps will be easy to assess and examine using parameters from the models used	Literature Review
DR5	Engagement of the communities through the construction phases and mobilisation campaigns including periodic open forums are pathways	DM1	Ensuring that the communities are engaged regularly about the satisfaction with the quality of hand pumps is a credible way of	This will make O& M a routine activity	Literature Review

Code	Derived requirements for framework	Code	Decision made	Relationship between decision made and design requirement	Source of Design Decision
	for shaping the attitudes of the communities to support the cause for maintaining the functionality of the hand pumps.		cultivating trusting relationships with water users and has the potential of inducing their willingness to fundraise for hand pump maintenance.		
DR6	Active engagement of every concerned stakeholder is necessary for enhancing integrated efforts for the sustainable management of the hand pumps.	DM1	Stakeholders such as spare part dealers are partners who cannot be kept on the fringes, lest they will continue to inflate the prices of the spare parts, leading to costly O&M activities.	Committed stakeholders will be supportive of the maintenance activities and will avail the accessories at tailor made price rates.	Literature Review
DR7	Training of local personnel is a tailor-made and cost-effective way of ensuring that the cost of maintaining the hand pumps is kept	DM4	This will fill the existing gap of limited local manpower in the area, consequently improving the maintenance of hand pumps.	Local manpower encourage preventive maintenance compared to hired manpower that usually prefers reactive maintenance for purposes	Literature Review

Code	Derived requirements for framework	Code	Decision made	Relationship between decision made and design requirement	Source of Design Decision
	within acceptable and affordable limits			of quoting exorbitant rates for O&M activities	

Source: Field data, December 2022. DR= Design Requirement; DM= Design decision made

DM1 Stakeholder engagement

The study findings reported in the preceding section indicated that user committees were non-existent in the communities. Besides, the water users were treated by the NGOs and District Water Office as quasi partners and passive recipients. This accounts for why issues such as solicitation of contributions from the users were met with stiff resistance. What is more to say, the scale and magnitude of vandalism of the hand pump installations were also an acute problem as reflected in the documented evidence in the Water Development Reports archived at the district. On account of this challenge, the designed framework prescribed the need for active engagement of the stakeholders so that there is improved commitment and feeling of ownership of the hand pumps. This also has a long way to go with regard to shaping the attitudes of other stakeholders such as the spare part dealers, who also inflated the prices leading to delays in the correction of any faults that happened from time to time. The respondents intimated that the failure to engage these stakeholders gave birth to a ‘community tax’. This referred to higher charges sometimes resulting from hoarding of the spare parts. This prescription is a corrective strategy for addressing the challenge of indifference among the stakeholders and will eventually lead to an improvement in community buy-in and commitment to the regular or periodic maintenance of the hand pumps.

DM2 Delegation of responsibility by District Water Office

The decision to delegate monitoring and maintenance responsibility to the community groups and teams helps to address the gap of the one-off clearance of the NGOs that have constructed many hand pumps in the sub county. The decision circumvents the possibility of shoddy works being delivered by the contracted companies. The delegates become the ears and eyes of the District Water Office and equally, they play a monitoring role that keeps the contracted companies focused on the agreed upon BOQs and project timelines. This is very critical and will serve as a quality

assurance strategy, given that other facets of community development are monitoring delegated projects by the government through the respective district offices. A case example is the seed schools that are being constructed by the government at sub county level.

DM 3 Synergistic linkages between District Water Office and NGOs

The design decision making on synergy is to ensure that there is integration of information sharing between the District Water Office and the NGOs. The District Water Office implements hand pumps for some donors and the government while the NGOs single-handedly implement the project with limited or no consultations with the District Water Office. Therefore, there are no established models that are followed by the two bodies for constructing standard hand pumps. Thus, when there are coordination linkages between the two, the resulting synergies will pave way for the formalization of the models and modalities which has potential for enhancing the construction of standard hand pumps as well as consequent maintenance systems.

DM4: Creation of a pool of local trained personnel

Results of the study showed that there was a serious problem of manpower for carrying out the maintenance work. As a result of this shortage, there was limited preventive maintenance. The reactive maintenance plans normally executed not only raised the ire of the community but also increased on the wear and tear of the hand pump system. In some cases, this leads to complete malfunctioning of the entire system in case the reactive maintenance activity was delayed. Therefore, this decision as integrated on the framework has the potential of changing the status-quo and consequently improving the maintenance of the hand pumps.

4.5.2 The designed framework

The hand pump water system maintenance framework presented in this section is consolidated output that marries the design requirements and the design decisions charted in Table 4.15. Figure 4.1 presents the schematic flow of the designed framework.

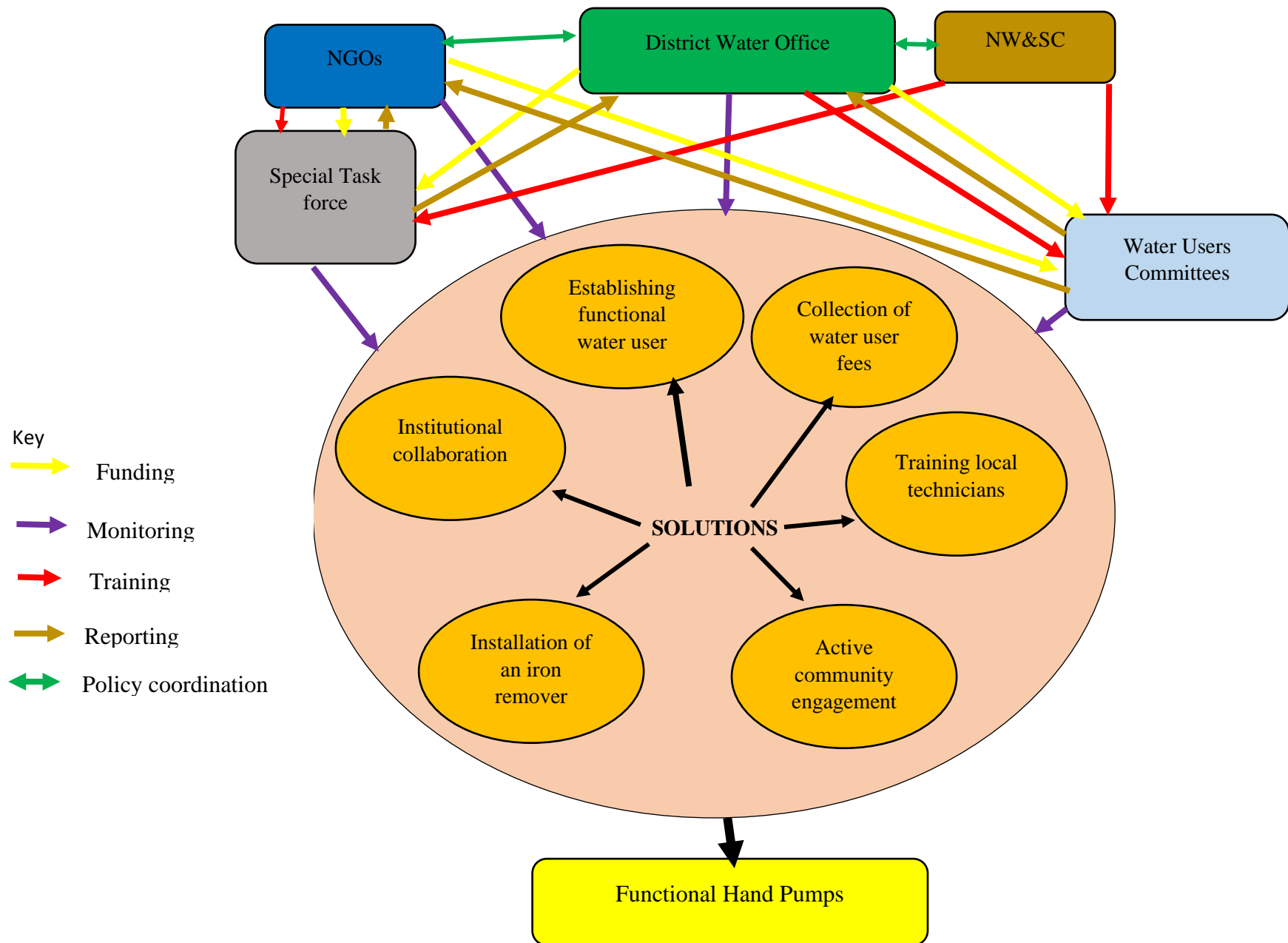


Figure 4. 10: Hand pump water system maintenance framework

Figure 4.10 above shows the functional handpump water system management framework developed from the design decisions and corresponding design requirements for closings identified gaps regarding the functionality of hand pumps in Bumbaire Sub County in Bushenyi District. The designed framework fulfills the requirements of objective two (2) of this study that was poised to design a framework for closing the gaps leading to nonfunctionality of hand pumps.

4.5.3 Key features of the hand pump maintenance framework

The designed framework incorporates 5 entities. These are District Water Office, NW&SC, NGOs, Water user committee and special task forces. The framework attaches prime importance to the District Water Office as the mandated body by the Local Government Act to oversee issues related to water governance in the district. The NW&SC office is also a cardinal institution earmarked by the framework for providing the technical expertise regarding quality of the water and any other maintenance roles. The NGOs are equally included because in the preceding sections, it was reported that majority of the hand pump water systems in the sub county were constructed by NGOs and a Build and Transfer (BaT) arrangement. Besides, the water user committees are included in the framework because these are community-based groups that serve as watchdogs for the security and proper use of the hand pumps. Lastly, the special task forces are incorporated in the framework because they play a vital role in the establishment of new hand pumps, much as they can also be engaged in overseeing the credible maintenance of the established and operational hand pumps. This recommendation is in agreement with Otieno (2019) who noted that functional water user committees have the potential of mobilising and sensitizing the water users consequently leading to change in attitude and perceptions. The shaped attitudes have the potential of increasing the willingness of the water users to contribute water user fees. The salient features of this framework are discussed below;

4.5.3.1 Training for local ownership

The framework puts thrust on the importance of training the water users regularly. This was one of the key gaps identified by the study. The framework proposes trainings from different entities, all targeting the members of the water user committees and the special task force. NW&SC, District Water Office and NGOs are all implored by the framework to ensure that there is regular training of the water users in order to change the perceptions that they currently hold about the maintenance of the hand pumps for continuity. This training can take the form of workshops, seminars and *barazas*. This recommendation in the framework is highlighted by Naiga (2021) who noted that local management of the water systems is trending and has shown signs of engendering sustainability. Capacity building is revered largely because it improved local ownership greatly. The decision to entrust the management of the water schemes to local people is premised on the belief that when water system maintenance is locally financed, it is maintained in a condition that ensures reliable and adequate water supply, and benefits of the supply continue to be realized by all users (Kativhu et al., 2022). Consequently, it becomes sustainable (Kativhu et al., 2022).

4.5.3.2 Information sharing through databases

The database is another notable salient attribute of the designed framework. A database is also called an electronic database (Britannica T. Editors of Encyclopedia, 2020). According to Oracle (2021), a database is an organized collection of structured information, or data, typically stored electronically in a computer system. Ashdown *et al.* (2018) defines it as an organized collection of information with a purpose of collecting, storing, and retrieving related information for use by database applications. Both NW&SC, District Water Office and NGOs will have databases from which information pertaining to maintenance of the hand pumps will be stored. This is indicated

by the double-banded green arrow. The sharing of information between the databases will provide a basis of implementing the best practices for maintenance of the existing hand pumps.

4.5.3.3 Multiple monitoring

The framework underscores the potency of multiple monitoring by the involved parties. This monitoring should be unstructured and impromptu such that the organic reporting and crafting of plausible solutions can be duly realized. This significance is reflected by the purple lines which are indicative of the assigned responsibilities for both District water office, media, NGOs, Water User Committees and the Special Task Force. This solution is mirrored in the observations of Klug et al. (2018) who noted that improved monitoring instruments that would be generated by the above stakeholders would enable actors to target appropriate resources to address specific breakdowns likely to rise based on system type and management characteristics in order to inform improved implementation of post-construction support.

In the framework, water quality monitoring is proposed. One of the ways in which the quality of water can be improved is by installing an iron remover in the handpumps. This is a technical matter that requires the intervention of the District Water Engineer and NW&SC. This will improve the quality of the water in the handpumps. A synthesis by Furey (2014) of online discussions on hand pump technology among rural water supply specialists and practitioners between 2012 and 2014 concluded that water quality, particularly related to high iron corrosion was a major issue. Thus, this solution as professed in the framework is very important. Further, the finding is in consonance with Casey et al. (2016) who established that high iron concentrations is a common problem in rural water supplies across many countries in Africa. Typical problems include metallic taste, discolored and turbid water following pumping, and discoloration of food and clothing (Casey et

al., 2016). To ameliorate this challenge, Casey and colleagues recommended the need for fixing an iron remover in the water systems so that the quality of water is maintained.

4.5.3.4 Funding

The Yellow arrow in the framework also obliges the District Water Office and NGOs to allocate a vouch in their budget for incentivizing the special task forces and water user committees. The motivated members will be dedicated to their work and will hardly be compromised in case of allocating the new hand pump construction work to contractor firms. This will eliminate the possibility of shoddy construction works, which was identified in the study as a key cause of nonfunctionality of the hand pump water systems. The component of funding is likely to become significant when there is multistakeholder collaboration as suggested by the framework. The solution is equally applauded by MacManus (2021) who established that multistakeholder collaboration leads to continuous service provision, regular fee collection by a committee, and technical capacity consisting of external support response, and an operations and maintenance plan.

4.5.3.5 Reciprocal communication

The framework will also enhance seamless and fluid two-way communication since it agitates for regular reporting between the parties involves. By doing so, the maintenance of the hand pumps will improve greatly since timely information will always be availed. Therefore, coordination and preventive maintenance of the hand pumps will be realized.

4.6 Evaluated Hand pump water system maintenance framework

Objective three (3) of the study sought to come up with and evaluated framework for effective management of hand pump water systems in a functional state in Bumbaire Sub County. The framework was evaluated in Bumbaire Sub County. The decision to use the naturalistic setting was based on the recommendations of Venable (2006) that preferably, frameworks that are aiming at addressing longstanding problems in communities should use real-life settings and involve real users of the framework. The evaluation of the designed framework was done in March 2023 and involved the purposively selected respondents from the communities and District leadership. Below, were the procedures followed in evaluating the framework;

4. 6.1 Evaluation criteria

The hand pump water system maintenance framework in the preceding was designed following the prescriptions of the DSR Methodology. It is important to note that in DSR methodology, designing is an intermediate stage. Without any evaluation, the designed artefact may appear attractive on paper but with little or no relevance to the environments where it is supposed to be applied. Therefore, by stopping at the design stage, the principles of science have not been duly fulfilled. This assertion is supported by Romme et al. (2021) who noted that DSR combines design and science and is akin to “mixing oil with water.” Romme *et al.* (2021) further argue that the task of mixing oil and water can never be complete when the two components are partially mixed and left to separate again. For this reason, gurus in science such as Benfell (2021) recommended that testing and evaluating of the solution developed through DSR should be the ultimate objective of any researcher who adopts the DSR methodology. By failing to do so, the solution at hand is subjective since it has not been approved by the actual people who are meant to use it. It can even attract apathy and therefore, the affected institutions can remain in the status quo, with no value

added. Thus, evaluation is a critical component of design science research because it provides the binoculars through which the efficacy of the proposed solution is determined and appreciated (Hevner *et al.*, 2004). The intent of evaluating the hand pump maintenance framework was to establish whether it was usable, simple, understandable, traceable, complete, applicable, useful and accurate. These parameters upon which the evaluation was based were underscored by several studies (such Baskerville *et al.*, 2018; Hevner, 2007; Hevner *et al.*, 2004; Pfeffers *et al.*, 2018) and confirmed to be credible and noteworthy. While it would have been plausible to evaluate the framework on all these parameters, this study largely aimed at establishing whether the framework was efficient and usable for the intended purpose and user groups respectively. The two parameters were considered very important by the researcher. This helped in scaling down the complexities involved in evaluating the framework on all the parameters mentioned earlier. This decision is rooted in the recommendations of Romme *et al.* (2021) that only the parameters deemed to be very relevant to evaluation should be selected by the researcher. After all, the study also had time and resource constraints further justifying while a few ingredients of evaluating the framework were taken into consideration.

There are two environments where a developed framework can be evaluated from. This can be artificial which entails the use of simulations. Differently, the evaluation can be carried out in the physical setting and engage real users of the solution. According to Venable (2006), since the intent of designing the framework was to address a long-standing problem, it is highly recommended that the framework be evaluated in a real-life setting involving the real users. By doing so, the existing gaps are addressed hence minimizing the escalation of the malaise that motivated the designing of the framework. In this study, the hand pump water system maintenance

framework was evaluated in Bushenyi District. The study sites in Bushenyi District and the actual questionnaire, interview and FGD participants took part in the evaluation.

4.6.3 Evaluation methodology adopted

Designed solutions or artefacts should adopt a commendable methodology so that the users in the physical setting are introduced to the artefacts and grounded into its applicability and the suggested recommendations that it is communicating (Hevner et al., 2004). Choice can be made from observation, experimental, analytical, test-oriented and descriptive evaluation. To achieve the ultimate goal of this study, the analytical evaluation methods was selected since it is widely used in evaluation of artefacts in different environmental settings (McLaren *et al.*, 2011). In this study, the researcher adopted the cognitive walkthroughs as the best analytical method for inculcating the participants into the efficacy of the developed framework. According to Shekhar and Marsden (2018) and Juliana (2023), cognitive walkthrough is a usability engineering method that helps one to evaluate how easy it is for users to learn and perform tasks with a developed product. This process involved use of peers to review the framework after they were taken through a step-by-step discussion. This was followed by sampling out a few users among those who took part in the initial data collection to establish the credibility of the framework in addressing the gaps which they had pointed out. The essence of the cognitive walkthroughs was to assess whether there were any digressions in the entire framework and how its applicability and efficacy would be improved. The evaluation process was formal and entailed responding to a survey. After the preamble information in the mini-survey, the real designed framework was included. This gave me the opportunity of taking the evaluation survey participants through the flow relationships before they took part in the survey. The participants after rating the efficiency and usability of the framework, were equally obliged to provide their recommendations that would improve the maintenance of

hand pumps but were seemingly not featuring anywhere on the framework and in the explanatory notes.

The evaluation involved 10 participants who were selected because of experiential and technical knowledge in rural water resources management. District Water Officer, the SCCDO and professionals in water resource management at community level were engaged. The community level professionals were retired officers. All the selected respondents responded to the evaluation questionnaire survey (Appendix H) the entire sample that participated in answering the questionnaire items.

4.6.4 Results from evaluation survey

4.6.4.1 Data Quality Control

The evaluation survey questionnaire was assessed by my supervisor and 1 subject matter expert from Bushenyi District Water Office. Their participation helped to increase the face and content validities. Besides, a reliability analysis was also run in SPSS. The coefficients from Content validity and reliability tests were interpreted using the reference threshold of 0.7. The same threshold was used in interpreting the validity and reliability results from the initial socio-economic survey. Table 4.16 presents the computations of validity and reliability

Table 4.18: Test values for validity and reliability of the evaluation questionnaire

Tested Aspects	Number of Items	CVI	α
Efficiency	5	0.83	0.84
Usability	4	0.80	0.87

Source: Field Data, March 2023

CVI=Content validity Index, α =Cronbach Alpha

Both CVI and Cronbach alpha values for the statements assessing the efficiency and usability of the framework were higher than 0.7. Therefore, the statements used were valid and reliable.

4.6.4.2 Survey evaluation results

4.6.4.2.1 Background characteristics of evaluation participants

The evaluation survey captured the socio-demographic characteristics of the respondents. The following results were obtained;

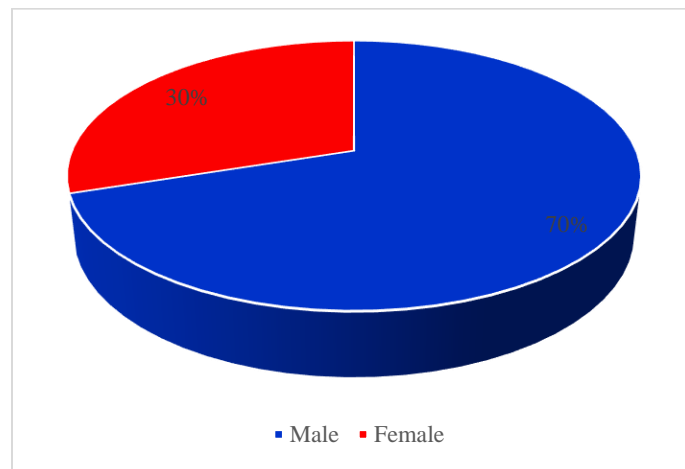


Figure 4. 11: Description of the participants in framework evaluation by gender

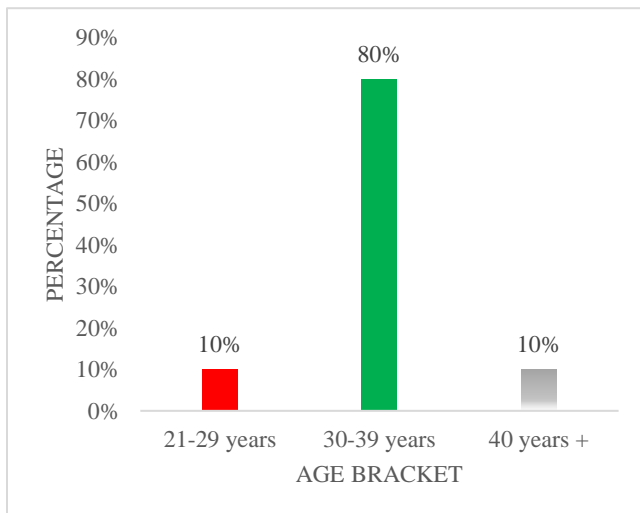


Figure 4. 12: Description of the framework evaluation respondents by age

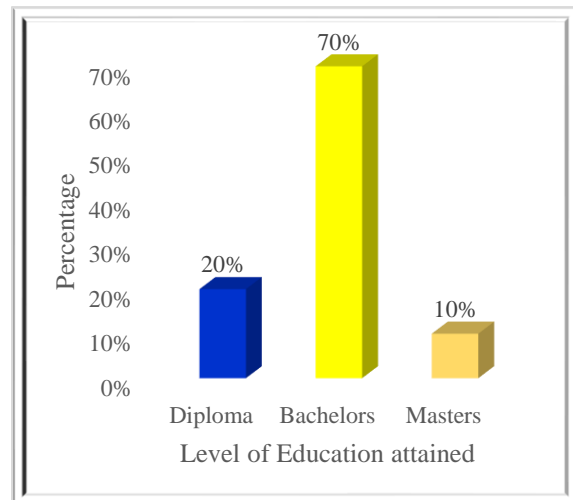


Figure 4. 13: Description of the framework evaluation respondents by level of education

Results in Figure 4.11 indicate that majority of the evaluation survey participants were male (70%). Besides Figure 4.12 Shows that corresponding bigger percentage (80%) were aged 30-39 years. Moreover, regarding education level, majority of the survey participants (70%) were holding a bachelor’s degree in water and water resource management related profession (Figure 4.13). This increased in the quality of the responses to the survey statements as well as ease in comprehending the explanations made during the cognitive walkthroughs.

4.6.4.2.2 Findings on ranking of the solutions provided by the framework

After taking the respondents through the structure and interrelationships in the designed framework, a follow up question in Section B of the evaluation survey required the respondents to provide a rank to each of the provided solutions. The following results were obtained;

Table 4.19: Views of the respondents on the relative importance of the solutions specified by the framework

Solution	f (%)	Rank
1. Active community engagement	10 (100)	1 st
2. Collection of water user fees	9 (90)	2 nd
3. Establishing functional water user committees	8 (80)	3 rd
4. Training of local technicians	8 (80)	3 rd
5. Institutional collaboration	7 (70)	5 th
6. Installation of an iron remover	3 (30)	6 th

n=10 respondents

Source: Field Data, March 2023

Results in Table 4.18 show that all the respondents ranked community engagement as the most important solution communicated by the framework. This was rated highly because the respondents that successive management of handpump functionality such as collection of water user fees for O&M as well as establishment of functional water user committees are dependent on how receptive the communities are. Still, the 3rd rank accorded to training of local technicians is largely influenced by the extent to which the communities feel they own the handpump water systems. Equally, the same aspect of active community engagement largely determines the success of institutional collaborations. While there can be formal and active institutional collaborations, the efficacy of their plans and interventions can hardly take course unless the communities are positive. Lastly, fixing and iron remover received less accreditation. What can be surmised from this result is that the respondents were not familiar with the iron remover, largely because apparently, it is not used in the study sites.

4.6.4.2.3 Findings on efficiency and usability of the framework

Findings on efficiency and usability of the framework are presented with tabular devices and interpreted using mean values as shown below;

4.6.4.2.3.1 Efficiency of the framework

The efficiency (efficacy) of the designed hand pump water system maintenance framework was evaluated using five items. The results obtained are presented in Table 4.19 below;

Table 4.20: Views of the participants on the efficiency of the framework

Statements	Mean	St. Dev.
1. The framework enables tracking of all issues associated with hand pumps	4.12	0.901
2. The framework simplifies the process of communication between the parties managing the hand pumps	3.66	1.142
3. The framework localizes the management and maintenance of the hand pumps	4.22	0.713
4. The framework encourages regular monitoring and consequent preventive maintenance of hand pups	4.45	0.519
5. Water user involvement is clarified by the framework	4.31	0.552

Source: Field Data, March 2023

Key for interpreting Mean: 1.00-2.49= *Disagreed*, 2.5-3.49=*Undecided*, 3.5-5.00=*Agreed*

Results in Table 4.19 have higher mean values against each statement measuring efficiency of the designed framework. The were above the lowest limit of agreed cases (3.5) which implied that the participants in the evaluation survey were convinced that the designed framework has the desirable features that made it relevant and suitable for mitigating and addressing the loopholes established by the study that had plagued the maintenance of the hand pumps in the sub county for a long period of time. For instance, the active involvement of all the proposed parties to the framework was hoped improve on the tracking of the issues relating to the functionality of the hand pumps such as loose nuts and bolts and rigid points that required oiling or any other form of maintenance (Mean= 4.12). Equally, the respondents agreed that the framework will simplify the process of communication between parties charged with the maintenance of the hand pumps and as a result, information hoarding and asymmetries that have existed before which prevented preventive maintenance to be done will become history (Mean=3.66). The respondents also convinced beyond

doubts that the framework will localize the management of the hand pumps, which has not been the case in the past. This assertion is reflected in the increased engagement of the local community at water user committee and special task force levels (Mean=4.22). The respondents further credited the framework for proposing the regular and multiple monitoring teams and agreed that this would greatly improve the preventive maintenance of the hand pumps (Mean=4.45). Lastly, the creation of avenues for water user involvement and engagement through trainings by the water user committees was also appreciated by the survey participants as it has the potential of causing significant behavioral changes consequently making the water users more receptive to programmes and activities focusing on hand pump maintenance (4.31).

4.6.4.2.3.2 Usability of the framework

The usability of the framework was evaluated using 4 items measured on a 5-point Likert scale. The results obtained are shown in Table 4.20. The framework was acknowledged by the survey participants as usable. For instance, majority agreed that it was simple and easier to learn and follow (Mean=4.24) and therefore, users of the framework required little training on how the framework is structured as well as the inherent relationships (Mean=4.54). Further, majority of the respondents (Mean=4.23) agreed that flows in the framework are well arranged, with more respondents (M=4.00) agreeing that the accompanying explanatory notes were clear and easy to comprehend.

Table 4.21: Views of the participants on usability of the framework

Statements	Mean	St. Dev.
1. The framework is simple to learn	4.66	0.566
2. Users require no or less training on its use	4.54	0.225
3. The phases in the framework are logically arranged	4.23	0.222
4. The various components of the framework are well explained	4.00	1.105

Source: Field Data, March 2023

Key for interpreting Mean: 1.00-2.49= *Disagreed*, 2.5-3.49=*Undecided*, 3.5-5.00=*Agreed*

The last section of the evaluation sought for views from the survey participants about additional views and recommendations that could make the framework comprehensive. The respondents suggested that part of the hand pump maintenance activities should incorporate water user comments. These were vital for providing basic information to the technical team that carries out system checkups and planned maintenance to make adequate preparations for correcting all the likely challenges that were faced by the users. This recommendation is rooted in the works of Otieno (2019) established that the time taken to repair broken down water facilities is a key determinant of the functionality of water supply sources. Thus, a system is likely to be functional if it takes less time to repair compared to the base category of less than 24 hours. Regular user reports are important in this situation because they would help in alerting the concerned leadership about the status of the handpumps thereby attracting immediate attention.

Secondly, the participants equally suggested that framework should include media houses and educational institutions such as Valley University of Science and Technology, Kampala International University (KIU) and Mbarara University of Science and Technology (MUST) as

standalone parties in the framework. The inclusion of the media houses was important because they were playing a vital role in information dissemination and educating the masses about WASH. For the educational institutions, the survey participants suggested that their involvement was beneficial to the communities since the institutions normally hold various community outreach activities and internship programmes. Therefore, they would play a vital role in shaping the attitudes and perceptions of the community members.

4.6.5 Evaluated hand pump water system maintenance framework

The incorporation of the suggested recommendation above slightly changed the structure of the designed framework. This was necessary because it added rigor as shown in figure 4.14.

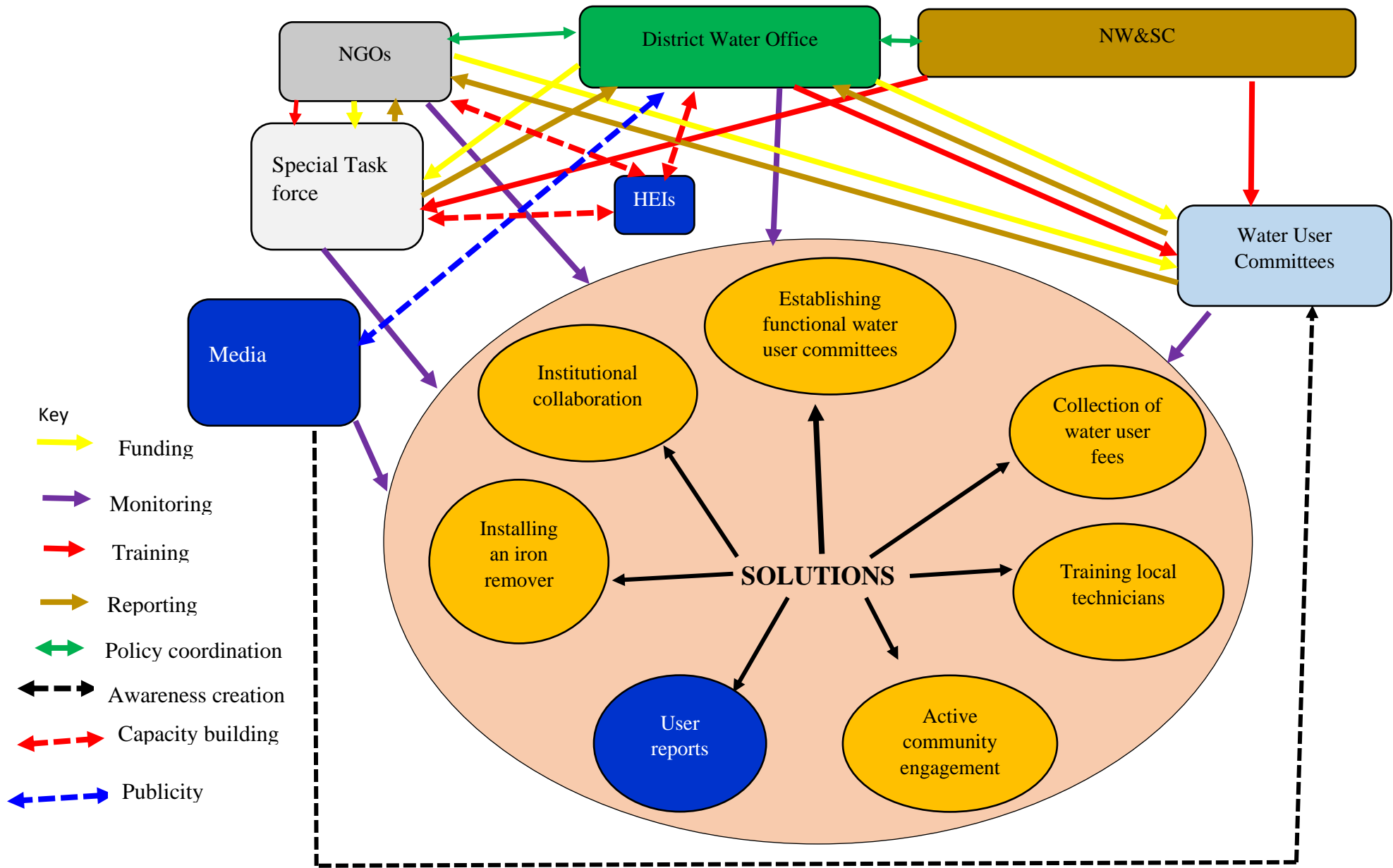


Figure 4. 14: Revised framework Added modification after evaluation of the framework

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter, conclusions are drawn and recommendations are made. The implications of the study are also included. The chapter ends with areas that have not been exhaustively covered by this study that are recommended for further research.

5.2 Conclusion

The study was informed by three specific objectives, namely: 1) To establish the causes of nonfunctionality of hand pumps; 2) to design a framework for managing the functionality of hand pumps; and 3) To validate and recommend the designed framework for deployment. The study findings are based on data that were collected using questionnaires, interviews, field and laboratory experiments, sanitary inspection survey and review of existing documents about functionality of hand pumps in Bumbaire Sub County. The study objectives were duly achieved. The study established that Bumbaire Sub County had most nonfunctional hand pumps. The majority of the cases were attributed to lack of maintenance of the water systems. The factors militating against regular and sound maintenance of the hand pumps were social, financial, technical and institutional. To ameliorate the challenges associated with the above maintenance factors, the study has developed and evaluated a framework for improving the maintenance of hand pumps. This study concludes that if the prescriptions of the evaluation framework are put into practice and ensured regularly by the parties indicated in the framework, the challenge of non- functionality of hand pumps will be minimized considerably.

5.3 Implications of the study

As noted throughout the study, access to potable water is a basic need and a conduit through substantial socio-economic development can be realized. The need for potable water is anticipated to grow manifold in the years to come especially with the running speculation that the world population will tip 10 billion by 2050. Developing countries and mainly the rural enclaves are feared to be the worst affected environments by that time. Thus, given their reliance on groundwater supply system through hand pumps, efforts are needed to address the current gaps in the maintenance of these systems. Therefore, the findings reported by this study and the plausible solutions proposed in the designed and evaluated framework should become working guidelines for leadership of rural environments such that the functionality of the hand pumps will be realized. This study therefore has implications to the planners and policy makers on water governance by among others providing a cocktail of information regarding stakeholder involvement and how best they can be engaged actively in water governance issues. To the practitioners in water governance, this study also provides insights on the scientific procedures of developing related action-based solutions that are capable of transforming the water and sanitation sector. To theory, the findings and most especially the designed and evaluated framework have added new knowledge to the existing knowledge base about maintaining the functionality of hand pumps in rural economies.

5.4 Recommendations

The study makes the following recommendations

1. The study recommends the need for district and local council officials to prioritize WASH campaigns throughout the settlements. These should be not be organized as one-offs but rather, they should be made a common place throughout the parishes. For effectiveness,

these should be localized such that the refugee households are incorporated as members of the committees.

2. The study recommends need for Government and other stakeholders to initiate sensitization campaigns about better ways of using and handling hand pump facilities in the sub county. This will minimise the careless handling of the facilities.
3. There is need for the government and Bushenyi District Local Government to ensure that water user committees are established at every village level where there is functioning hand pump. This will help in attitude and behavior change. The engagement of the water user committees that are formed will increase on stakeholder participation in the management of hand pumps.
4. NGOs and Government of Uganda should also endeavor to engage and involve the communities right from the hand pump project inception stage. This very critical for enhancing stakeholder buy-in and completed hand pump project ownership.

5.5 Areas for further research

This study focused on only one Sub County. To make plausible and comprehensive conclusions and recommendations, the study should be extended to cover the entire district.

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Appendices

Appendix A: Questionnaire for Water Users

Dear respondent, my name is Titus Nuwamanya, a student from Uganda Christian University, Department of Engineering and Environment pursuing a Master of Science Degree in Water and Sanitation Degree. I am undertaking a research study titled “*Assessment of causes of nonfunctionality of hand pump water facilities in Bumbaire sub-county, Bushenyi District*”. Your participation in this survey is voluntary as there won’t be any form of financial benefits extended to you. The research study is guided by Uganda Christian University research code of ethics and integrity and therefore responses given will only be reserved for academic purposes. Thank you very much for time.

Do you agree to participate in this study voluntarily?

Yes

No

- a- Proceed with the interview
- b- Please don’t proceed with the interview

.....

.....

Signature/Thumb print of respondent

Date.....

Part I: Socio – Demographic Characteristics

1: Age:

2: Marital status (Tick option): 1=Married 2=Divorced 3=Widowed 4=Never married 5=Other (specify)

3: (a) How many people live in your household (yourself, spouse, children, other relatives, lodgers & servants)?.....

(b) How many of them are engaged in any business or employment?

4: What is the total number of children that you have?

5: What is the main occupation of the household head? (Tick) 1=Farm 0=non-farm

8: Do you hold any leadership position in the community? (Tick) 1=Yes 0=No

Specify if Yes:

Part II: Nonfunctionality of hand pumps

2.1. Are you the beneficiary of developed potable drinking water from hand pump?

0= No ____ 1=Yes ____

2.2. If yes, what amount of water do you obtain from the hand pump per day ____litters?

2.3. What amount of water do you need per day____litters?

2.4. Does the hand pump is currently functional?

0= No ____ 1=Yes ____

2.5. If your response to Q2.4 is “No”, when was it become nonfunctional____year?

2.6. How frequent does it fails to render service?

1) Always (more than once in a year) ____

2) Sometimes (in 2 to 3 years interval) ____

3) Rarely (in more than 3 years interval) ____

4) not happened since constructed____

2.7. How long does it take to fetch water_____minutes for round trip and queuing?

2.8 From which source do your households currently obtain drinking water?

1) River ____ 2) Unprotected Spring ____ 3) Hand dug well fitted with Hand pump ____ 4) Traditional hand dug well ____ 5) Shallow well fitted with Hand pump ____

Part III: Causes of nonfunctionality of hand pumps based rural water supply

3.1. Issues related to community Factors

3.1.1. Who selected the site for development of hand pump? 1) Community ____ 2) Government ____ 3) NGO ____ 4) all in collaboration ____ 5) if other, specify ____

3.1.2. Have you participated in the development of the water supply hand pump?

0= No 1=Yes 3.1.2.1.

If your response to Q3.1.2 is "yes", at which phase you participated? 1) during planning ____ 2) during construction ____ 3) post-construction ____ 4) in all ____ 5) if other, specify ____

3.1.3. What was your contribution in development of hand pump? 1) Labor ____ 2) Local material (e.g., Stone, sand, wood) ____ 3) both labor and local material ____ 4) Money ____ 5) all (money, labor, local materials) ____ 6) if other, specify ____

3.1.4. Do you feel that the developed hand pump belongs to you too (sense of ownerships)?

0 =No 1 =Yes

3.1.5. Do women participate during water scheme development?

0= No 1=Yes

3.1.5.1. If your response to Q3.1.5 "No" what do you think the reason behind their nonparticipation? 1) Burden of home activities ____ 2) Religions reason ____ 3) Cultural reason ____ 4) non-permitting husband ____ 5) Not interested ____ 6) if others, specify ____ 87

3.1.6. Is there established management system for the developed water supply hand pump?

0=No 1= Yes

3.1.6.1. If your response to Q3.1.6 is "Yes", who manages the hand pump? 1) Water committee____ 2) Government____ 3) NGO____ 4) nobody____ 5) I don't know____ 6) if other, specify ____

3.1.7. Does the management body adequately perform their duties and responsibilities? 0= No
1=Yes 3.2.

Related Technical Factors

3.2.1. Have you been informed of the advantage, costs and disadvantages of the potential technologies or schemes type to be installed?

0=No 1=Yes

3.2.2. Who selected the type of the existing scheme (technology choice)?

1) Governmental office____ 2) NGOs____ 3) NGO & Response governmental office in collaboration____ 4) community & local leaders____ 5) Governmental office, community & NGOs____ 6) I don't know____ 7) if other, specify____

3.2.3. Did the preliminary study conducted before scheme selection to develop? 1) Yes ____ 2) No ____ 3) I don't know____

3.2.4. How do you evaluate the construction quality of the water supply scheme? 1) Very Good ____ 2) Good ____ 3) fair ____ 4) Poor ____ 5) Very Poor ____ 6) I don't know____

3.2.5. Is the water scheme hand pump is simple to operate and suitable to the users?

0= No 1=Yes

3.2.6. Are there local technicians for the operation and maintenance work?

0= No 1=Yes

3.2.7. Is the training on the hand pump scheme operation & maintenance given to the technician or the water committee? 0= No 1= Yes

3.2.8. Which major technical problems have you encountered to make the water supply scheme properly function and sustain the service to the community? 1) Lack of adequate spare parts and tools_____ 2) Inappropriate technology/pump type selection_____ 3) Lack of the technical skill to carry out operation & maintenance____ 4) Poor construction quality____5) if other, specify_____

3.2.9. What do you recommend to alleviate the problems that the water supply is experiencing and to make the scheme proper functional for long period of time? 1) Training on proper use while fetching water _____ 2) Fencing and locking the pump _____ 3) Doing both (1 &2) _____

3.2.10. What do you think are the difficulties related to the fitted hand pump technology? 1) Hard to move the handle____2) easily wearing and breaking parts; ____ 3) if other, specify____

3.2.11. Are spare parts are available and easily accessible at community level when needed?

0= No 1= Yes

3.2.12. From where does the community get spare parts to carry out maintenance? 1) Purchase on market____2) provided/supplied by regional/zonal/woreda water offices/government agency____3) Donated by NGOs ____4) I don't know____5) if other, specify__

3.2.13. Is the price of spare parts affordable at community level when needed?

0=No 1= Yes

3.2.14. If the price is not affordable what you will do? 1) Abstain from maintenance until sufficient money collected from beneficiary ___ 2) Appeal to government office or ___ 4) I don't know ___
3) Request NGO for support (donation) ___ 5) if other, specify ___

Related to Financial Factors

3.3.1. Who financed the developed water supply hand pump? 1) Community__2) NGO__3) Government__ 4) All in collaboration __5) if other, specify ___

3.3.2. Do you pay cash (money) for the developed water supply service? 0= No 1= Yes

3.3.2.1. If your response to Q3.3.2 is "Yes", how much do you pay? Birr/ household/month_____

3.3.3. Do you support the idea of paying water tariff/user fee? 0= No 1= Yes

3.3.3.1. If your response to Q3.3.3 is "Yes", what is your reason for supporting water payment? 1) For scheme maintenance____ 2) To pay for water attendant and guard salary____ 3) To construct other scheme if this get ruined/completely damaged____ 4) if other, specify____

3.3.3.2. If your response to Q3.3.3 is "No", why not? 1) Lack of awareness about its importance____ 2) Dissatisfaction with the service____ 3) Water is natural gift, so no need of payment____ 4) I don't have confidence on water committee; ____5) I don't have financial capacity____6) if other, specify ____

3.3.4. How much money are you willing and able to pay for the service per month_____?

3.3.5. Do you/your family/regularly pay for the water supply service? 0= No 1= Yes

3.3.6. Who set the price of the water fees? 1) Community___ 2) Government ____3) NGO ____4) Water committee ___5) All in collaboration; ____6) if other, specify _____

3.3.7. Do you think the water fees collected from the beneficiaries is adequate to cover all operation & maintenance costs of the hand pump? 0= No 1= Yes

Related Institutional factors

3.4.1. Is there follow up and supervision by the stakeholders about the status of the water schemes? 0= No 1= Yes

3.4.2. Do the community/water committee receive any external support from government to enable them effectively manage their water supply hand pump? 0=No 1= Yes

3.4.3. Do your community get support from NGO in relation to managing the water supply schemes to make properly functional and sustainable? 0=No 1=Yes

3.4.3.1. If yes Q3.4.3 what support your community (your hand pump user community and committee) from NGO 1) Training___ 2) Material ___ 3) Technical ___ 4) Financial support___ 5) if other, specify___ 3.4.4. What types of supports are needed by the community to make the water supply hand pump functional for long period of time? 1) Spare parts___ 2) quality construction___ 3) local technician___ 4) in all_____

Part IV: Coping mechanisms of the community in times of water supply shortage and schemes nonfunctionality

4.1. Is water which you get from hand pump sufficient for your household domestic (drinking, cooking, cleaning) 0= No 1= Yes

4.2. If your use of water from main source does not cover the entire household utility purposes, what type of adaptation strategies do your families use? 1) using open sources ____2) Rain water harvesting____3) Buying from water vendors____ 4) if other, please specify____

4.3. What kind of mitigation measures do the communities use to minimize water shortage risks in the long run? 1) watershed management____2) Afforestation____3) Reforestation____4) if other, specify____

4.4. Does water shortage occurs from the hand pump schemes? Do you have water shortage from the water point throughout the year? 0= No 1= Yes

4.5. If your answer to question Q 4.4 is yes, when the water shortage is happened? 1)Dry season____2) Wet season____3) Throughout the year____

4.6. What is the reason behind the occurrence of shortage of water? 1) decreasing of water volume ____2) hand pump leakage____3) imbalance of water demand and supply____4) I don't know____

4.7. Do your families save the amount of water gained during water shortages? 0) No 1) Yes 4.8. If your answer to question Q 4.7 is yes, what strategy do the families mostly use to save the amount of water? 1) Reusing water____2) Reducing daily consumption____3) if other, please specify____

Thank you for participating in the survey

Appendix B: Interview Guide for District Water Engineer/Sub County CDO.

1. Gender
2. Number of years working with your institution
3. What is your highest education qualification?
4. How many hand pumps are in Bumbaire Sub County?
5. Who owns the hand pumps?
6. What is your general assessment of the functionality of the hand pumps?
7. In your opinion, what are the causes of frequent breakdown on hand pumps?
8. What do you propose to be undertaken in order to keep the hand pumps in this community functioning?
9. Any other thing to tell me about functionality of hand pumps in this community?

Thank you for participating

Appendix C: FGD For male and Female Water users

Instructions

- (i) Audiotape the discussion to capture all the details. Let the FGD participants become aware that they are being recorded for ethical purposes.
- (ii) Encourage brainstorming, make follow ups with cause and effect and Five whys

Statements/Questions

1. What are the major benefits of effective operation and maintenance of the water facilities?
2. What are the major constraints of effective operation and maintenance of the water facilities?
3. Why is that people are willing to participate in operation and maintenance of the water facilities?
4. What factors influence the people's participation in operation and maintenance of the water facilities?
5. What rules do you have in your communities pertaining to operation and maintenance of the water facilities?
6. How is participation enforced?
7. What are your immediate needs?

Thank you for participating in the FGD

Appendix D: Observation Checklist

1. Location of the handpump
2. Cleanliness of the handpump area
3. Status of the apron area
4. Handpump is fenced
5. Handpump has tight bolts and nuts
6. Drainage systems of handpump surroundings

Appendix E: Document Review Guide

The following documents will be reviewed to extract secondary data on nonfunctionality of hand pumps

1. Annual Reports of District Water Office

2. Reports of Community Development Officers
3. Reports of Sub County Field Water Officers
4. Relevant newspaper articles both local and foreign
5. MWE Reports on hand pumps in Bushenyi District
6. Any other relevant Reports/Publications

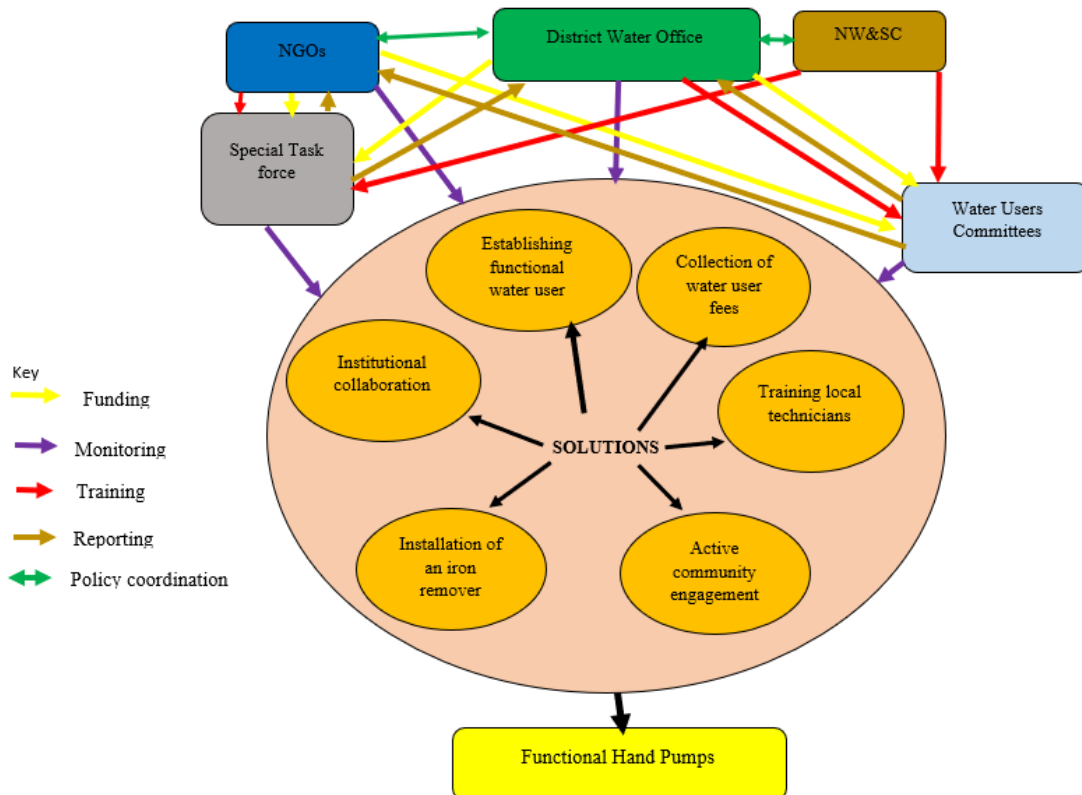
Appendix F: Survey tool for evaluating framework

Dear respondent,

My name is Titus Nuwamanya, a student at Uganda Christian University, Mukono pursuing a Master of Science in Water and Sanitation Engineering. As part of the requirements for the award of this degree, I am undertaking a study titled “*Assessment of the causes of nonfunctionality of*

the hand pump rural water systems in Bumbaire Sub County, Bushenyi District, Uganda". The major outcome of this study was a hand pump water system maintenance framework as shown below. This mini-questionnaire is seeking for your views in regard to the efficiency and usability of the framework. The survey is not an examination. It is seeking your opinion and therefore, there are no wrong and right answers. Feel free to give your opinion. The questionnaire is anonymous. I will be grateful if you return the questionnaire to the receptionist two days from now.

Thank you in Advance;



Section A: Background Characteristics of Respondents

Please, put a tick (✓) in the appropriate box provided

1. Gender of the Respondents

Male Female

2. Age of respondents

Below 20 years 20-30 31-40 41 +

3. Highest Level of education

Diploma Bachelors Masters

Section B: Provide a rank to the importance of the solutions provided by the framework in the management of functionality of the hand pumps

Solution	Rank
7. Active community engagement	
8. Collection of water user fees	
9. Establishing functional water user committees	
10. Training of local technicians	
11. Institutional collaboration	
12. Installation of an iron remover	

Section C: Efficiency of the hand pump water system maintenance framework

In this section please tick in the box corresponding to your response according to a scale of 1= Strongly Disagree, 2=Disagree, 3= Undecided, 4=Agree, 5= Strongly Agree

Statements	1	2	3	4	5
13. The framework enables documentation of all issues associated with hand pumps					
14. The framework simplifies the process of communication between the parties managing the hand pumps					
15. The framework localizes the management and maintenance of the hand pumps					

16. The framework encourages regular monitoring and consequent preventive maintenance of hand pumps					
17. Water user involvement is clarified by the framework					

Section D: Usability of the framework

In this section please tick in the box corresponding to your response according to a scale of 1= Strongly Disagree, 2=Disagree, 3= Undecided, 4=Agree, 5= Strongly Agree

Statements	1	2	3	4	5
1. The framework is simple to learn					
2. Users require no or less training on its use					
3. The phases in the framework are logically arranged					
4. The various components of the framework are well explained					

Section E: Recommendations


Based on your experience with operations of hand pump water system in Bushenyi District, what do you think ought to be done to improve the efficiency and usability of the hand pump water system maintenance framework?

Thank you for participating in this evaluation survey

Appendix G: Krejcie and Morgan (1970) Table of Sample Size Determination for finite population

15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	200	132	460	210	1600	310	10000	370
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	226	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	254	2600	335	100000	384
<i>Note: N is Population Size; S is Sample Size</i>					<i>Source: Krejcie & Morgan, 1970</i>				

Appendix H: Experiment Results



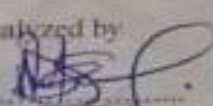
NATIONAL WATER AND SEWERAGE CORPORATION
P.O BOX. 339, BUSHENYI AREA

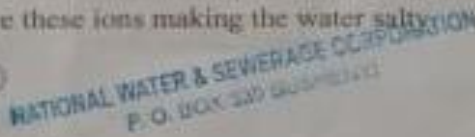
Student's Name: NIWAMANYA TITUS
Sample Source: Shallow well
Sampling Date: 12th Nov 2022
Reporting Date: 14th Nov 2022

A REPORT OF ANALYSIS SHOWING PHYSIO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS ON ASSESSING THE WATER QUALITY OF A HAND PUMP BASED RURAL WATER SUPPLY IN BUMBAIRE SUBCOUNTY IN BUSHENYI DISTRICT

Parameters	Unit	78300	National standards for potable water (Maximum permissible)
PH	-	6.45	5.5 – 8.5
Electrical conductivity	µS/cm	1200	1000
Total dissolved solids	Mg/l	768	700
Turbidity	NTU	0.9	5.0
Colour	ptco	2	15
Total suspended solids	Mg/l	0	0.0
Alkalinity	Mg/l	40	500
Hardness	Mg/l	550	500
Calcium : Ca ²⁺	Mg/l	89	75
Magnesium Mg ²⁺	Mg/l	64	50
Manganese Mn ²⁺	Mg/l	0.02	0.2
Chlorides	Mg/l	6.4	250
Total Iron	Mg/l	0.14	<0.30
Sulphates	Mg/l	30	200
Nitrates	Mg/l	0.07	5.0
Faecal Coliforms	CFU/100ml	0	0
Ecoli	CFU/100ml	0	0

Analysts comment
 The water sample picked from this borehole has very high Electrical conductivity and Very high hardness values beyond the maximum permissible of potable water. There is need to install an ion exchanger to remove these ions making the water salty.

Analyzed by 
MUGUME DHO SAMUEL
 SENIOR QUALITY CONTROL OFFICER
 GREATER BUSHENYI



Appendix I: Transmittal Letter



**UGANDA CHRISTIAN
UNIVERSITY**

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN, AND TECHNOLOGY
Department of Engineering and Environment

21st October, 2022

TO WHOM IT MAY CONCERN

Dear Sir/Madam;

**RE. INTRODUCTORY LETTER FOR MR. NUWAMANYA TITUS REG.NO
RM17M45/009**

Greetings from Uganda Christian University.

This is to introduce to you, the above mentioned, a second year student of Uganda Christian University, pursuing a Master of Science in Water and Sanitation Degree. Part of the requirements for this masters degree program is to conduct research for a period of one year in the students second year of study in the water and sanitation sector.

The student is undertaking research on *“Assessment of causes of non-functionality of hand pumps based rural water supply in Bumbaire Sub County as the case study”*.

The purpose of this letter therefore is to kindly request you to grant the student access to the study area and collect data to aid his academic research.

I appreciate your assistance on this matter.

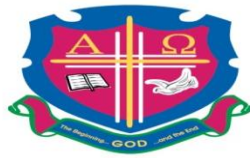
Sincerely,

Mr. Rodgers Tayebwa (MSWATSAN)
Head of Department- Engineering and Environment

A Complete Education for A Complete Person

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Founded by the Province of the Church of Uganda. Chartered by the Government of Uganda.



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UGANDA CHRISTIAN UNIVERSITY

SCHOOL OF RESEARCH & POSTGRADUATE STUDIES

DISSERTATION CORRECTION COMPLIANCE REPORT BY THE CANDIDATE (POST VIVA FORM)

Date: 7 April 2025

Name of Candidate: Titus Nuwamanya. **Reg. No:** RM17M45/009

Title of Dissertation: A FRAMEWORK FOR MANAGING THE FUNCTIONALITY OF HAND PUMP RURAL WATER SUPPLY SYSTEMS IN BUMBAIRE SUB-COUNTY, BUSHENYI DISTRICT.

SN	COMMENTS BY EXTERNAL EXAMINER	ACTION TAKEN	INDICATOR
1	<p>Quite a few citations provided in the 'Introduction' and 'Background to the Study' sections have not been included in the List of References.</p> <p>The conceptual framework has not been described and explained. What do the arrows imply? How do the literature sources shown at the bottom explain the interrelationships? between the variables?</p>	<p>All in-text citations are incorporated in the list of references</p> <p>Explanatory notes provided describing the framework</p>	<p>Entire Thesis</p> <p>9-10</p>
2	<p>Facts and principles should be properly referenced, for example the Integrated Water Resources Management Dublin Principles which were established as part of the Declaration of the International Conference on Water and the Environment in 1992 - were wrongly credited to Katusiime & Schutt, 2020.</p> <p>Figure 2.3 is wrongly captioned. It shows the proportion of handpumps that are non- functional.</p> <p>Figures 2.5 and 2.7 are interesting. They have not been adequately discussed. A comparative analysis would have been useful.</p>	<p>Digression corrected. Meran et al. (2021) and Global Water Partnership (2020) included as the prime sources. This is included under section 2.2.2</p> <p>Anomaly rectified</p> <p>Action not taken as the two figures communicate different information and carry incomparable figures</p>	<p>15</p> <p>18</p> <p>-</p>

SN	COMMENTS BY EXTERNAL EXAMINER	ACTION TAKEN	INDICATOR
	<p>Uganda’s sector performance report cited in the literature (p23) is outdated. There are more recent sector performance reports (up to 2022) available as open source on Uganda’s water and environment website.</p> <p>Some of the cited sources of literature have not been included in the List of References.</p>	<p>Update effected. 2020 replaces 2017</p> <p>All the in-text and end of thesis lists of references have been audited and harmonized to cater for this anomaly</p>	<p>26</p> <p>Entire Thesis</p>
3	<p>Figure 3.1 is not adequately discussed.</p> <p>Page 50 - ‘self-administered questionnaires’ are those the respondents read and fill without the help of enumerators.</p> <p>Ordinarily, a pilot study should have been conducted with members of the ‘study population’ not selected as part of the sample.</p> <p>You have stated ‘Since this short time required precision in capturing the dialogue, the researcher audio-taped the proceeds of the interviews. Did you request for their permission to record</p>	<p>A green ring has been included and brief summary about it is provided before the figure</p> <p>Anomaly rectified. The word-Self–Administered is omitted.</p> <p>Suggestion adhered to. Kibaare Parish is included as the pilot test site</p> <p>Suggestion undertaken. Indeed, consent was sought before any recording took place</p>	<p>43</p> <p>52</p> <p>52</p> <p>53</p>

SN	COMMENTS BY EXTERNAL EXAMINER	ACTION TAKEN	INDICATOR
	<p>the interviews? This should be explicitly stated, as it has research ethical implications.</p> <p>The sanitary inspection tool was for water points, NOT the users of water points (Page 61).</p> <p>It is not clear how Content Validity was computed.</p> <p>Some of the cited sources of literature have not been included in the List of References.</p>	<p>Sanitation inspection replaced with observation checklist as appendix D</p> <p>Figures used to compute CVI and the final value of CVI are now included</p> <p>All the sources for this chapter are included in the list of references</p>	<p>164</p> <p>63</p> <p>136-153</p>
4	<p>On the technical factors (4.4.2.2), there are some aspects which community members of Results may not be knowledgeable about, for instance, Table 4.10 -if 'a preliminary study (was) conducted before establishing the pump?'; and most questions asked in Table 4.11. I think such questions would best be answered by the key informant</p>	<p>Tables 4.10 and 4.11 adjusted to take the suggestion into account</p>	<p>91,93</p>

SN	COMMENTS BY EXTERNAL EXAMINER	ACTION TAKEN	INDICATOR
	<p>interviews.</p> <p>‘The framework prescribes need for maintenance of close linkages so that best work practices such as models can be shared and used whenever new hand pumps are to be established in the area’ (page 97/98). What do you mean by ‘models’ in this context? Figure 4.10 is a good representation of a handpump maintenance system framework. What is not clear from the framework is who will be carrying out the maintenance activities presented in the circle. Neither has this role been clarified in the narrative following the figure.</p> <p>It was great to evaluate the framework and modify it based on the feedback. It would have been useful if you had provided more details on how this consultation was made, such as when, where, how -was it moderated? etc.</p>	<p>The responsibility lines for monitoring the proposed solutions are reflected by the Purple arrows. A further explanation is provided under section 4.5.3.3</p> <p>Framework was evaluated in March 2023. The procedures followed are discussed under section 4.6</p>	<p>113</p> <p>121</p>
5	Were there any study limitations?	Section 3.12 is introduced in Chapter to cover this gap	69
6	Some cited articles are not included in the list of references	The list of references has been well audited vis-à-vis the in-text citations. The anomaly has been cleared	Entire thesis
7	Some of the sentences are overly long;	Entire thesis revised. All the long sentences shortened into meaningful statements	Entire thesis

SN	COMMENTS BY EXTERNAL EXAMINER	ACTION TAKEN	INDICATOR
8	There are some grammatical and typographical errors, which could have been eliminated after a good proofreading	Document spell-checked with Grammarly and all digressions rectified	Entire thesis

PANELIST	COMMENTS BY VIVA VOCE PANELISTS	ACTION TAKEN	INDICATOR
Prof. Wozzi	<ol style="list-style-type: none"> Clearly define non-functionality in relation to the information collected. What is it according to your research? How have you improved it and what is it according to the Ministry? 	Clarity provided. The definitions of functionality and nonfunctionality by authorities including MWE are provided. The latent definition used in this study is equally provided	2-3
Dr. Owor	<ol style="list-style-type: none"> How many pumps were standing when not used? Those not broken down. What if they are not using it because water quality is not good? How did you know water quality was bad? 	Only 1 coded Kiya003. Water quality was determined using both field and laboratory analytical tests	77
Dr. Mutyaba	<ol style="list-style-type: none"> Where did you focus on in your study? How did you do the cluster sampling? 	<ol style="list-style-type: none"> Focus was on both defunct handpumps to establish the causes of nonfunctionality. Focus was equally on a deserted handpump with running water. Water quality tests were performed on this handpump (Kiya003) Cluster sampling not used. I applied stratified and simple random sampling techniques. Parishes were the strata. From each stratum (parish), I applied simple 	77 50-51

	<p>3. How did you determine your sample collection?</p> <p>4. What are the independent variables?</p> <p>5. What variables did you pick out in technical aspects?</p> <p>6. Link framework based on the parameters</p> <p>7. The definition of functionality needs to be brought out very well.</p>	<p>random sampling</p> <p>3. Households were the main unit of analysis. Sample size determined using household survey records at Bumbaire Sub County. Actual sample determined using Krejcie and Morgan (1970) Table of sample size determination from a known population</p> <p>4. Independent variables were: community factors, institutional factors, technical factors, financial factors and water quality factors (See Conceptual Framework)</p> <p>5. Technical aspects investigated were: Site selection, Feasibility study, Local Technicians for O& M and Availability of Spare parts for O&M</p> <p>6. Solutions provided by the framework are linked to the gaps established in the independent variables</p> <p>7. Definition of functionality both scholarly and latent are provided in Chapter One</p>	<p>51</p> <p>11</p> <p>157-158</p> <p>105</p> <p>2-3</p>
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Panel Recommendations	<ol style="list-style-type: none"> 1. There is need to define non functionality and functionality. 2. There is need to revisit the data which has to be linked to the topic. 	<ol style="list-style-type: none"> 1. Functionality and nonfunctionality are provided under background to the study 2. Data on the regression revisited as advised 	<p>2-3</p> <p>102</p>
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Nuwamanya Titus

Candidate's Name

Signature