Water Is Life

Praise for this book

'A very rich and powerful book with great insights on sustainable rural water systems.'

Rebecca Amukhoye, Country Director, Self Help Africa, Kenya

'A book which brings together the findings of eight detailed PhD studies, all focused on aspects of water and sanitation in one small geographical area of Uganda would be expected to provide some valuable insights, and this book does not disappoint. The geographic focus of the studies is restricted, but it is in some sense representative of the experiences of rural life in many parts of Africa; it also allowed a greater depth of investigation than would have been offered by a similar number of studies scattered across multiple locations. I highly commend this publication to all who are interested in the realities of the rural poor in Africa, and the contributions of in-depth research to the water and sanitation issues which such households and communities face daily.'

Richard Carter, Chair, Rural Water Supply Network, and Visiting Professor, Cranfield University, UK

Water Is Life

Progress to secure safe water provision in rural Uganda

Edited by G. Honor Fagan, Suzanne Linnane,
Kevin G. McGuigan and Albert I. Rugumayo

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Abbreviations and acronyms

amsl	above mean sea level
APHA	American Public Health Association
ARTES	Africa Rainfall and Temperature Evaluation System
AU	African Union
AVHRR	advanced very high resolution radiometer
AWWA	American Water Works Association
CBOs	community-based organizations
CDAs	Community Development Assistants
CDOs	community development officers
CBWMS	community-based water management system
CFUBMSIP	closed field unbalanced magnetron sputtering ion plating
CMO	Catchment Management Organization
CMPs	Catchment Management Plans
DCU	Dublin City University
DFID	Department for International Development
DkIT	Dundalk Institute of Technology
DLC	diamond-like carbon
DWD	Directorate of Water Development
DWOs	District Water Officers
DWSDCG	District Water and Sanitation Development Conditional Grant
EARS	East African Rift System
EAWAG	Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (the Swiss Federal Institute of Aquatic Science and Technology)
FAO	Food and Agriculture Organization
GFSAs	gravity flow scheme attendants
GIS	geographic information systems
GoU	Government of Uganda
HAs	health assistants
HEA	Higher Education Authority
HEIs	Higher Education Institutes
HIs	Health Inspectors
HPC	heterotrophic plate count
HPMs	handpump mechanics
HRW	harvested rainwater
HWTS	household water treatment and safe storage technologies
IDPM	Institute for Development Policy and Management
IDRC	International Development Research Centre

IDWSSD	International Decade of Water Supply and Sanitation
IPCC	Intergovernmental Panel on Climate Change
IRC	International Water and Sanitation Centre
ITCZ	Inter Tropical Convergence Zone
IWMI	International Water Management Institute
IWRM	integrated water resource management
JMP	Joint Monitoring Programme of the WHO
LGs	local government authorities
MDG	Millennium Development Goal
MMMs	Medical Missionaries of Mary
MoU	Memorandum of Understanding
MWE	Ministry of Water and Environment, Uganda
NGO	non-governmental organization
NICB	National Institute for Cellular Biotechnology
NOAA	National Oceanic and Atmospheric Administration
NORAD	Norwegian Agency for Development Cooperation
NTU	nephelometric turbidity units
NWP	National Water Policy
NWSC	National Water and Sewerage Corporation
O&M	operation and maintenance
OBA	Output-Based Aid project
PAF	Poverty Action Fund
PEAP	Poverty Eradication Action Plan
PET	polyethylene-terephthalate
PGIS	participatory geographic information systems
POU	Point-of-use
PRA	participatory rural appraisal
RCSI	Royal College of Surgeons in Ireland
RGCs	rural growth centres
RSWN	Rural Water Supply Network
RWH	rainwater harvesting
SANDEC	the EAWAG department of water and sanitation in developing countries
SAPs	Structural Adjustment Programs
Si	silicon
Sida/SAREC	Department for Research Cooperation, Swedish International Development Cooperation
SODIS	solar disinfection (of drinking water)
SWGS	School of Women and Gender Studies, at Makerere University
SWTWS	South Western Towns Water and Sanitation Project
TDS	total dissolved solids
TPC	Technical Planning Committee
TSUs	technical support units
TTC	thermotolerant coliforms

UBOS	Uganda National Bureau of Statistics
UIUC	University of Illinois at Urbana-Champaign
UN	United Nations
UNCST	Uganda National Council for Science and Technology
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
USAID	US Agency for International Development
UV	ultraviolet
UWASNET	Uganda Water and Sanitation NGO Network
VAT	Value Added Tax
VEC	village executive council
VLOM	village level operation and maintenance
WHO	World Health Organization
WMZs	Water Management Zones
WSCs	Water and Sanitation Committees
WSCC	Water Supply and Sanitation Collaborative Council
WSS	Water Supply and Sanitation
WSSP	Wetlands Sector Strategic Plan
WUCs	Water User Committees

CHAPTER 1: INTRODUCTION

Water is Life: Community-based research for sustainable safe water in rural Uganda

G. Honor Fagan, Suzanne Linnane,
Kevin G. McGuigan, and Albert I.Rugumayo

Abstract

This is a book about community-based research in the service of improving the sustainability and equity of safe water production, consumption, and management at community level in rural Uganda. It provides an account of the findings of a five-year combined social science, natural science, and engineering research work programme (2009–14) which took place within and with the community, in the sense that the community identified their water needs and related their everyday struggles with water resourcing to the research team, and they contributed to the outcomes. Our research programme began 14 years after the Ugandan government enacted the 1995 Water Statute (which provided the framework for the use, protection, and management of water resources and supply, the constitution of water authorities, and the devolution of water supply undertakings), 10 years after the 1999 National Water Policy was rolled out, and six years short of the delivery date for the Millennium Development Goals on water.

Keywords: sustainability, research capacity building, water, equity, rural poverty

The project

The programme of research which forms the basis of this book was Water is Life: *Amazzi Bulamu*, supported by Irish Aid/Higher Education Authority funding for research capacity building around sustainable water development.[1] It involved the creation of a partnership between Irish third-level institutes and the University of Makerere in Uganda to involve Ugandan-based and Irish-based teams of academics in training Ugandan or Ugandan-based researchers to doctoral level in the practical action setting of a poor rural community. The involvement of the community in the programme from the outset was intended to empower the local community in the management of its own water resources into the future. Additionally, the programme was devised to build research capacity in a two-dimensional way – at third level by enhancing the quality of community-engaged research and at community level by providing access to the resources of the team of scientists and social

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scientists contributing to the goal of sustainable community water supply in that specific community. The project raised a number of key questions in relation to aspects of the realities of safe water in this community: accessibility, affordability, management, use of technological advances, impact of climate change, and gender relations. Issues were described and interventions were devised, all of which were based on sound and robust evidence-based research 'in the field'. In order to be truly capable of contributing to the agenda of poverty reduction, and have societal relevance, the research involved all key stakeholders from the outset.

This book tells a story about carrying out evidence-based research at community level in response to community needs; it is also a story about science being put to use in the building of sustainable communities. It was in order to assess and improve the community's access to and participation in water management that the researchers and the community entered the research collaboration. It was also in order to engage in the proposed practical action of producing and improving a community-managed sustainable water system for the parish. Overall, it describes and analyses what is happening in the water lives of a rural Ugandan community. In addition, it is a story of critique. It does not presuppose that community management is the right way to increase the sustainability of water supply systems, but only that it is the current emphasis in terms of policy roll-out of water systems as experienced by the community we report on here.

Global and national water context

The United Nations (UN) estimates that in excess of 1 million Africans still die every year from sanitation-, hygiene-, and drinking water-related diseases, which equates to approximately 115 Africans per hour or one person every 30 seconds. This is despite the fact that the targets for the UN Millennium Development Goal (MDG) 7C – to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation – have been reached (WHO and UNICEF, 2012). Challenges remain and the WHO/UNICEF 2012 report highlights that global figures mask massive disparities between regions and countries, and within countries, with only 61 per cent of people in sub-Saharan Africa having access to improved water supply sources, compared with 90 per cent or more in Latin America and the Caribbean, northern Africa, and large parts of Asia. In fact, the 2014 WHO/UNICEF update estimates that 43 per cent of all people globally who lack access to drinking water live in sub-Saharan Africa. It also confirms that in cases where water supplies are not readily accessible, the burden of carrying water falls disproportionately on women and girls, and in many countries the wealthiest people have seen the greatest improvements in water and sanitation access, whereas people in poorer countries still lag far behind.

Access to safe drinking water has been greatly expanded through implementation of the MDGs. However, the MDGs will reach their target date at the end of 2015, and therefore the post-2015 development agenda will need to ensure the creation of a development framework which takes into account the inconsistencies between sub-Saharan Africa and the rest of the world, and which also reflects the fact that nearly half of the more than 700 million people who still lack ready access to improved sources of drinking water live in sub-Saharan Africa.

According to the WHO/UNICEF Joint Monitoring Programme (JMP), as a result of a combination of government and non-governmental organization (NGO) interventions, access to an improved water source in Uganda increased from 39 per cent in 1990 to 68 per cent in 2010 (WHO and UNICEF, 2012). Generally, Uganda's institutional framework for water management follows a decentralized system in which powers have been devolved from the national to the lower levels of government. The structure operates at four levels: national, district, sub-county, and village/community. At the village level, water users or water user groups for a particular water source are supposed to decide on the type of 'improved' water facilities they want, pay their share (5 per cent) of construction costs, and manage the operation of the facilities, as stipulated in the Water Yes Statute (1995) and National Framework for Operation and Maintenance of Rural Water Supplies (GoU, 2011a). At the time of this study's inception, it was estimated that in rural areas 20 per cent of handpumps had broken down and 17 per cent of 'improved' water sources were not functioning MWE, 2011b; RWSN, 2012). The national average in terms of use of unprotected sources for rural communities was reported as 30 per cent (UBOS, 2010: 121). 'Unimproved' water sources are defined by the JMP as those that, by nature of their construction or through active intervention, are not protected from outside contamination, especially faecal matter; examples include unprotected springs, unprotected dug wells and surface water (WHO and UNICEF, 2000: 4). The logic of the community-based research was to place multidisciplinary research teams at the service of the community to help assess the reality of their water needs, to develop sustainable water provision and to advise government, community and household-level actors on practical actions to be taken to resolve some of the enduring problems, of which there are many.

The community

Focusing on water sustainability at community level required an in-depth focus; thus, one case study area, or social space, was identified – a parish comprising 15 villages. The parish selected for this research is located in the Lwengo District in south Uganda, an area containing approximately 11,786 households (UBOS, 2006), where the baseline survey[2] showed that the majority of households earned less than 50,000 Ugandan shillings a month (Macri et al., 2013: 19). The survey recorded that while over 64 per cent of the households interviewed had three meals the previous day, 25 per cent had only two meals and 11 per cent had only one meal (Macri et al., 2013: 21).

Almost half (48 per cent) of the households surveyed comprised more than six members and over a quarter (27 per cent) comprised either four or five members (Macri et al., 2013: 16). In addition, the main source of income was agriculture, either crop farming (62 per cent) or mixed farming (20 per cent), which obviously involved accessing water (Macri et al., 2013: 19). This community-based research was, therefore, carried out in a poor rural setting of intertwined economic poverty and water poverty.

This community remains water poor despite some progress nationally in this regard. What do we mean by 'water poor'? Poverty of water supply clearly equates with poverty of household. The time spent accessing water severely impairs household wealth. In particular, the burden of water carrying militates against income-generating activities for women, and increases the educational disadvantage of their children. In addition to this, the consumption of poor-quality water adds health poverty into the household equation, which further exacerbates the household's economic and social problems.

Health problems related to poor-quality water supply are rife in the case study area. The baseline quantitative research carried out in the area indicated that in the previous year 76 per cent of the households had members who experienced malaria, 42 per cent had at least one family member who suffered from stomach complaints, 37 per cent had members who experienced diarrhoea, and 18 per cent had experienced worms (Macri et al., 2013: 34). This information was provided by households that were asked to calculate the incidence of water-related illnesses in their households in the previous year. Diarrhoea and worms are two commonly reported problems resulting from the use of poor-quality water. Apart from the health implications, water-related diseases have a significant impact on the income of the household, with 67 per cent of respondents indicating that these diseases had resulted in increased family expenses over the previous year (Macri et al., 2013: 34). In addition, water-related illnesses had an impact on school attendance for 43 per cent of households, and led to diminished ability to earn money in the case of 38 per cent of households (Macri et al., 2013: 35). For this community, a great many of their problems stemmed from poor water quality, to the extent that 90 per cent felt that improved health of their household members and a reduction in the frequency of water-related diseases in their community were of paramount importance (Macri et al., 2013: 36). This was a community that recognized the importance of water all too well and believed wholeheartedly in the true colloquial meaning of *amazzi bulamu*, that is 'water is life'.

There is no access to piped water in the case study area, nor are there any plans to introduce this; by contrast, in urban areas, progress is being made on this front. In rural areas, water collection is time-consuming, and women and children invest an inordinate amount of time and energy collecting water. This community had experienced improvements in water supply through government organizations and NGOs to the degree that, according to our survey of the area in 2011, there were 10 boreholes, 24 shallow wells, and one protected spring. Almost all of the surveyed households were within a

1 km radius of an improved water source and, if these sources were properly maintained, there would be few quality issues with the water collected there. Access to safe drinking water was possible so long as the improved water source was in a functioning condition and householders: 1) were in an economic position to afford jerrycans; 2) were able to carry them; and 3) had the time to queue. Only one of the 10 local boreholes was functioning, however. Of the 24 local shallow wells, 17 were not working. When asked about the main source of water used, about 40 per cent of all survey participants said that they used an unprotected source as their main supply of water (Macri et al., 2013: 28). Therefore, the number of dysfunctional 'improved' water sources in this community was well above the reported rural average (MWE, 2011b; RWSN, 2012). The community was also above the national average in terms of use of unprotected sources for rural communities, which was 30 per cent (UBOS, 2010: 121). Use of these water sources creates ill health; needless to say, a combination of economic, water, and health poverty was evident among the villagers. Clearly, water problems remained in abundance and it was in this context that we were to engage in practical action with the community.

These are poor households and their water expenses can be crippling. When asked about their water-related expenditure, a majority of respondents indicated that most expenses were generated by the purchase of water storage equipment, normally jerrycans, and secondly, pump repairs. In this community, most households (45 per cent) used one to three jerrycans (5 gallons/22.7 litres per jerrycan) of water per day on average, while almost as many used between four and six jerrycans per day (44 per cent), and another 9 per cent collected seven or more jerrycans per day (Macri et al., 2013: 31). This is extremely time-consuming, given the reported problems with queuing, particularly in the dry season; it is also labour intensive, particularly for women and children, and debilitating, given the physical problems created for women and children as a result of carrying jerrycans on their heads. When asked about the qualities they would like to see in a water source, most respondents (70 per cent) referred to the clean and safe quality of the water, while 56 per cent of all survey participants said they would like to have access to an improved water source and 53 per cent said they would like the source to be closer to home (Macri et al., 2013: 32).

What we meet here in this book is a community of people experiencing water poverty imbricated with health, economic, educational, and gendered poverty. They continue to experience these difficulties after new water systems have been installed. The success or failure of these new water systems' operation is to some degree relegated by the state to the community, which is now held by the international community as being somewhat responsible for its own water – or, rather, water problems. Quality of water and access to it, given current national policy, is now considered to be to some degree the responsibility of the parish, although the government does recognize that the capacity for it to be delivered on a sustainable basis is dependent on the level of skills in the community, the quality of the leadership at community level, and the willingness or ability in a neoliberal age of the community members to pay for water.

This research programme began with a needs-based assessment, wherein the community told us that the key problems faced in relation to water were failing pumps, quality of water supply, difficulties in accessing safe water, management difficulties, and associated costs. The parish resources were examined critically, under the advice of the local community, in terms of: the quality of the water resources available; the changing nature of those specific water resources; pump technologies in use; the possibilities of community engagement with solar technological advancements for safe water; the governance structures for managing water, household access, and equity of access to safe water; the gendered relations of water; and the resilience of the community to the impact of climate change on water supplies.

The chapters that follow are based on the findings produced by the researchers as they worked with the community towards the application of their own professional expertise to the problem, its solution, and associated actions. The knowledge for the practical action recommended was constructed from the combined knowledge of the community and the scientific disciplines engaged, as they worked together in the context of the reality of the everyday challenges of poor communities accessing and managing safe water.

Gender and governance

This book begins with the social arrangements for the provision and management of safe water in the community. Starting at the level of the smallest scale unit – the household – the gendered aspect of social arrangements is described. In this community, providing water for the household was strictly the responsibility of the women, who in turn often passed the work on to the children. On the other hand, accessing water for large stock animals or for commercial purposes was usually carried out by men. Where water was being accessed by vendors for resale, these were normally men and they usually had bicycles or motorbikes at their disposal. This gendered division of labour regarding water sourcing is the norm in Africa and beyond, and because of the key significance of gender, the first two chapters look at the gendered dimension of 'water life' and a variety of gender/water relationships that are at play in this community. In Chapter 2, Asaba et al. look into barriers to poor rural women's access to good-quality water for their households, since safe water remains a central problem for women and children in the case study area. They examine gender relations and inequalities in most of the mechanisms of access to water and in the governance structures at national and local levels, quantitatively and qualitatively. They examine payment arrangements, particularly maintenance and repair fees, to identify if these are impeding access by women and vulnerable children to water resources. They question whether the gender ratios for committees which are stipulated in government policy are actually enforced and, based on in-depth interviews with water communities in their villages, they examine barriers to progress in the implementation of these gender ratios. Their approach, and indeed that of Magala et al. in Chapter 3, confirms that a gender-based analysis remains an essential tool for identifying access issues and, indeed, for an equality intervention for progressing the future gender equity and sustainability-based quality water supply for this community, and of course for the future health of households in the parish. Magala et al. explore the socially ascribed gendered roles at play in relation to domestic water collection and management. Women are culturally responsible for domestic water supplies and management. They explore the role of men in domestic water management, and seek to uncover the power they hold, given that fees are now required for the operation and maintenance of water resources in the community. They introduce us to how women see these responsibilities and provide rich cultural data which arises from the ethnographic work of Joyce Magala, who lived and worked in the community for over a year.

Moving beyond the household level and 'upwards' to the community level, Mugumya et al. tackle the other key social arrangement, namely the role of the community in managing water resources, in Chapter 4. 'Community-based water management' is the social and political arrangement for delivery and management of safe water in rural domestic water supply, and is the policy instrument that dominates the water lives of this community. While it is strongly advocated, and is in place as the key strategic and practical way to sustainable service delivery in developing country contexts in general, its effectiveness in the context of this poor community is critically scrutinized. The authors take us through the various governance dynamics in the policy and service delivery framework at national, regional, and community level as a backdrop to explaining what we see happening at the community/village level in terms of governance or lack of governance of the improved water sources. Since the majority of 'improved' water sources were not functioning in this community at the beginning of the Water is Life project, this chapter is critical to an understanding of why this sorry state of water affairs existed. It describes the household and village water management structures, as do Asaba et al. in Chapter 2, but also crucially examines service delivery by the relevant local government water-sector actors, water-focused NGOs, spare-parts dealers, handpump mechanics, and technical support units. Technical personnel from the Directorate of Water Development of the Ministry of Water and Environment (MWE), national-level spare-parts dealers, donors, and key water-sector government organizations and networks were all interviewed to form the basis of this chapter's examination of key governance dynamics in the rural safe water-service delivery framework. This chapter asks and answers the question: do, or can, poor communities have the capacity to sustainably manage water facilities, and are they part of the route to equitable access to, and sustainability of, safe water in rural communities?

Asiimwe and Naige take a step back from this specific community with an overview of the national picture (Chapter 5). They summarize the overall water policy in Uganda and the governance challenges faced there. Providing us with an overall history of the issues and barriers at national level to safe water provision, they go on to discuss the paradox of water as either a public good and right or a profitable commodity affordable by a few. They generate a critical discussion on how this paradox should or could be managed at national level. Private–public partnership arrangements and state dependence on donor and development partners are critically scrutinized, while keeping in mind the government's responsibilities to both the urban and rural poor.

Findings in the first few chapters, in common with other research, clearly articulate that the provision and management of water at household level are firmly the responsibility of women, with water collection duties often being assigned to children. Chapters 2 and 3 stress that when men do get involved, it is not normally to assist in the management of water at household level. In Chapter 2, Asaba et al. highlight that a number of social and environmental factors interlink women and water in rural Uganda. In particular, they have established that despite the fact that 64 per cent of the rural population in Uganda are considered to have access to 'improved' sources of water (MWE, 2014), access to safe water remains a significant issue for women and children in the study area. As well as the enormous amount of time that women must invest every day in the process of collecting and managing water supplies for their households, both women and children face a number of risks associated with the process of collecting water. Such risks include walking long distances over uneven and hilly terrain, animal attacks, accidental drownings, verbal and physical abuse, and in some cases sexual violence. In addition, the heavy loads being carried lead to a number of chronic physical ailments, including chest pain, fatigue, headaches, and nosebleeds. Asaba et al. point out that as most of the power in relation to the 'formal' institutions around water management are male-dominated, as are water payment arrangements for the most part, these arrangements can leave women and children without the necessary access to water resources, particularly when men, as heads of households, do not pay the operation and management fees levied by community water committees. They therefore conclude that education and sensitization in relation to safe water and community-based management could bring about genuine transformation.

The narrative of the lived experiences of the daily routines of women in relation to water management in the study area, as described by Magala et al. in Chapter 3, clearly reaffirms that the burden of water collection takes a heavy toll on women and children. It is not just a physical burden, but is also a time burden, which impacts on their ability to engage in other activities. This means that their ability to reach their full potential is compromised. The findings described in Chapter 3 confirm that the majority of water management tasks at household level are carried out by women, with little or no involvement by men in this activity. The authors therefore recommend that men must be encouraged to become involved with water management at household level through a combination of appropriate dialogue and social inclusion processes. It is concluded that by increasing access to water, either by ensuring effective operation and management procedures for nearby pumps, or by bringing water supplies closer to households through harvesting rainwater, opportunities for women to improve their personal circumstances could be increased.

In Chapter 4, Mugumya et al. have validated, from their findings, that rural water policy implementation in Uganda is greatly challenged by complex and multifaceted community-level issues. Their findings demonstrate that while coordination efforts exist both at national and local government levels, the activities of the relevant institutions and bodies remain insufficiently anchored in communities. The authors argue that while in the framework of community-based water management systems (CBWMS), stakeholder collaborations are largely based on trust, the evidence gathered from their study reveals that these partnerships and collaborations, which are crucial for CBWMS and the functionality of rural domestic water supply infrastructure, are being threatened by declining trust among all stakeholders. This is particularly so in relation to operation and management, and supply of parts. The authors conclude that the way in which policy actors directly engage with communities is vital in realizing the goals of CBWMS.

In Chapter 5, Asiimwe and Naige confirm that the challenges associated with the operation and management of water resources account for much of the non-functionality of water sources in Uganda – in fact, more than half of all failures. They, like Asaba et al., confirm that girls in particular are often not safe when engaged in the process of collecting water. Throughout this chapter the authors address the challenges of management and access to safe and affordable water in Uganda, not least the underfunding of the water sector by the government. They emphasize the role of the state and its responsibility in the provision of safe and affordable water, but stress that NGOs and communities are important players in the proper management and provision of water. They argue that the rural and urban poor who cannot afford to pay should remain the focus of the government and its National Water and Sewerage Corporation. They also stress that there is a strong argument for the private sector to provide water to institutional and commercial users who can afford to pay.

Scientific and technological interventions towards improving resilience

In Chapter 6, Rugumayo et al. point out the realities of the challenges that Uganda faces in relation to integrated water resource management, including spatial and temporal variability in water resources, potential impacts of climate change, a lack of public and sectoral awareness (including limited and inadequate availability of data), inadequate funding for the sector, and limitations in human resources capacity in the water sector. A distinction is made between those environmental factors that cannot be controlled (e.g. geology, topography, and climate), and those factors that can be controlled (groundwater contamination, deforestation, wetland degradation, and directional climate change). In addition, the potential impact of projected increases in temperature through climate change on Uganda's future water availability is pointed out as being of huge concern for the future sustainability of both water quality and quantity. This reality must be managed effectively and in an integrated manner in order to ensure development and sustainability for Uganda and Ugandans in the coming decades. The remaining chapters describe technological or scientific interventions explored and pursued by the science-based researchers.

Following the overall challenges already described earlier and in Chapter 6 in particular, the later part of the book deals more directly with interventions at household and community level – technical interventions designed to work alongside communities to improve their water supply.

Safe water interventions, through schools and through households, are the focus of the next two chapters. In Chapter 7, Asiimwe et al. describe a research intervention with 700 pupils from 14 primary schools in an effort to make water from a variety of both improved and unimproved water sources safer. Since so-called improved water sources may not be adequately protected and therefore may not supply safe water, pupils agreed to drink only solar disinfection (SODIS) treated water whether at school or at home. The SODIS technique involves filling transparent plastic/glass containers with contaminated water, exposing it to unobscured sunlight for a minimum of six hours in strong sunny conditions, or longer (usually 48 hours) under cloudy weather, in order to improve its quality. The team monitored the effectiveness of SODIS on the microbial quality of water by recording incidence of diarrhoea and/or gastro-intestinal complaints that had been causing pupil absenteeism. Asiimwe et al. provide an account of the success of this strategy. A further intervention, closely linked, but approaching the problem of poor-quality water with householders as opposed to primary school children, is described by Nalwanga et al. in Chapter 8. Thirty households participated in this study of their harvested rainwater systems. The quality of the water in the tanks was examined, as was the usefulness, practicalities, and training requirements of applying SODIS treatment to improve the water quality from the rainwater harvesting tanks.

In Chapter 7, Asiimwe et al. found that open water sources such as ponds and unprotected open dug wells were the most frequently used water sources for the schools and communities in their study area. They further identified that none of the schools had any form of drinking water treatment plan in place, and pupils drank untreated water from whatever source the school used. All untreated water samples tested during the course of the study were found to be unfit for human consumption and were contaminated with coliform bacterial pathogens of faecal origin. This included water from 'improved' sources. SODIS, however, proved to be effective in improving the microbial quality of drinking water; absenteeism fell from 1.9 days per child per semester pre-intervention to 0.2 days post-intervention. Based on these findings and on the fact that schoolchildren proved to be effective 'ambassadors' for SODIS at household level, the authors therefore conclude that SODIS technology should be promoted at school, community, and household level to improve access to safe water, and thus improve people's health. In Chapter 8, Nalwanga et al., who explored the potential of using SODIS to disinfect harvested rainwater (HRW) found that although the practice of HRW is promoted and encouraged throughout Uganda, and especially in rural areas where centralized distributed water systems are rare, little thought has been given to the quality of the HRW. They present SODIS as an effective and low-cost alternative to other, more traditional forms of treatment, including sand filtration, boiling, and chlorination. Their findings clearly showed that when SODIS was carried out on HRW following the correct procedures, treatment efficiencies of up to 100 per cent could be achieved. They therefore recommend that 2 litre bottles should be exposed for a minimum of seven hours in sunny weather, but under cloudy conditions, bottles should be exposed for two full days (48 hours) so as to ensure total disinfection. In addition, they recommend that training is required at community level on the effective use of SODIS and on the dangers of using contaminated water.

Engineering expertise forms the basis of Chapter 9, in which a very direct intervention is designed for the handpumps in the area which, it has been noted, were in an almost continuous state of disrepair. Functioning handpumps are essential in order to provide access to safe drinking water from groundwater sources. The functional sustainability of handpumps is poor in this community. Lubwama et al. identified handpump problems faced by the rural community, specifically related to wear of piston seals, and investigated a novel surface-engineering approach to improve the wear resistance. Out of a total of 34 handpumps they examined in this area, only 10 were functional. By observing handpump usage on a daily basis and through a series of targeted community interviews, many of the problems highlighted by handpump users were identified as being either directly or indirectly related to the functionality of the piston seal. Consequently, as expected, direct consultations with the resident handpump mechanics in the immediate area revealed the piston seal to be the component replaced most often during breakdown maintenance interventions. Based on extensive testing under a range of conditions, the deposition of diamond-like carbon and silicon doped diamond-like carbon films onto the nitrile rubber piston seals, which increases wear resistance and thus reliability and functional sustainability, is suggested as a potential solution into the future.

The final chapter in Part II looks to the uncertain future of water in this community given the reality of encroaching climate change. Since the people in this community rely on surface water, it can be predicted that they will endure additional hardships. Tembo et al. argue that there need to be processes in place to support adaptive capacity in a changing climate. They go on to prescribe what they consider to be quality processes for this community (and other vulnerable communities) that will genuinely help its resilience in the face of climate change. Their model of 'dynamic' assessment emerges from deep ethnographic work in the community, holding informal discussions with community members, and involving them in generating data about their village with geographic information systems (GIS) for their capacity enhancement, specifically regarding water sources and their use. They demonstrated, through their mixed-methods approach, which involved prolonged and repeated interactions with the community, that participatory GIS (PGIS) can assist in revealing critical data about people and their environments – data that otherwise might not materialize. They make the suggestion that PGIS could assist communities in communicating their situation to decision-makers, which in turn might lead to a shift in attitude on the part of local government. The authors strongly advocate that strategies to address the effects of climate change on populations should take into account the knowledge contained within the local community to enhance future adaptive capacity.

There are clearly huge unmet water needs in this community requiring action by people both in the community and outside it. This book examines why these needs remain unmet despite the enactment of the Water Statute in 1995, the rollingout of the National Water Policy in 1999, the improved water resources, the community-based management schemes, and their stipulated gender ratios. The deficiencies of these enabling frameworks are apparent to the community and the researchers alike. While much activity has been generated to meet the MDGs (UN, 2000) on water, this book tells the tale of how water resources, as well as their quality and sustainability, are currently distributed, protected, and managed in one case study parish with a view to working with communities towards development.

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Notes

1. Water is Life: *Amazzi Bulamu* is a research project designed to build research capacity in Ireland and Africa and to conduct research that supports sustainable water resource management as a catalyst for sustainable economic and social development in rural Uganda. The project comprises a partnership of Irish Higher Education Institutions (Dundalk Institute of Technology (lead), NUI Maynooth, Dublin City University, Trinity College Dublin, the Royal College of Surgeons in Ireland, University College Dublin and Queen's University Belfast, Makerere University, Uganda, the Medical Missionaries of Mary, and various NGOs. The project is funded directly through the Irish Aid/HEA Programme of Strategic Co-operation in support of the Irish Aid mission to develop the capacity of the higher education sector for developmental research. The programme is managed by the Higher Education Authority (HEA on behalf of Irish Aid).
2. The field research for the baseline survey was carried out in 2011. The overall findings are published as Macri et al. (2013).

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CHAPTER 2

Women's access to safe water and participation in community management of supply

Richard Bagonza Asaba, G. Honor Fagan, and Consolata Kabonesa

Abstract

Poverty is rife in Uganda in both urban and rural communities. This chapter outlines the situation for poor women securing water for their households in a rural village. It gives an account of poor women's 'fluid lives' as they engage in efforts to secure water for their households and participate in water governance at community level where there are persistent water-related problems. The authors conducted a socio-economic study of households in a poor rural parish in order to better understand women's safe water access and participation in the management of a healthy community water supply. The study findings confirm that gender remains an important analytical tool for identifying access issues, since gender relations and inequalities are evident in most of the mechanisms of access to water in this community. The chapter explores how women and children remain vulnerable to lack of access to safe water, even where there are community schemes and improved water sources in place, since for the most part powerful, formal positions such as village chairperson, water user committee member, and handpump mechanic continue to be held by men. This is despite the fact that, in the case of water user committees in particular, the 1999 National Water Policy stipulates that women should make up 50 per cent of such committees. In addition, payment arrangements, particularly maintenance and repair fees, frequently result in denying vulnerable children and women physical access to water resources whenever men, as household heads, do not pay these fees. Strategies which seek to improve women's access to safe water and power in community organization of water remain essential.

Keywords: gender, water, women, access, community management

Introduction

Poverty is rife in Uganda in both urban and rural communities. The form it takes in rural communities provides the context for this chapter, which outlines the current situation with regard to poor women securing water for their households.

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According to the WHO/UNICEF Joint Monitoring Programme (JMP), targets set in the Millennium Development Goals (MDGs) on access to safe drinking water have been reached, with 89 per cent of the global population now using 'improved'[1] drinking water sources (WHO and UNICEF, 2012). However, 768 million people do not have access to safe water, and 40 per cent of these live in sub-Saharan Africa (WHO and UNICEF, 2013). This chapter provides an account of women's 'fluid lives', as described by Farhana (2009), in a community where securing safe water places women and children in potentially life-threatening situations. Efforts by poor women to access water for their households and participate in water governance at community level, where there are persistent water-related problems, were the focus of this research. The chapter reports on working with households, and with women and children in particular, to better understand and support their access to, and participation in, the management of a healthy community water supply.

The importance of safe water in rural communities

In most developing countries, people in rural areas are five times more likely to use 'unimproved'[2] water sources compared with their counterparts in urban areas. In addition, distances to water sources are very long and, compared with men and boys, women and girls spend a lot of time and energy collecting water (Crow, 2001; UNDP, 2006; WHO and UNICEF, 2000, 2012: 6–12, 31). In Uganda, access to safe water[3] is considered crucial for economic growth and development, good health, and an economically productive population, especially in rural areas, where 85 per cent of the entire population live (UBOS, 2010). The National Household Survey (UBOS 2010) revealed that over 90 per cent of the country's poor households[4] (or 7.1 million people) are in rural areas. Rural areas also have the highest levels of illiteracy, poor education facilities, poor health, and inadequate infrastructure, including water, roads, and electricity. Whereas access to safe water in rural Uganda has improved in the past 11 years, current estimates indicate that only 64 per cent of households use 'improved' water sources (GoU, 2012). This is mainly due to natural/geological and social challenges, the latter including inadequate operation and maintenance (O&M) mechanisms, continuous breakdown of improved water sources, and low involvement of women in water governance at local levels (Asingwire, 2011; GoU, 2009, 2010; Nimanya et al., 2011; Otiso, 2006; UWASNET, 2009). These conditions mostly affect women and children, who are sometimes forced to use water from unimproved water sources (e.g. Asaba et al., 2014; GoU, 2011b; Kanyesigye et al., 2004). Due to traditional stereotypes, norms, and practices, women and mostly girl children bear the burden of collecting water, using heavy water containers and procuring it from distant water sources (e.g. Danert and Motts, 2009; GoU, 2010, 2011a, 2012; UBOS, 2006, 2010).

Water plays a vital role in reducing poverty, especially in agriculture, which is the main source of livelihoods and income for rural populations in Africa (FAO, 2011). Access to safe drinking water improves physical and mental health, and, together with adequate sanitation and hygiene, reduces water-related diseases among the poor (UNDP, 2006; WHO, 2003). Improved water service delivery can also empower marginalized groups such as women and children, leading to their improved health, education, economic production, and security, as well as the governance and sustainability of water supplies (Cleaver and Hamada, 2010; Trémolet and Hunt, 2006; WaterAid, 2009).

Accessing safe water

As part of the case study research, the researchers surveyed approximately 600 households regarding their access to, and use of, safe water (Macri et al., 2013). The major improved water technologies that operated under formal 'rules' were tube wells or pumps (28 Indian U2 design shallow wells and eight U3M design deep wells/boreholes) and one protected spring. Whereas boreholes and shallow wells existed in almost all of the 15 villages in the study area, the researchers located only one protected spring; this spring was used by communities from the surrounding three villages. In August 2011, when the survey began, no boreholes were functioning and only seven shallow wells and the protected spring were usable. The main unimproved sources in the parish, most of which were run under customary rights, were ponds, open or hand-dug wells, and unprotected springs. Interestingly, approximately 40 per cent of survey respondents in the case study area mainly used water from unimproved unprotected sources. A further 26 per cent of all households studied mainly used shallow wells, and the rest used boreholes (20 per cent, when functioning), rain-harvested water (9 per cent), and the protected spring (5 per cent). Boreholes and shallow wells were the predominant sources for households occupying permanent and semi-permanent dwellings (Macri et al., 2013: 26).

When asked why they mainly used unimproved water sources, the survey respondents, in particular the women, indicated they used the unprotected sources because these were more permanent and 'reliable' sources of water. In addition, these sources were located closer to their households. The correlation between the main water sources used and proximity was highly significant, with unimproved water sources accounting for 35 per cent of the responses for shorter distances of less than half a kilometre to households (Macri et al., 2013: 27). Other reasons provided for using unimproved water sources were that they were felt to meet all the household water needs. When probed further on this point, however, respondents indicated that frequent breakdown of pumps and slow repairs left them feeling that the O&M fees were not worth paying. This added to the belief that, according to some women, the water did not even taste that nice from the improved sources and that water from pumps was salty or 'less tasty' (referred to locally as *tegawooma*). This was unfortunate given that the improved sources were the safer, although more expensive, option. Therefore, despite the existence of improved water sources, communities had their own understanding of what constituted good water, depending on their sense of taste, their own sense of value for money, and their own calculations regarding the labour involved in accessing safe water from these sources.

The household survey found that 88 per cent of the respondents made their water safe by boiling it (Macri et al., 2013: 34). Due to the use of unimproved water sources, and despite the commonly reported strategy of boiling water, 76 per cent of people in the households surveyed had experienced malaria during the previous year, 42 per cent had experienced stomach ache, and 37 per cent had experienced diarrhoea (Macri et al., 2013: 35). Water-related diseases were associated with significant costs, with 67 per cent of households indicating that their household expenses increased as a result of such diseases, 43 per cent reporting that water-related diseases had an impact on school attendance, and 38 per cent reporting loss of earnings due to diminished labour (Macri et al., 2013: 36).

Other studies have also documented high dependence on unimproved water sources in Uganda. For example, a participatory poverty assessment undertaken 12 years ago, and a review of water service delivery in other districts in eastern and central Uganda showed that rural women and children mostly relied on unimproved technologies for drinking water (GoU, 2002; Kanyesigye et al., 2004). Reasons for relying on unsafe water sources, such as shorter distances, refusal to pay high O&M fees, and pump breakdowns, have also been reported in northern, eastern, and central areas of rural Uganda (e.g. Asingwire, 2011; GoU, 2010, 2012; Kanyesigye et al., 2004).

Poor roads and paths

Roads and paths can facilitate the ability to physically reach a water resource by altering the number of people or vehicles that can reach a remote locality (e.g. Geisler and Silberling, 1992, in Ribot and Peluso, 2003: 165). If roads and paths are not in good condition, this can increase the burden and risks of carrying water (Sorenson et al., 2011). In the case study area, the use of poor roads and paths while collecting water was one of the major problems faced by survey respondents. Observations in four villages showed that community roads and paths leading to improved and unimproved water sources were uneven, hilly or steep, potholed, and in some cases stony. The paths were also narrow and 'bushy', a condition that potentially increased the risk of accidents for women and children. Women and children struggled to carry water around the steeper areas close to the water sources, sometimes falling and spilling the water in their containers or jerrycans, or even rupturing the jerrycans. Children also complained about stubbing their feet on stones, tree stumps, and other objects, or 'missing steps' on the rugged paths or roads they used while carrying water by hand/head-loading to their homes. Furthermore, some of the water sources were accessed by crossing major village roads used by vehicles, motorcycles, and bicycles, which increased the risk of injury or death while walking to and from the water sources.

The findings from this study highlight the need to have good road infrastructure in place for water collection, not only in rural Uganda but indeed in most developing communities. The hilly, bushy, and often unsafe roads and paths leading to water sources make water fetching more difficult for the women and children who use them while carrying heavy water loads by hand or by head-loading. The hills or steep slopes further increase the burden of carrying water. In addition, vehicles and motorcycles affect access to some water sources, and accidents involving these vehicles and women and children who are carrying water can also lead to injuries or death.

Women's role in community management of water sources

Formally constituted institutions, such as local government structures and user groups or associations, mediate access to water by different groups through processes of management and practice (e.g. Cleaver and Hamada, 2010: 29; Cleaver and Toner, 2006; Fabricius and Collins, 2007; Franks and Cleaver, 2007: 295, 300). In rural Uganda, some water associations and authoritative local administrative arrangements are gender sensitive, and therefore influence women's access to water.

Village chairpersons are elected leaders and are the most authoritative individuals in all villages in rural Uganda. Their authority is accorded to them by the Local Government Act (1997). Village chairpersons supervise all developments in their villages, including water developments. They are ex officio members of village water user committees (WUCs), as stipulated in rural water policies (e.g. GoU, 2007, 2011a); they monitor these committees, approve by-laws made by WUCs, and then forward them to higher local government authorities and the police for approval.

At the time the survey was carried out, all 15 village chairpersons in the case study area were men; this was due to patriarchal norms, values, and stereotypes – such as the view that, compared with women, men are seen to be 'better and stronger village leaders' – coupled with views on what are considered acceptable roles for men and women. The authority and influence of the male village chairpersons determines who accesses water, how active WUCs are, and when pumps should function. For example, village chairpersons sometimes deny or allocate access to especially improved water sources to certain individuals and households, depending on the status of the relationships they have with them, even in cases where the households had not paid O&M fees. In one village, a widow in her 70s alleged that the village chairperson, through the caretaker and some members of the WUC, had denied her, her grandchildren, and members of her household access to the borehole because she had supported a rival candidate during elections for the position of woman councillor in the parish.

Village chairpersons also often wield their authority whenever pumps malfunction by contacting the handpump mechanics (HPMs) and requesting them to repair pumps, even on occasions when the chairpersons do not have funds available to pay for such work. Village chairpersons also often urge individual community members to pay their share.

WUCs are formally constituted user groups that mediate access to water resources (Jonsson, 2005). Moreover, they provide a forum where the voices of women can be heard (Cleaver and Hamada, 2010; Plummer and Slaymaker, 2007: 19). WUCs also act as the established and recognized executive organs of water user groups for each improved water point in rural Uganda (GoU, 2007: 12; RWSN, 2010). In the case study area, WUCs existed for all improved water sources in each village, although many of these sources were inactive. The WUCs were male dominated in terms of leadership positions. Similarly, all of the WUC chairpersons for a protected spring, borehole, and two shallow wells were men. Women held only five key positions: vice chairperson (two); secretary (two); and treasurer (one). Of these five positions, three related to just one WUC. Only two women held positions in the remaining WUCs in the case study area.

Gender composition in leadership roles in WUCs seems to shape women's ability to access safe water. The WUC for the shallow well in one village, where three women were involved in leadership roles, was reported to be the most active in the parish, as it collected pump repair fees promptly. Because pump repairs were carried out quickly, the community was able to obtain clean water from the well without having to endure long periods of time waiting for work to be carried out. Such success was due to the good mobilization skills of the women WUC members. The WUCs that had a number of women in key roles enjoyed good relationships with the village chairpersons, and they also enjoyed the trust of water users with regard to handling and utilizing O&M fees and repair fees. Where WUCs were not active, the malfunctioning of pumps continued for long periods, usually between six months and a year, or even longer. Such prolonged periods with malfunctioning pumps increased women and children's physical burden of collecting safe water, as they had to obtain it from neighbouring villages, which were located at a distance of at least 1–3 km from their homes.

HPMs are critical to the proper functioning of improved water technologies in African rural communities (RWSN, 2012: 16). In Uganda, HPMs operate as private individuals hired by local government authorities or NGOs to handle, maintain, and repair pumps. In the case study area, only men hold these positions, as is the case in most rural areas of Uganda. Their expertise in terms of technical skills, and their relationships with communities and village chairpersons determine the functionality of the pumps. Other research carried out in Uganda shows that most HPMs, or improved water source technicians,[5] are men. For example, an assessment of the effectiveness of the community-based maintenance system for rural water supply facilities in 16 districts representing different regions of Uganda noted that about 97 per cent of all improved water source technicians were males, with females making up only 3 per cent (Asingwire, 2011). In some rural districts, especially in northern, southern, and eastern Uganda, accessing HPMs is not easy, and in other districts they are not well trained (e.g. Ademun, 2009; Nimanya et al., 2011; YODEO, 2007, in Mommen and Nekesa, 2010). Given the shortage of women in this position, there remains a deficit of technical 'know-how' within the female community at local level, thus limiting their ability to maintain functioning pumps.

Education and training

Access to certain forms of knowledge and privileged information, higher education, or specialized training shapes access to resources (e.g. Foucault, 1981; Ribot and Peluso, 2003).

The village chairpersons (all men, as discussed in the previous section) were in most cases more educated than other people in their communities and were in the 'knowledge loop' with regard to water technologies to be established or repaired by government. Through their actions, decisions, and relationships, the village chairpersons could affect access to water resources. Training on community-based management of water resources – particularly on the role of a WUC – can enable water users to mobilize others and even kick-start collection of repair funds whenever shallow wells break down. Such initiatives may in turn lead to pump repairs being carried out quickly.

In the case study area, 79.3 per cent of men and 81.6 per cent of women had not received any form of sensitization or training on water resource management (Macri et al., 2013).

Gender and payment for securing safe water

Fees to access, payments for maintenance, rights, and 'in kind' arrangements control access to safe water resources (Bolt and Fonseca, 2001; Franks and Cleaver, 2007). In the case study area and in rural Uganda in general, financial payments and payments in kind for water determine whether women and children can access water. Formal O&M fees are established by the WUCs for access to their improved water sources, as outlined in water policies (e.g. GoU, 1999, 2007). The payment of these fees allows access to water in the parish.

When asked about the financial contributions made by their household towards the operation and maintenance of their water sources, 20 per cent of respondents confirmed that they had never made such a contribution, 12 per cent could not tell when they had last contributed, and 14 per cent said they had contributed more than two years previously. However, it is important to note that, given the overall poverty rate in the community, over half the respondents (51 per cent) had contributed during the past year (Macri et al., 2013: 46). Survey respondents and WUC members reported that it was difficult to collect monthly O&M fees, and so the common practice was that repair fees (estimated to be between UGX 50,000 and UGX 100,000, equivalent to US$ 21–41)[6] were collected only when the pumps broke down. Culturally, men – the breadwinners and household heads – were responsible for paying these fees; the exceptions to this rule were cases where a woman was household head. In the villages where household heads paid O&M fees promptly, pumps were repaired within short timeframes, as WUCs easily raised sufficient funding to cover this expense. Whereas most women willingly paid the fees, many men and male-headed households declined to pay. In the case study survey only 38 per cent of respondents said that adult males or male household heads paid O&M or repair fees.

Men's failure to pay can be partly attributed to their limited cultural roles in domestic water provision. While some men claimed they were poor, or did not have the money, others simply never took payment of the fees seriously. Some men argued that it was the responsibility of the providers of the pumps (local government, politicians, and NGOs) to fix them. Studies from other areas of rural Uganda also indicate that community members, especially men, do not pay O&M fees, even when denied physical access to pumps, and this often leads to conflicts with their WUCs (e.g. Asingwire, 2011; CREAM, 2009; GoU, 2009, 2011; Socio-Economic Data Centre, 2001). Women and children from defaulting households tend to be denied physical access to improved water sources, and are thus forced to use the less restricted unimproved sources and to move to other far-off sources. However, in the case study area and in other districts in rural Uganda, vulnerable individuals such as very poor and widowed women and the elderly are usually exempted from paying O&M or repair fees through local entitlements. Exemptions for the very vulnerable is also an issue that is emphasized in rural water policies (e.g. GoU, 2011).

Conflict and deepening insecurity arise in cases where there are difficulties in paying O&M fees. Non-payment can lead to conflict at water sources. In the case study area, in-depth interviews revealed incidents where men and boys from households that defaulted on fees used pumps out of hours (usually after 8 p.m.) or early in the morning (between 4 a.m. and 5 a.m.), times when WUC members, especially source caretakers, were not available to restrict their illegal physical access. There were also cases of vandalism in some villages, where men and boys broke the padlocks put on pumps to control access out of normal working hours.

In some cases, access to water can also be achieved through providing direct communal labour, indirect labour (such as collecting money for running committees), and 'ancillary' labour or preparing food for community labourers (Coles and Wallace, 2005: 71). In the case study area, all types of labour were in place whenever communities themselves organized work on constructing, repairing, or cleaning both the improved and unimproved water sources.

Here, both cultural practices and a gender division of labour prevent men and women from working side by side. Men carry bricks, gravel, and other materials during the construction or repair of improved water sources, whereas women work together in a separate area, picking up rubbish lying around the open wells, slashing grass and surrounding bushes, or cooking food for the working parties.

Women and water collection

Water collection is a cultural and gender-related activity in terms of the burden of responsibility and distances travelled to access water sources (Coles and Wallace, 2005; Franks and Cleaver, 2007: 301; Makoni et al., 2004). As is the case in most developing countries, studies from rural Uganda indicate that responsibility for fetching water as well as overall water management in households is dictated by gender and cultural norms, in that these tasks are almost entirely undertaken by women. Other studies from rural Uganda demonstrate that the burden of water collection is borne by both women and children, with the latter missing school or arriving at school late due to having to collect water for their households (Danert and Motts, 2009; GoU, 2011b; Rudaheranwa et al., 2003; UBOS, 2006).

In the case study area, 54 per cent of respondents said that women were responsible for collecting water in households. In contrast, in-depth interviews and observations revealed that girl and boy children aged 5–15 were more heavily involved in water fetching. Girl and boy children made several trips to water sources in a single day, carrying heavy containers varying between 5 litres and 20 litres depending on the children's age, and they arrived at school late on many occasions, especially in the dry season. Thus, traditional norms in the parish mostly accorded the task of fetching water to children. Additionally, women in households with children were less involved in water collection than women in households with no children. Men rarely collected water for domestic use, due to traditional patriarchal norms and stereotyping, whereby water fetching is deemed shameful, demeaning, and inappropriate for them. Men fetched water for other than domestic use – often for its resale – but usually when they had the use of some technological support for its transport. Observations at water sources showed that men and male youths mostly used bicycles to fetch water, and, less often, motorcycles and wheelbarrows. Most women, on the other hand, did not have access to these modes of transport, unless mediated through men.

With regard to distances travelled to fetch water, recent statistics indicate that people in rural households in Uganda travel an average of 0.9 km to their main water sources (UBOS, 2014: 138). While the average distance travelled to fetch water from improved water sources in at least three villages was also slightly less than 1 km, women complained about arduous journeys due to the hilly terrain, bad roads, and the paths they had to use in order to reach the water sources.

Women and children in other areas of rural Uganda travel even longer distances than women in the case study area. In mid-eastern, central, and south-western Uganda, they travel between 1 km and 5 km to fetch water for domestic use (Ademun, 2009; Danert and Motts, 2009; DMTC, 2009; GoU, 2008, 2011a; Sugita, 2006). These distances, coupled with factors such as difficult terrain, poor water flow, and queues at the water sources, mean that every day these groups spend a lot of valuable time – ranging from several minutes to several hours – fetching water. For example, women and children in the case study area spent between 30 minutes and 1 hour collecting water on a single trip in an average day.

It is worth noting that women and children in rural Uganda also face other challenges which increase their burden while collecting water, and many of these challenges are less reported in the literature. They include ill health due to carrying heavy water loads, accidental injuries, drowning, assault, rape, and defilement. In this case study area, women and youths aged between 15 and 24 years carried 20 litre jerrycans; children aged 10–15 carried 10 litres; and those aged 5–10 carried 5 litres. As a result, they all frequently suffered from chest pain, with children in particular complaining about fatigue, headaches, and nosebleeds. Children also sustained injuries due to falling while carrying heavy water containers, skidding on the rugged and slippery roads during the rainy season, and tripping over stones. The researchers were told that three children had drowned while attempting to draw water from unimproved water sources, particularly open wells and ponds. Women and children also suffered from verbal and physical assault while collecting water. For example, girl children alleged that boys insulted them while queuing at improved water sources, and child fights resulting from quarrels and boys trying to jump the queue led to injuries such as minor body cuts and swellings. Threats of being attacked by animals and reptiles were also real, with 'big' snakes frequently sighted at one of the open wells. At least three cases of child defilement were reported, one at an improved water source and the other two at an unimproved water source. There was also one case of attempted rape of women at an unimproved source.

Conclusion

This study has provided evidence from rural Uganda of the intricate, gender-related nature of access to water in areas where community schemes are in operation. Access to safe water sources remains a central problem for women and children in the study area. Gender relations and inequalities are evident in most of the mechanisms of access to water. Women and children are also burdened by the physical challenges and other risks they face while collecting water. For the most part, powerful formal positions such as village chairpersons, WUC members, and HPMs continue to be held by men. This is despite the fact that, in the case of WUCs in particular, the 1999 National Water Policy stipulates that women should make up 50 per cent of such committees. The gender ratios for committees that are stipulated in government policy are not enforced despite the fact that, as demonstrated in this study, women's involvement in WUCs translates into more active WUCs and increased access to safe water. Payment arrangements, particularly maintenance and repair fees, frequently result in denying vulnerable children and women physical access to water resources whenever men, as household heads, do not pay these fees. Encouraging men to pay fees, improving education or sensitization on safe water, and increasing women's involvement in the management of community water resources can bring real change.

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Notes

1. 'Improved' water sources are defined by WHO/UNICEF JMP as those that, by nature of their construction or through active intervention, are protected from outside contamination, especially faecal matter. Examples include piped water into dwellings, boreholes, protected springs, protected dug wells or shallow wells, and rainwater.
2. 'Unimproved' water sources are defined by WHO/UNICEF JMP as those that, by nature of their construction or through active intervention, are not protected from outside contamination, especially faecal matter. Examples include unprotected springs, unprotected dug wells, and surface water.
3. Defined in Uganda as the ability of households to use 20 l of water per person per day from an improved source that is located not more than 1.5 km from their dwelling (GoU, 2007), and more recently redefined as not more than 1 km from their dwelling (GoU, 2010: xii).
4. A household is defined as a group of persons who normally cook, eat, and live together irrespective of whether they are related (UBOS, 2006).
5. Including HPMs, plumbers, gravity flow scheme attendants, and masons.
6. Exchange rate US$1 = UGX 2,425 during the data collection period March to December 2011.
7. In this study, youths were defined as people aged between 18 and 24.

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CHAPTER 3

Lived experiences of women as principal gatekeepers of water management in rural Uganda

Joyce Mpalanyi Magala, Consolata Kabonesa, and Anthony Staines

Abstract

In most of the developing world, women are the principal gatekeepers of water at the household level. Given the socially ascribed role of water management, women are culturally responsible for domestic water supplies and management. Women see these responsibilities as a symbol of womanhood. However, activities associated with water management have a significant effect on their health. In addition, they spend considerable time making decisions with regard to water management (collection, use, and storage) within the household. Restricted access to water influences the social role performance of women at household level. For example, it negatively affects their ability to practise effective hygiene. Within the household, children are often the key collectors of water. Men, on the other hand, play a minimal role in water management but nevertheless wield a great deal of power in relation to decisions on paying community water fees and the funding of the equipment and materials necessary for water collection and water storage. Increased access to water, and bringing water closer to households, could enhance women's social role performance and opportunities to realize their full potential. Dialogue should be promoted at community level to get men more involved in the social processes of water management at household level.

Keywords: women, water management, gatekeepers, role performance, household

Introduction

This chapter draws substantially on an ethnographic study of women's experience of water management in a rural Ugandan community. Water management is shown to be a complex task for these women. The seasonal factors and forces that influence women's access to water at household level are discussed. Women play a critical social role in decision-making and negotiating around

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water management in order to fulfil the family's water needs, whereas men pay either little or no attention to water issues. Ideally, men should be responsible for the purchase of water containers (known locally as jerrycans), but this is a role they rarely fulfil. Although children are the key collectors of water for household needs, women bear the primary responsibility to ensure the availability of domestic water.

Global perspective

Women carry out the complex process of planning, coordination, negotiation, and decision-making in relation to the management of water at household level. This is considered to be a burden:

> because women shoulder the bulk of domestic responsibilities in most societies, [and] women are unable to allocate their time to more productive (or remunerative) uses unless their labour productivity increases. Introducing technologies that reduce women's time and energy expenditures can enable women to invest in income-generating activities, child care, or much needed rest and leisure time. (Quisumbing and Baulch, 2009: 4)

Leite draws a distinction between 'women's role [which] is focused [mainly] on the home and reproductive responsibilities, whereas men are primarily focused on activities outside of the home, including commercial farming activities' (2010: 71–2). Although men also experience a need for water in the domestic context, according to local norms and customs, it is not up to them to provide it; that responsibility falls to women as part of their everyday activities. The WHO/UNICEF Joint Monitoring Programme (JMP) shows that 'at household level, women still shoulder the largest burden of collecting water, at 64 per cent compared to 24 per cent for men' (2010: 29). In an earlier study, UNICEF and WHO (2008) observed that women generally collect more water than men. It is important to note, therefore, that water management in the home forms a large part of women's daily activities.

The Ugandan context

Although access to water in Uganda is still a challenge for many families, particularly in rural areas, the government has put in place a number of strategies to improve water delivery services. For example, the government 'designed the rural water strategy aimed at developing water and sanitation services to become effective, efficient, equitable and sustainable' (MWE, 2009: 50). The strategy focuses on the distance to the water source, the quality of water, and representation on the water committees as some of the specific indicators that were established to measure progress towards access to water (MWE, 2012: 3). Whereas quality and 'distance remain important determinants of the burden of water collection, socio-cultural … and health-related conditions are equally critical in understanding the troubles that children and women face while collecting water in rural developing communities' (Asaba et al., 2013). This chapter thus presents an understanding of the socio-cultural perspective, which is drawn from a larger ethnographic study on women and water management conducted in a village in the Lwengo district, south-western Uganda.

The village in question is located in a rural setting, south-west of Uganda's capital city Kampala. It lies within a semi-arid region where water is scarce and technological options to ensure a constant supply of water are limited. Water sources are located within 500 m to 2 km of the villagers' homes. This ethnographic study involved a deep immersion in the life of the women struggling to manage their domestic supply of water. The long stay in the field allowed for an exploration of how people make sense of their world (Lofland and Lofland, 1984). As a result, the study findings provide a unique understanding of the meaning of various activities carried out by the women around water management.

Lived experiences of women collectors of water

Water is of symbolic importance to the women, as demonstrated by the everyday activities in which women are engaged. Water usage at household level is of critical importance to the health of the entire family, and is of socio-economic value. Water is a means of survival and livelihood, as it is used for nutrition (including water for drinking), hygiene, and small commercial activities such as rearing birds and small-scale brewing. Water management in the village involved in this study is a daily activity that begins when the women wake up, usually around 4.30 a.m. The women in this village spend considerable time managing the collection and usage of water, which may include actually collecting water themselves. They begin their day by organizing containers for collecting water, and then wake up the children (aged between 3 and 12 years), who are the principal collectors of water in this village. Boys cease involvement in such activity when they reach the age of 16. Younger children collect water before having their breakfast and heading to school. Where women do not have children, or have younger children (< 3 years), they fetch water alone. In this village, women go to the well between 5.00 a.m. and 6.00 a.m. and may have to walk more than 2 km each way. For some women, their load is greatly increased if they have to carry small children with them. When they return from the water source, they prepare breakfast and eat with the family. Thereafter, they must plan how to efficiently use the water they have collected that morning for drinking, cooking, washing dishes and clothes, bathing, and watering animals.

The socially ascribed role of water management places a bigger burden on women. Moreover, planning how to use the little water available is a frustrating experience for women. Water management revolves around water collection, usage, and storage. This poses a dilemma, especially in times of scarcity, thus hindering women's self-actualization. In contrast, men's role in water management relates mostly to the provision of resources for women to

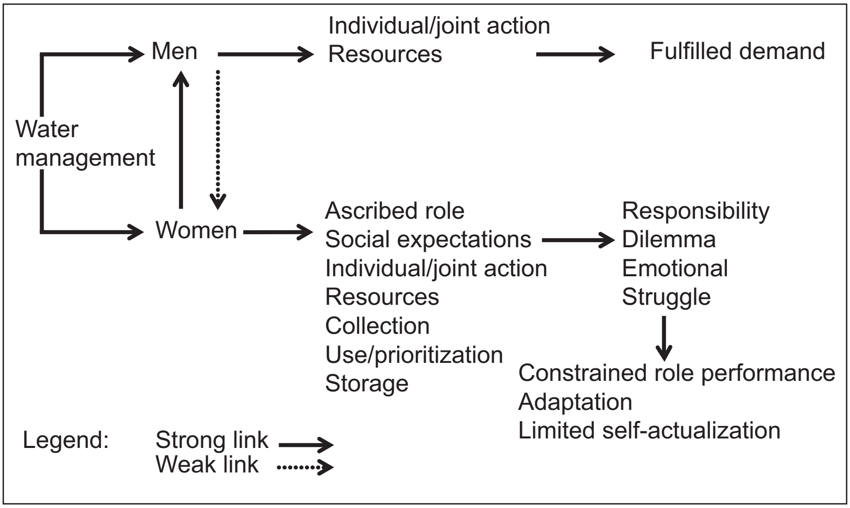

Figure 3.1 Roles in water management at household level

acquire water containers. Figure 3.1 illustrates the different roles played by men and women in water management at household level.

The scenario described above is exemplified by Mrs Kafeero (real name withheld), one of the women in the village, who said: 'There is a low expectation of men's participation in collection of water for domestic use. Thus women organize this. Where men participate, it is on a voluntary basis: it is not an obligation' (Magala, 2014). Mr Juma (real name withheld), a local leader, said: 'It is difficult for a man to carry water in this typical rural village … people would think he was bewitched' (Magala, 2014). These statements suggest that men believe they have an entitlement vis-à-vis household water management, but do not accept the responsibility of the physical labour associated with it.

Seasonal patterns and forces influencing water management

In a discussion on the role of gatekeeper, Shoemaker et al. noted that forces which 'vary in intensity and polarity', and could be 'either positive or negative', influence social events (2001: 233). In the village involved in this study, the seasonal patterns and forces that positively or negatively influence decisions around the management of water are many, but the type of water source and the distance to that water source determine the quality and quantity of available water in an individual household. In this village, water is collected from open ponds, open wells, protected shallow wells, and a spring.

It is also important to note that the circumstances of water collection and management are not static. For example, for the women in this village, the proximity of a water source is more important than access to clean water at a source that is situated a long distance from the village. Ms Teo (real name withheld), an elderly woman, said: 'The water from the pond is not good for drinking and cooking, since cows also drink from the pond. This could bring with it illness/disease. However, because it is nearer to the households, we mostly use this water so as to avoid travelling long distances to the spring, which has cleaner water' (Magala, 2014).

Before the children leave for school, they engage in activities including taking the animals for grazing, sweeping the compound, and removing dirty dishes and utensils from the home for cleaning. Upon completion of these tasks, the children wash their faces and their feet. Again, just a small amount (less than 2 litres) of water is shared by all children in the household for this purpose. The limitation of hygienic practices to washing just the face and the feet is a reflection of the reality of water scarcity and, at the same time, a reflection of a desire to respond to social expectations that children are clean when they arrive at school. Schools carry out hygiene inspections on a weekly basis to enforce compliance, with random inspections of children's hair, fingers, and feet by teachers on any given day.

After the children have left for school, most women set off at around 8.00 a.m. to engage in farming activities at distances ranging between 200 m and 2 km from home. Farming activities are predominantly focused on seasonal crops – beans, maize, groundnuts, potatoes, and cassava – which are the main sources of food. A few cash crops – for example, coffee and bananas – are grown to generate income for the family. At around 12.30 p.m., the women return home to prepare food, carry out essential household tasks, and water the animals.

Many households rear one or two pigs and keep poultry on the compound. Some have one or two goats grazing on common land. Animals are a source of food for the family and are also a source of income.

For women with babies and young children, the washing of clothes is a daily activity, whereas other women tend to dedicate one particular day each week to this task. On such days, the requirement for water is greatly increased, usually by at least 40 litres, depending on the volume of clothes to be washed. Often, women must collect this additional water requirement themselves. The distances and the effort involved in collecting water are not the only physical challenges facing women. UNDP (2006) and WaterAid (2009) noted that women are also at risk of sexual harassment, assault, falls, and injuries while walking to collect water.

The scarcity of water dictates the level of activities aimed at maintaining cleanliness. Personal hygiene, where the whole body is washed, is usually carried out irregularly during the week, often with water that has already been used for washing clothes; on other days, only the face, hands, and genitalia are washed. Women's inability to wash properly due to scarcity of water leads to health problems.

Poor health can be described as an inability to perform certain roles and not merely the presence of disease. Ability to carry out a role performance is a health issue from a socio-cultural perspective (Smith, 1983).

A separate but related dilemma facing women is that they often have to decide between giving their animals recycled soapy water, or not watering them at all. Most women choose the former.

Typically, once women have completed their household chores and have eaten their lunch, there is little or no water left over for any other activities, such as washing the dishes used for lunch. Thus, another cycle of water collection begins, albeit delayed to a cooler time of day, i.e. around 4.00 p.m., when the children have returned from school and are available to fetch water. This cycle of water collection deprives women of the opportunity to relax or address other responsibilities. In Pakistan, Ilahi and Grimard (2000) noted that improvements in access to water increase the time women have available to engage in income-generating activities. Evidence suggests that 'those spending more than half an hour per round trip progressively collect less water and eventually fail to meet their families' minimum daily drinking water needs' (WHO and UNICEF, 2010: 28).

After the afternoon cycle of water collection has been completed, women return to their farming activities, but this time usually at a location closer to home. These farming activities continue until the older children return from school, around 6.00 p.m., when the final round of water collection for the day takes place. This last journey is particularly challenging for women, because not only is daylight beginning to fade, but also the children are already tired after their school activities and are therefore generally disinterested in water collection. The time required to collect water is greatly increased at this time of the day due to the larger numbers of people present at the water source (which in turn is due to the fact that more children are available to collect water in the evenings and most women are freer to make the journey without having to carry small children with them). The evening water collection is usually completed by 7.00 p.m. During the dry season, when the water volume decreases at the water sources, it takes longer to fill the water containers and the task may not be completed until 8.00 p.m. or 8.30 p.m. In addition, those queuing for water can become fractious, leading to interpersonal conflict. If children's return from the water source is delayed, women may become concerned for their safety and set off to ascertain their whereabouts. Related evening-time safety issues include children becoming embroiled in physical conflict with others in the rush to access water, and the fear of children being out in the dark.

For women, the final household chores of the day include washing the dishes used during the day. Also around this time, a woman will set aside a dedicated amount of water to cater for the daily washing needs of her husband – normally about 5 litres of water. Before retiring to bed, the women and children will bring all items relating to water, food, and farming into the house. Younger children are generally asleep from 8.00 p.m. onwards and older children from 9.00 p.m. onwards. Women retire to bed at 10.00 p.m., following what is for most an 18-hour day of activities and responsibilities around water and water management. As noted by Koolwal and Van de Walle (2012), the demands of water collection take a heavy toll on women and children, thus depriving them of opportunities to engage in other activities.

Men rarely, if ever, get involved in water management activities at household level. However, where water is associated with productive roles such as income-generating activities, men are directly involved. For example, where there is small-scale brewing, they engage in water collection specifically for that income-generating activity. In addition, men who are engaged in vegetable growing as an income-generating activity take responsibility for collecting the water used for watering and spraying vegetables. Men with cattle also take responsibility for watering their animals. In the village which was the subject of this study, while women and children played a critical role in home and domestic water management on a daily basis, men engaged in water-related issues on an irregular basis and often for personal and economic reasons.

If one is to gain an understanding of the issue of women and water management, one needs to explore the local context, factors around water, and the environment in which the women live.

Routes to water management

As the principal gatekeepers, women govern most routes to water management and therefore determine how water is provided to the household. In the case of the village in question, communal water sources are predominantly located at the bottom of a valley, whereas many households are located higher up the side of the valley. Such topography makes water transportation to the household challenging for both women and children.

It was noted that the geographical location of a particular water source was the key factor influencing the women's decision about the quality and quantity of water collected. It was also noted that trips to the wells interfered with their capacity to manage the home and engage in other activities effectively. The women weighed up the amount of travel time required to collect the water and this ultimately determined which water source they used. The need for a sustained water supply, and one that is easily accessible all year round, is critical for the women in this village.

Another access route to water is through harvesting rainwater run-off from roofs. Most women collect rainwater using small saucepans, clay pots, and basins, with the amount harvested determined by the type and size of the roof and the number and size of the containers available for storage. As Ilahi and Grimard (2000) observed, infrastructure such as water containers and water sources is of paramount importance.

According to Lewin (1947), routes to water are influenced by 'states of affairs or significant happenings', which are mostly seasonal in nature. For example, the arrival of the rainy season is an example of a 'significant happening' with regard to water sources. It increases the amount of water available for domestic use, especially for women who have sufficient containers to harvest rainwater.

In addition to states of affairs or significant happenings, there are also social, physical, and economic 'forces which influence the person who manages the collection of water' (Lewin, 1947). The availability or unavailability of adequate numbers of jerrycans is one example of how a 'state of affairs' influences water collection.

Once water is delivered to the home, decisions around usage and storage come into play. Access to water is of paramount importance to women due to the numerous domestic tasks they must carry out (Koolwal and Van de Walle, 2012). Ms Adela (real name withheld), an elderly woman in the village involved in this study, said: 'Water is the reason we live as women; it is precious, but limited and difficult to get. It makes us work like donkeys. There are many problems with water: containers, time, distance, and money as well as [the] other activities [we] have to do. The amount, colour, taste of water determines how we use it' (Magala, 2014).

It was also observed that in this village, social factors, such as the educational status of the woman, her life cycle stage, and the numbers and ages of children in the household who are able to collect water, determine the capacity for water collection and the management of water at household level. Women who have had some education have a better sense of self and are more empowered to manage resources and water-related issues, including personal hygiene. With regard to the management of water collection in particular, the educational status of the woman is more significant than the number of children she has. Access to income and other resources is a positive force which determines the amount of water available to a household. For example, educated women, such as teachers, can plan better for water collection and are able to purchase additional containers or buy water from vendors. Therefore, since water does 'not move by itself' to the household, the patterns of forces around water collection become critical (Lewin, 1947).

While younger women collect water on a daily basis, elderly women have limited capacity to carry water and are occasionally assisted by their grandchildren. In the village that was involved in the study, the purchase or non-purchase of jerrycans, which are the main containers used to transport and store water, has the potential to create conflict (Lewin, 1947). Such conflict may arise from a lack of readiness on the part of the men to spend money on the purchase of jerrycans. Moreover, the lack of adequate containers for water collection results in less water being available for household use, which in turn leads to conflict within the home. School term or holiday time, planting or harvest season become major variables that determine the forces influencing water collection. Such forces 'vary in intensity and polarity' (Shoemaker et al., 2001: 233). For example, during the rainy season and during school holidays, women who have access to storage containers are able to collect more water for their household needs.

Conflicts arise when many people from this village gather at a water source at the same time and long queues develop. The situation is exacerbated by the sharing of one of the most reliable shallow wells with a neighbouring village. Ms Nabiryo (real name withheld), a young mother of five children, said:

> In the dry season, the lines [queues] become longer at this well and, as women, we get more involved in water collection at the source. We need to protect the younger children from quarrels and fights. These quarrels are caused by young men (mostly water vendors) who force their way to the water source, without respecting other people who came before them. (Magala, 2014)

The engagement by women in water collection during the dry season affects the rest of their work schedule. Furthermore, they must adapt to seasonal patterns, as routes to water become more difficult to access during a drought.

Ms Naaka (real name withheld), an old woman in the village living with HIV/AIDS, spoke about the benefits of rainwater harvesting:

> The rainwater tank is one of my most valuable assets let alone the comfort of living in a brick laid house with an iron roof. This illness robbed me of my ability to work for myself. Having water within the compound has made me live longer. I cook and eat on time. Bathe when I want. But also my neighbours and friends collect water from the tank during the rainy season. (Magala, 2014)

This statement reaffirms that villagers make decisions to share water with others in the village as a way of supporting each other with the burden of collecting water.

Discussion

In reflecting on the actions and the words of the women interviewed, in order to gain an understanding of why they acted the way they did around water, one gets a sense that decision-making power in this case is an act of resilience and adaptability towards life tasks (Phillips, 1997: 282). The incidents described illustrate the complexity of decision-making around water management within the home, and how this complex decision-making process determines how and when household members are allowed to use water. These tasks relate to women's compliance with cultural expectations and norms of womanhood, such as fulfilling the water demands of the men in the household.

Water availability in this village is influenced by both internal and external factors. Internal factors relate to the many competing needs for water in the home, including planning and decisions around water and how it is managed. External factors include the different seasons, distance to the water sources, the condition of the sources, and the size of the population drawing water from the particular sources. The symbolism of water is reflected in the decisions and actions of the women with regard to water. They are obliged to make choices with regard to how to use the available water and what amount to allocate to each activity. This includes having to make a conscious decision to recycle water for various activities, such as watering their animals. The choices made reflect the women's sense of womanhood by prioritizing their water-related activities to meet the family needs.

The ascribed social roles place the burden of domestic work on women, and water collection is one of the core activities they are expected to perform. Men are expected to engage in income-generating activities, which are mainly based outside the home. Therefore, they are not expected to engage in domestic water management.

Water usage, through such activities as washing of school uniforms, is prioritized by women in the village involved in this study, and is a significant undertaking. Women's conformity to society and school authorities' expectation that children should wear clean uniforms demonstrates an attentiveness and a concern with how children are seen in the wider community. Women respond to the actions and reactions of others, and their decisions on how to use water dictate the types of action they take – for example, keeping clothes washing to the minimum required to maintain a sense of conformity, while at the same time managing limited resources. While rationing water use and planning the next water refill impact on individual actions, they also impact on group actions, such as those of the school with regard to hygiene inspections.

Scarcity of water at household level influences hygiene and sanitation behaviour as well as prioritization and utilization of water on a daily basis. The lack of sufficient water generally presents a risk to health. Failure to wash properly on a regular basis leads to poor health, which can be described as an inability to perform certain roles and not merely the presence of disease.

Given the seasonal patterns and forces influencing access to water, women's gatekeeping role involves regular planning, coordination, organization, negotiation, and monitoring of water collection and water use at household level. Constant water-related endeavours leave little time for the women to engage in development activities and to work towards self-actualization.

Conclusion

This ethnographic study presents the social world of women and their lived experience in water management as a complex concept. The preciousness of water is demonstrated by the women's adaptation to scarce water. Water is of symbolic importance in their everyday lives and to their sense of womanhood. Such symbolism is a form of language used by women, and this is demonstrated in the way they relate to water sources, water containers, children, and men. During times when less water is available, decision-making about ever-competing priorities becomes even more arduous for women. It is more important to have some water available than to have quality water, in order for women to be able to perform their social roles. The decisions they make demand creativity and entrepreneurship, in order to find solutions such as water reuse, recycling, and rationing at every stage of their everyday lives.

While older women cope better as a result of assistance provided by their grandchildren, younger women with young children are caught in a web of despair, dilemma, and struggle as they juggle the tasks of water collection, childcare, and fulfilment of the family's water needs. The study recommends that health be regarded as an issue that extends beyond concern about disease; it also recommends that greater attention be paid to the socio-cultural perspective of women and water. The study explains the complexity of the lived experience of women and water management which emanates from the socially ascribed role of water provision. It recommends the promotion of dialogue to get men more involved in social processes related to water management at household level. Moreover, increased access to water and bringing it closer to households could enhance women's role performance and opportunities to realize their full potential.

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CHAPTER 4

Leveraging community capacity to manage improved point-water facilities

Firminus Mugumya, Ronaldo Munck, and Narathius Asingwire

Abstract

Community-based water management systems (CBWMSs) are now a popular policy strategy for sustainable rural safe water supply in Africa. However, the effectiveness of the model is marred by numerous bottlenecks of varying character and scale. This chapter, which is based on a case study of a rural parish in south-central Uganda, examines some of these bottlenecks. The study indicates that whereas CBWMSs are well known among water-sector actors as desirable for achieving functional sustainability of improved water facilities, conscious actions have not been taken to leverage the effectiveness of these water management systems. This failure is at the very heart of the weaknesses within the new policy frameworks which embrace principles of community participation, privatization, and public–private partnerships. The study advocates a public authority with renewed attention to local conditions that determine CBWMS effectiveness, especially in developing countries like Uganda.

Keywords: community-based water management system, CBWMS, functional sustainability, rural water supply, improved water supply, Uganda

Introduction

Inadequate community capacity to sustainably manage (own, operate, and maintain) improved safe water facilities remains a key obstacle to equitable access to and sustainability of safe water in rural communities of most of sub-Saharan Africa. Paradoxically, this challenging reality forms the backdrop of increased knowledge and experience which indicates that sustainable access to and utilization of safe water depend on the collective efforts of service providers and users as espoused by the community-based water management system (CBWMS) model. In Uganda the model operates on the premise that when community-elected water management structures, commonly known as water and sanitation committees (WSCs), are functional – that is, when they meet regularly, collect funds for operation and maintenance (O&M) of their improved water facilities, have a signed contract with a handpump mechanic (HPM), report handpump breakdowns, ensure proper sanitation and

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hygiene at water sources, and formulate and enforce by-laws – high levels of functional sustainability of water sources can be realized (Lockwood and Smits, 2011; MWE, 2011a; Schouten and Moriarty, 2003). Indeed, evidence from research and practice in Uganda and elsewhere shows that effective CBWMSs are a pre-condition for functional sustainability of improved water facilities, defined as the ability of a water source to continuously yield adequate clean and safe water for users at any particular time (Carter and Danert, 2003; Lockwood and Smits, 2011; Nabunnya et al., 2012). However, this relationship (as illustrated in Figure 4.1) is not usually smooth and linear, as might be expected. Our study confirmed that various governance dynamics in the policy and service delivery framework at national, regional, and community level often combine to determine what we see happening at the community/village level.

Studies on rural safe water supply in developing country contexts, especially in sub-Saharan Africa, have consistently demonstrated dismal performance of CBWMSs. In Uganda, for example, the functionality/effectiveness of WSCs in 2011 was shown to be 50 per cent (MWE, 2011a), and it has not significantly changed in the interim. This dismal performance is epitomized by low levels of full functionality of water sources, which is estimated to be just over half (53 per cent) of the improved water sources in Uganda (MWE, 2013a). In essence, deliberate interventions to leverage the effectiveness of communities and their water management structures are crucial, and once initiated, these actions need to be maintained at a pace that allows community capacities to be built on a sustainable scale, including assessing the extent to which such capacities have been built and the potential for their sustainability. Moreover, communities are most affected when there is poor yield or no water yield from their improved water facilities. Functional sustainability goals, therefore, should include a deliberate focus on building community capacity and efficiency in the O&M of their water supply infrastructures, which are often situated at particular points in their localities due to the dictates of technology,

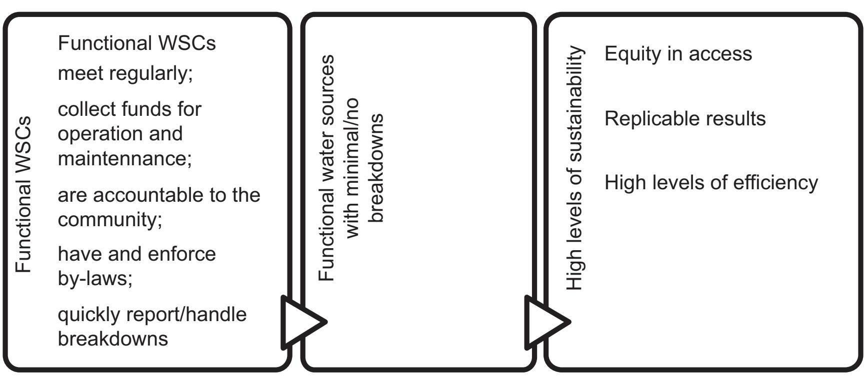

Figure 4.1 Operational relationship between effective CBWMS and functional sustainability of rural point-water facilities
Source: Mugumya, 2013

groundwater potential, or funding mechanisms. Building community capacity for O&M in Uganda means a new focus on the CBWMS.

The CBWMS oversees rural point-water facilities serving more than 85 per cent of Uganda's approximately 34 million people. In order for this community-level capacity to be built, the concerted efforts of water-sector actors need to be harnessed to address the key governance-related obstacles to the effectiveness of the CBWMS.

This chapter examines how the key governance dynamics in the rural safe water service delivery framework affect and are affected by those at the community level, where water users and their committees take important water management decisions and actions under the CBWMS framework. The chapter is primarily based on research findings from a case study of a parish in south-central Uganda undertaken in 2011 (Mugumya, 2013). The study employed a mixed-methods research approach utilizing both qualitative and quantitative methods of inquiry in a single case study design (Yin, 2003). At the community or micro level, the study targeted households and village water management structures, while at the meso or intermediate level of service delivery, relevant local government water-sector actors, water-focused NGOs, spare-parts dealers, HPMs, and technical support units (TSUs) were interviewed. At the macro or national level, technical personnel from the Directorate of Water Development of the Ministry of Water and Environment (MWE), national-level spare-parts dealers, donors, and key water-sector NGOs and networks were interviewed.

Key findings

Research carried out among members of the case study community revealed a set of governance dynamics within the rural safe water policy implementation architecture that continue to undermine the CBWMS in Uganda. Local government dependence on central government grants to finance rural water supply activities, coupled with the complexities surrounding local government decision-making, political interests, fragile market regulatory systems, and ineffective and weak water-sector actor collaborations or networks remain key bottlenecks that directly affect community-level water governance institutions. Similarly, at the community level, the lack of continuous support and capacity building for the community, prolonged periods of community dependence on 'free' services, the lack of enforceable community-level by-laws, perceived policy inconsistencies, a general poor quality of service delivery, and a declining trust in the government's capacity to deliver services combine to impact the effectiveness and functionality of the CBWMS. The discussion in this chapter elaborates on these issues.

Fiscal dependence of local governments on central government and the limits of conditional grants

Central government funding for rural water supply in Uganda is channelled through district local governments in the form of *conditional* and *equalization* grants. Conditional grants define specific expenditure items and ceilings for districts, while equalization grants are issued based on the least-developed district criteria, and may target the development of infrastructure including water supply. Our analysis of the dynamics in national budget allocations for the water and environment sector (up to 2011) revealed steady reductions in the national budget share for the water sector (particularly rural water supply). The analysis also revealed delays in disbursement of funds, hurried implementation of activities, and consequently poor budget performance (MWE, 2011b). This situation was found to be aggravated by the fact that not all funding amounts approved for the water supply and sanitation budget were actually released. Furthermore, not all funds released were spent by the districts. Funds disbursed to the districts for rural water supply were also highly skewed in favour of *hardware* as compared to *software* activities. In Uganda's water sector, software refers to a package of activities aimed at community mobilization, education, and sensitization on the need to own, operate, and maintain improved water sources provided to them in the framework of the CBWMS. Hardware refers more to technical or engineering work, and often takes the form of new water source installation or rehabilitation of existing water sources. As the evidence from past studies has revealed, a weak CBWMS negatively impacts on functional sustainability of improved water supply infrastructure (Carter and Danert, 2003; Lockwood and Smits, 2011; Nabunnya et al., 2012).

Therefore, whereas rehabilitation or installation of new water sources remains important, we argue in this chapter that it becomes counterproductive when mechanisms to leverage routine O&M, as embedded in the CBWMS framework, are ignored or taken for granted. The 2012–13 district water and sanitation conditional grants guidelines (MWE, 2013b) provide that 70 per cent of the funds be allocated to cover hardware costs for new rural point-water supply projects compared to software activities, which are allocated only 8 per cent. The rest of the budget funds cover administrative costs (6 per cent), construction of sanitation facilities (3 per cent), and rehabilitation of boreholes and piped water schemes (13 per cent). Our study further found that the inadequate software budget is not always assigned to its intended purpose by the district water officers (DWOs), who tend to prefer investing in hardware as opposed to software activities. The 2010 water and environment sector performance report attests to this scenario. It indicated that expenditure on rural water supply activities and office operations went above the threshold by 2 per cent and 5 per cent, respectively, whereas expenditure on software activities was 3 per cent lower than the level of funds that had been disbursed to local government authorities (LGs). Thus, while central government may set ceilings or guidelines in relation to expenditure on certain activities, LGs can, at their discretion, alter budget guidelines at their convenience and 'hurt' prospects for the CBWMS. With the low rate of functional sustainability of improved point-water sources established at only 53 per cent (MWE, 2011a), the decision to continue allocating larger amounts of the budget to establish new point-water facilities undermines the effectiveness of the CBWMS.

The MWE guidelines stipulate that community mobilization for rural point-water supplies should be undertaken by community development officers (CDOs), community development assistants (CDAs), and health assistants (HAs) or health inspectors (HIs) in district and sub-county LGs. HAs and CDAs not only form part of the sub-county LG extension services workforce, but are also members of the sub-county local government Technical Planning Committee (TPC). As members of the TPC, they are responsible for identifying community needs using participatory planning methods. This makes them the most qualified and eligible team for prioritization while implementing software activities. In essence, while they are regarded as support staff, HAs and CDAs are part of the technical team directly responsible for rural safe water and sanitation. However, sidestepping of the community development department by the DWOs – who prefer investing proportionately more funds in hardware, including part of what is allocated to software activities – is a significant meso-level issue that is disabling the CBWMS.

It was reported that inadequate financing of the water sector in LGs is sometimes used by DWOs to undermine the role of CDOs, as stated in an interview with an LG staff member in a Ndagwe sub-county: 'We usually incorporate follow-up activities for supporting water and sanitation committees in our work plans, but they are never funded by the district … and it is not possible to do anything useful without transport facilitation to be able to cover all the communities in this sub-county'.

It is arguable, therefore, that advocating a budgeting mechanism whereby substantial amounts of funds are allocated to software activities would go a long way towards leveraging resources for the CBWMS. Differing amounts favouring both software and hardware could, for example, be switched over a period of time, in order to allow more capacity for the CBWMS as well as cost recovery on investments. This calls for a change of mindset among decision-makers at district and national levels of service delivery. In relation to the above predicament, Carter and Rwamwanja (2006) argue that a credible CBWMS should be ready to continually support and work with communities if it is to achieve real functional sustainability. This study shows that policy prescriptions on the CBWMS of rural point-water facilities in Uganda can be frustrated by the personalities, behaviours, and attitudes of decision-makers. The tendency not to involve technical staff responsible for software activities reflects not only the lack of capacity by DWOs, but also directly impacts negatively on functional sustainability for improved rural point-water facilities.

Political interference and central government policy inconsistencies

Our study findings showed that in order to serve self-interests, some local politicians undermined the ideals of the CBWMS by discouraging communities from making financial contributions towards O&M. This was on the pretext that rural safe water is a service that is provided free of charge by government.

Communities questioned the rationale for paying for water when other public services such as primary and secondary education, as well as immunization programmes, were provided free of charge by government. Political interference also seemed to worry actors in the NGO sector. For example, they noted that budgetary management at district level seemed to favour what politicians could easily demonstrate to their electorates as a tangible contribution. The government decision in 2001 to suspend the collection of graduated tax was found to have impacted negatively on the CBWMS. This tax used to be paid by every 'able-bodied' male citizen aged 18 years and above, and women aged 18 and above who were engaged in gainful employment. Community leaders indicated that they were grappling with this challenge whenever they wanted to justify the need for financial contributions for the initial cost of construction and for routine maintenance or repair of water sources. In particular, they argued that 'the policy' was not only delegitimizing cost sharing, but was also reducing local government revenues that would otherwise have filled some of the funding gaps in central government conditional grants. Accordingly, such funds would be utilized to address community problems including the operation and maintenance of facilities.

Communities in rural Uganda and sub-Saharan Africa tend to depend heavily on a few elite members in their localities for policy interpretation. However, these elites are not always able to provide such interpretation with minimal subjectivity, thus requiring service providers and politicians to invest more time in explaining why government policies may sometimes look contradictory, even if they do not intend to depict themselves as such. Previous studies have indeed shown that provision of timely and reliable information to citizens enhances the quality of public service delivery (Jacobson et al., 2010; Krishna, 2007).

Inadequate regulation and governance of private sector-activities that directly impact on the CBWMS

Our study showed that private-sector roles which directly support the CBWMS are yet to be effectively regulated by central and local government institutions in Uganda. At the community level, HPMs still wield significant power and have discretion not only to determine prices, but also to individually supply handpump spare parts to their 'clients'. The risk is even higher in situations where only one-fifth (20.1 per cent) of households served by handpumps are able to name at least one part of a handpump, as was the case in the community involved in this research study. Whereas availability and pricing problems of spare parts stem from macro-economic dynamics in the production and distribution chains, it is essential that communities know the range of prices as well as the quality of parts, particularly those parts that regularly break down. This study confirms that privatization in the context of CBWMSs does not automatically lead to free-market behaviour (Pérard, 2008); rather, it brings with it a new role of ensuring that communities are not exploited.

Information asymmetries on pricing and distribution mechanisms for rural point-water facilities tend to favour HPMs, and could serve as incentives for them to exploit the system. Recent efforts to mitigate this problem through formalization and regulation of associations of HPMs have not yet yielded much fruit; being semi-literate, many of the mechanics are unable to establish effective and credible organizations that can regulate the activities of individual HPMs.

The literature on private-sector participation in the delivery of public services has also often highlighted concerns about the capacity of the private sector, especially in resource-poor settings of the developing world (Barungi et al., 2003; Delamonica and Mehrotra, 2005; Pérard, 2008). As noted earlier, community capacity to negotiate prices for spare parts, or fees for repair of water facilities, is weak. Most of the case study village leaders had the telephone contact details of their HPM, indicating that they could access him whenever there was a need. However, the lack of effective WSCs meant that in many cases, any negotiations with the HPM were carried out by an active member of the village executive council or any other concerned member in the community. As a result of this management gap, there were fears in the community that the HPM was likely to connive with the leaders or do inferior work because 'he single-handedly determined the costs for everything, including spare parts', as was stated in one of the focus group discussions with the community members. In addition, HPMs are expected to fix minor repairs beyond the capacity of communities, while water source caretakers undertake routine maintenance functions (oiling and servicing). WSCs were found to have difficulties in undertaking routine maintenance functions, however, due to lack of skill and/or basic equipment. Therefore, they remained totally dependent on mechanics, who charged fees for carrying out such functions.

Weak collaboration and networks of actors undermine CBWMS effectiveness

Within the new governance framework, there is strong advocacy for networks, collaborations, or partnerships between different actors, in order to extract comparative advantage to enhance service delivery (Skelcher, 2005). Our findings show that initiatives such as the formation of the Uganda Water and Sanitation NGO Network in 2001 have provided an opportunity for a more effective NGO and government collaboration and engagement on issues of policy and sector governance. However, difficulties in collaboration and networking at lower levels of service delivery complicate opportunities for replication and scaling-up of some of the good practices of NGOs. Suffice to note that this study found that collaborations and networks exist between central government actors, national NGOs, and development partners to address policy issues, budgeting, and finance, or to monitor sector performance. The impact of these networks tends to be thin or weak at district local government level and within communities. Our study found that working relations between local NGOs and lower-level government institutions are not as strong as they are at national level. Tendencies by the different actors at district local government level to place blame on one another as responsible for failures in the CBWMS were not uncommon. In addition, some NGOs operating at district level tended to pronounce themselves as more 'for the people' compared to local governments, which, despite the realities associated with it, seemed to raise considerable levels of discomfort on the part of the local government technical staff. On the other hand, distrust and bureaucratic behaviours in the districts tended to 'compel' NGOs to implement their activities with minimal, and sometimes no, district involvement. Consequently, the NGOs were accused of 'hurrying water projects without always reporting to the districts, or undertaking water quality tests or effectively training and sensitizing communities about their roles'. Local government authorities are responsible for monitoring activities of NGOs and community-based organizations in their jurisdictions, but this function seems to be heavily challenged by attitudes and unfulfilled expectations on both sides.

Weak and demotivated CBWMS

In the context of Uganda in general and the case study community in particular, village executive council leaders and WSC members constitute primary actors on whom the CBWMS of point-water facilities hinge. While both committees are important, the WSC remains the most critical for the CBWMS. As indicated in the Introduction of this chapter, a functional WSC should have an O&M programme, and it ought to meet regularly, report water source breakdowns, and collect, keep, and account for monthly contributions from water users. The committee should have a signed contract with an HPM, well-articulated by-laws, and clear sanctions for non-compliance. The WSC should routinely carry out O&M of the water facility, including cleaning the site, and it should have a toolkit – kept by the sub-county chief or a member of the WSC (MWE, 2011a). In this study, none of the improved water sources in the parish had a WSC that met these conditions. The study also found that WSCs tend to be active immediately after inauguration of newly constructed water sources, but later lose interest and disintegrate. The community's perception of the performance and functionality of WSCs was somewhat average, with the respondents who reported having WSCs for their water sources rating their performance as very good (15.2 per cent), good (40.5 per cent), and fair (29.8 per cent). Almost half (44.6 per cent) of the household survey participants had never heard of, nor personally witnessed, any community meeting being convened by the WSCs to discuss water-related issues. Just over one-fifth (21.7 per cent) of respondents stated that meetings were taking place at least once a year, while 19.3 per cent of respondents could not tell whether such meetings had been taking place or not.

Ad hoc methods of financing O&M replace official guidelines

Owing to the ineffectiveness of WSCs, ad hoc approaches to financing O&M were found to have almost formally replaced the policy-recommended monthly household contribution to O&M. Our study found that the financial contribution each household had to make towards O&M was determined whenever a breakdown occurred. In most cases, the HPM estimated repair costs covering, for instance, spare parts, transport, and professional fees for repair. When determining the amount to be contributed, the community leaders decided on the modality for raising funds from the community. This study found that the common practice included obtaining the number of water-user households and the total cost of the repair, and then dividing that cost by the number of households in the village to determine the amount each of the households would have to contribute. Subsequently, the village executive council leaders, together with some of the active members of the WSC, moved from household to household demanding contributions. The leaders argued that this method was increasingly becoming popular for O&M, since collecting money for actual breakdown was more 'trusted' and therefore more effective because 'people know there is a problem to be addressed'. The arguments for the increasing adoption of the ad hoc approach in community financing of safe water service delivery in part relates to questions of accountability and efficiency. The burden of responsibility for ad hoc financing was found to be almost entirely that of the village executive council leadership rather than the WSCs.

Willingness, rather than ability, to contribute to O&M undermines the CBWMS

It has become clear that the success of CBWMS models in ensuring functional sustainability of point-water facilities largely depends on the ability and willingness of water users to make financial contributions to meet the initial cost of construction, major repairs, and routine O&M (Carter and Rwamwanja, 2006; Jones, 2011; Lockwood and Smits, 2011). These financial contributions, which are supposed to be managed by WSCs, are in turn utilized and accounted for whenever water sources break down. However, our study involving community members of various water facilities in the case study parish shows that financial contributions towards the provision and O&M of improved water facilities were irregular and did not adequately follow policy guidelines. Furthermore, a number of locally contextual factors were found to have significantly undermined community willingness to make financial contributions for reasons other than households' inability to pay. We discuss these factors in more detail here, based on our qualitative inquiry with the community.

Our findings show that community motivation to participate in O&M of water facilities was shaped by the actual knowledge and perception of the quality of safe water service delivery (access to and functionality levels of water sources). Whereas almost all households surveyed were within a 1 km radius of an improved water source, several of these sources were non-functional. Only about 7 per cent of the 377 households with handpumps in their villages reported that their handpumps had never failed, while the rest reported that their handpumps failed nearly every month (14.5 per cent), about twice or more in a year (54 per cent), or once a year (15.6 per cent). Due to frequent water source breakdowns, community leaders mentioned that they always found it difficult to approach households for contributions towards O&M. In an interview with village leaders, one said: ‘People complain a lot whenever they are asked to contribute in short interval periods due to frequent breakdowns … Many think that the last pump mechanic to repair the water source could have done substandard work’.

In light of this situation, the motivation to contribute to O&M was found to have gradually declined or completely ‘withered’ in some communities where water sources repeatedly broke down. The study findings are in line with earlier assertions that enhancing poor people’s ability to participate in delivery of services requires providing the very services that people lack (Krishna, 2007).

The success of a CBWMS greatly depends on the extent to which local leaders demonstrate commitment to service delivery through strategies that build trust and cohesiveness in the community. In the context of this study, elected WSCs and the village executive council leadership remain very important actors in leveraging the CBWMS. However, it was repeatedly reported by study participants that the conduct of some of the leaders was derailing prospects for a meaningful CBWMS. Some leaders took advantage of breakdowns to ‘earn’ money, and in extreme cases they were reported to falsify some of the breakdowns in order to defraud unsuspecting water users. In rural contexts such as those in our case study community, the problem of invented water source breakdown is compounded by the lack of vigilance by community members, which limits their ability to quickly detect and/or report such fraudulent practices. While there was an official HPM allocated to the community, in light of the sub-county local government public–private partnership arrangements, it was still unlikely that such unscrupulous conduct by some caretakers would be detected. In some instances, community members who agreed to contribute financially did so ‘reluctantly’, due to lack of trust in their leaders. This study confirms that the capacity and competence of local leadership, politicians at local level, and national governments is critical for the mobilization of the general public to engage service providers on the quality and adequacy of service delivery. However, the gradual decline in the way in which leaders are perceived by the community as trusted service providers working in the best interests of the community suggests that these institutions are not adequately prepared to steer local-level development initiatives. This is compounded by the fact that community members are also not very enthusiastic about attending village meetings.

Self-supply and dynamics associated with water vending

Households that are able to supply themselves with water – including those that buy water from vendors and households with rainwater harvesting facilities – were found to be reluctant to contribute to O&M. Those who bought water from vendors argued that they did not care where the vendors obtained the water, provided it was clean and safe. Some of the people in villages where water vending was common also complained that water sources had been 'taken over by water vendors who, accordingly, should repair the water source'. In one of the villages in the case study parish, the main water vendor was also the caretaker of the water source and, as one of the village leaders observed, 'some community members felt that he owned the water source' – a perception that exacerbated the already difficult task of mobilizing contributions for O&M. Therefore, the importance of building community cohesion over the maintenance and sustainability of improved water sources cannot be overstated. Such efforts would demonstrate to all stakeholders in the community, including customers of water vendors, that a water source breakdown affects all people regardless of how they obtain their water. Moreover, as observed in an earlier study, households that pay for water from vendors end up paying more than they would otherwise pay for O&M of water facilities (Whittington et al., 1990).

Declining trust over government responsiveness to need

The extent to which communities trusted that the government would serve their best interests was quite limited. Such attitudes and experiences served to compromise levels of motivation by the communities to participate in government programmes, including those related to the CBWMS. Less than one-tenth of the studied household respondents (7.7 per cent) believed that the government was interested in providing services to their communities. About 43 per cent stated that they sometimes trusted the government, while over a quarter (28 per cent) stated that they did not believe the government service delivery systems would ever be in the best interests of the people. In the context of a CBWMS, stakeholder collaborations are highly emphasized strategies for ensuring service delivery efficiency and sustainability (Skelcher, 2005). However, these collaborations are largely based on trust building. The evidence generated from this study shows that these partnerships and collaborations, which are crucial for the CBWMS and the functional sustainability of rural domestic water supply infrastructure, are being threatened by fading trust.

History of dependency on external support/charity

The case study community, like many other rural communities in Uganda, has a history of dependence on NGO support, with the most recent and strong actor being the Medical Missionaries of Mary (MMM); other actors have included World Vision International Uganda, UNICEF, and Kitovu Mobile, which worked closely with the MMM. While such service providers have hitherto been indispensable, they have always faced high risks of breeding dependency syndromes among the target communities. In the case study community, virtually all water-related problems were seemingly directed to the MMM. This situation was compounded by poorly clarified roles and responsibilities of the community and their leaders, the absence of by-laws, and weak leadership capacity, as outlined earlier in this chapter. Increased levels of dependency on external support from NGOs, government, and politicians seeking to be elected for positions also served as an impediment to the cost-recovery strategies embedded in the CBWMS. Evidence from this study suggests that the work of the MMM has generated and sustained some degree of dependence. This was found to have been compounded by limited education and sensitization of communities on their roles and mandates for an effective CBWMS and the absence of enforceable by-laws on O&M.

> The sisters are so generous. Sometimes they repair water sources without waiting for people to contribute … they also know that the men don't want to pay and it is the women and children who will suffer. The MMMs have built houses for poor community members, especially orphan-headed households, and could also put up rainwater harvesting tanks on these houses. (Community development worker)

While such interventions are purely driven by charity and are based on need, the lack of community knowledge of the factors compelling actors to undertake such interventions was frequently misinterpreted by the community, further undermining the goals of the CBWMS.

Conclusion

This chapter has demonstrated the existence of a conceptual and operational relationship between an effective CBWMS and functional sustainability of rural point-water facilities. It has also unravelled the range of contextual dynamics that disable the effectiveness of the CBWMS in enhancing functional sustainability of improved water facilities. These are traceable, both at the local community level where services are consumed and at higher levels where decision-making takes place. The findings and discussions generated from this case study demonstrate that rural water policy implementation in Uganda is heavily challenged by complex and multifaceted community-level issues as well as meso-level and macro-level challenges. These owe a lot to weak systems of service delivery and support at national and sub-national levels, and yet it is important to argue that effective government institutions, more than any other agencies, are vital for the success of the CBWMS. The findings therefore generate insights into the fundamentals that need to be adhered to by policy actors wishing to build effective synergies with service beneficiaries, particularly those living in rural developing areas of sub-Saharan Africa, and Uganda in particular. The study findings substantially corroborate earlier findings which indicate that the challenge of improving rural safe water service delivery in Uganda is not the lack of a policy direction, but the right action in policy implementation at macro, meso, and micro levels (Asingwire 2008; Carter and Rwamwanja, 2006; Quin et al., 2011).

Addressing the underlying factors that undermine community interest towards local development initiatives in the context of this study seems to require not only education and sensitization strategies aimed at the community, but also strategies that will revitalize commitment to collective development initiatives among community members, such as establishment and enforcement of by-laws. Some members of the community may fail to contribute to the O&M of water sources, not because they cannot afford to, but because they do not expect any sanctions to be placed on them. Local authorities have constitutional powers to develop and enforce by-laws, but they continue to rely on central government for major decisions.

The ability of local politicians and technical authorities to appreciate and play their roles both before and after construction is imperative for the sustainability of rural point-water supply infrastructure. Effective cooperation among stakeholders also helps to build a high level of trust that has a strong bearing on tangible social mobilization for the CBWMS. In their design, CBWMSs strategically and rightly place water users in the most important positions in the rural safe water governance framework. However, the effectiveness of the position of water users in this framework greatly depends on whether and how policy actors directly interface with communities to ensure their important position in the service delivery framework is tapped for the attainment of the goals of the CBWMS. An effective government (central and local) would positively influence the various functions of the market (HPMs and spare-parts distribution/availability). These in turn would positively influence the CBWMS (effective communities) to enhance functional sustainability of point-water facilities. The cycle in the relationship is therefore expected to remain continuous through intra-sector actor interactions, learning, innovation, and capacity building.

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CHAPTER 5

Towards understanding challenges to water access in Uganda

Godfrey B. Asiimwe and Resty Naiga

Abstract

This chapter explores challenges related to safe water access in Uganda. Safe water is a crucial resource and entitlement, yet still scarce for many people in Uganda. Inaccessibility to water impacts on health, utilization of time, gender asymmetries, conflicts, and development issues. In this chapter, we point out the dynamics and challenges of water provision management. Water is a social and an economic good, thus the state should play a major role in funding its provision and regulation. In addition, approaches to water governance and provision should move from supply to demand-driven and community-centred approaches, where appropriate. Overall, the chapter calls for appropriate regulatory framework and monitoring mechanisms, and partnerships to enable proper management of and equitable access to water.

Keywords: water access, supply-driven, demand-driven, governance, gender, public–private partnership

Introduction

Water is essential for human development. Lack of access to safe water is regarded as both a cause and symptom of poverty and under-development (GoU, 2001; Mathew, 2004; UNDP, 2006; UNICEF/WHO, 2000). Lack of access to safe and clean water results in morbidity and mortality in both adults and children. Uganda spends approximately USD 10 million annually treating waterborne diseases, including cholera, dysentery, diarrhoea, intestinal worms, bilharzia, and typhoid (AU, 2013; UBOS, 2009). Each year there are 4 billion cases of waterborne diseases such as diarrhoea, intestinal worms, coughs, and scabies, and studies further indicate that neonatal and under-5 mortality rates in Uganda for households without access to safe water are twice as high as those with adequate access to safe water (AU, 2013; GoU, 2001; WSSCC, 2004). Given the centrality of water, there have been concerted efforts to provide safe water to the majority of the population as a prerequisite for reducing poverty and achieving gender equity, equality, and development (DWD, 2011a, 2011b; GoU, 2001, 2002).

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The Basic Needs Approach puts water, food, shelter, and clothing as the traditional immediate 'basic needs' for human well-being and socio-economic development (Sen, 1999). The UN recognizes access to clean and safe water and improved sanitation as essential to human health and development (WWAP, 2006: xviii). The 2002 UN General Comment No. 15 underlines water as an entitlement, a public good, and a right, while the 1992 Dublin Principles highlight the economic value of water. In Uganda, these international efforts and aspirations towards clean water access and sustainability are affirmed by the 1995 Water Statute, with the objective of promoting the provision of clean, safe, and sufficient domestic water supply to all people; the 1999 National Water Policy, which affirms the right of all Ugandans to safe water; the 2004 Poverty Eradication Action Plan (PEAP); and the 2010–14 National Development Plan, in which water and sanitation were recognized as crucial sectors.

In striving to provide safe water to its citizens and to address the continued poor performance of past water supply programmes, the Government of Uganda has grappled with different approaches. Prior to the Structural Adjustment Programs of the 1980s, the public sector dominated the water sector. Safe water provision was solely the responsibility of the government, with little or no community participation. The aim was to decrease socio-economic disparities through universal access to water. However, areas of concern emerged under this supply-driven approach. These included ensuring the pace of progress needed to provide the majority of the population in rural areas with safe water within a reasonable timeframe, and how to ensure the long-term sustainability of water services, particularly in terms of the operation and maintenance (O&M) of water infrastructure (DWD, 2001, 2011a; World Bank, 1999). These concerns resulted in a shift from the supply-driven to a demand-driven approach. The demand-driven approach is expected to be pro-poor and a means of overcoming state inefficiency, ensuring long-term access to water, and empowering women (World Bank, 1999).

Despite the international and national efforts, 53 per cent of Africa's rural population does not have access to safe water (Mathew, 2004). In Uganda, safe water coverage is estimated at 72.8 per cent of the population in urban areas and 64 per cent in rural areas (MWE, 2014). However, the actual water coverage levels are considered much lower in rural areas given the hypothetical statistical procedures of deriving the coverage and the fact that most dysfunctional water sources are not controlled for, and the tendency by political leaders to portray a rosy picture towards water coverage statistics (Carter et al., 1999; Naiga and Penker, 2014; Naiga et al., 2015). Further still, the national access goal of 77 per cent in rural areas and a functionality rate of 80–90 per cent by 2015 are far from being met (GoU, 1999). For instance, O&M accounts for non-functionality of over 50 per cent of water infrastructure, hampering long-term access to safe water in rural Uganda (Foster, 2013; Naiga and Penker, 2014; Naiga et al., 2015).

Actors in water provision

The NWSC, NGOs, and CBOs

Water has traditionally been considered a public and social good, which should be availed in unlimited quantities to everyone, free of charge. However, the increasing demand as a result of an ever-surging population and competing demands has overstretched the welfare provision model and called for other actors and different approaches in water provision. A shift from supply to demand-driven water governance ushered in different actors (government, donors, private sector, NGOs, and community users) and is characterized by a complex interaction of factors such as power, ecology, location, and gender. While the government continued to underfund the water sector, development partners such as the World Bank played an important role in rehabilitating and extending the water network in Kampala (World Bank, 2007). In 2000, development partners accounted for up to 75 per cent of total sector funding. Particularly significant was the Poverty Action Fund under the framework of the PEAP (WWAP, 2006). NGOs and community-based organizations (CBOs) reported investments of USD 5 million in 2006, while NGO and CBO members of the Water Sanitation and Hygiene cluster, which provides emergency water supply and sanitation in northern Uganda, reported investments of USD 15 million from January 2005 to August 2006. As a result, in 2006 the total sector investment was estimated at USD 85 million (WWAP, 2006). The government's underfunding of the water-sector was contrary to its stated targets of providing safe and clean water to the population. In Uganda, water sector reforms included the commercialization of the National Water and Sewerage Corporation (NWSC), which became a public enterprise operating on a commercial basis and increased customer base. Increased connectivity was attributed to a drastic reduction of connection charges from 400,000 Ugandan shillings (USD 274) to UGX 25,000 (USD 17) in 1999 (Jammal and Jones, 2006). Flexibility in technical requirements[1] was also key to increasing water service coverage in poor urban communities (NWSC Annual Report, 2006–7:27). Connectivity to those consumers who can afford to pay, as well as large-scale commercial and institutional users, enables the NWSC to recoup operational costs.

While humanitarian NGOs focused on providing water to the rural and urban poor, CBOs played an important role in the protection and maintenance of community water sources. CBOs underline the people's power over resources such as water. NGOs and CBOs operate under the umbrella organization Uganda Water and Sanitation NGO Network, which has over 200 members. These organizations received funds mostly from development partners in the sector. During the 2010/11 financial year, the majority of their investment (UGX 12.6 billion) was in water supply. With the shift to a demand-driven approach, the private sector, water users, and lower tiers of government (i.e. districts, sub-counties, and communities) have become major players in water policy implementation. The national framework for O&M of rural water supplies sets out the rules, requirements, and responsibilities of all the stakeholders involved in rural water governance (DWD, 2011b) and has shifted decision-making, management functions, and O&M responsibilities to local water user groups. Their executive organ is a locally elected water user committee[2] that has to be established at each improved point-water source. Despite the efforts of the NWSC and NGOs, the challenge of connecting water to the rural and urban poor remains. While the NWSC and government should remain major players, their capacity to provide safe water to all is overstretched, hence the call for private-sector involvement.

Public–Private Partnerships

The public sector is supplemented by private-sector providers, particularly in the expansion of coverage and provision. Partnership with the private sector can also involve the outsourcing of specific tasks such as billing, metering, maintenance of various components, or water loss tracking (Lewis and Miller, 1997). Private-sector participation is central to the debate on marketization/commercialization and cost recovery versus public provision of front-line services and utilities. Private-sector mechanisms such as competition and the efficiency imperative are considered by some to be the panacea for public-sector failures. In theory, efficiency would enable the provision and proper management of a scarce resource like water (McGranahan and Lloyd Owen, 2006); particular attention has, for instance, been drawn to efficiency gains from outsourcing (Savas, 1987).

It is noted that despite problems relating to the technology of water provision, transaction costs, and regulatory weaknesses, there is evidence of better performance in private utilities compared to state-owned utilities (Kirkpatrick et al., 2004). However, privatization of utilities such as water and energy became widely unpopular and encountered strong political opposition, partly due to perceived conflicts between privatization and equity, and the role of the state and community in these sectors (Hall et al., 2005). It has also been pointed out that claims of efficiency of market mechanisms are based on studies, surveys, and assertions of managers' perceptions (Walsh, 1995). Furthermore, the problem of acceptability of private actors vis-à-vis public interest/good remains a challenge (Cook and Minogue, 1990). Batley (1996) further argues that the evidence of greater efficiency and effectiveness through privatization or contracting-out of public services remains slim and the case seems to rest to a high degree on assumption and assertion of the benefits of private-sector competitiveness and entrepreneurialism. While the supply model can be wasteful, the demand model is presumed to be efficient: proponents of marketization point to cases of wastage in the supply model, compared to efficiency of resource utilization in the demand model. Privatization and the shift to the demand-led model have varying implications for safe water management, equity, and sustainable access among different sections of the population (Regmi and Fawcett, 2001).

Challenges to water access and governance

As already mentioned, the O&M challenge accounts for over 50 per cent of the non-functionality of water sources (DWD, 2011a; Foster, 2013; Naiga and Penker, 2014; Naiga et al., 2015). Non-functionality of water sources, especially in rural areas, is mainly due to water users' unwillingness to contribute user fees (Naiga and Penker, 2014). It is noteworthy that the poor cannot afford the full market costs of water, hence the importance of government as a major player. There are wide poverty variations among the different regions of Uganda as well as within and between urban and rural settlements (Bahiigwa, 2008: 2–3). The PEAP estimated that water consumption ranged from 12 litres to 14 litres per capita per day in rural areas and 17 litres per capita per day in urban areas. This was below the national target, which is an average consumption of 20 litres per day, the minimum quantity of water a person needs in order to meet basic health requirements (GoU, 1999).

The NWSC implements a uniform tariff structure for each consumer category in order to ensure equity in supply and pricing. However, water tariffs are still high for the rural and urban poor, hence the need for government subsidies in the water sector. The average unit cost of production increased over time, from UGX 600 per m^3 in 2001 to UGS 1,638 per m^3 in financial year 2010/11. In small towns, the unit cost increased from UGX 766 per m^3 in financial year 2008/9 to UGX 1,068 per m^3 in financial year 2009/10, and to 1,247 per m^3 in financial year 2010/11 (MoFPED, 2002). Energy costs were particularly high, contributing over 90 per cent of inputs for the systems using electricity or other fuel in water production (MWE, 2011). Additionally, value-added tax (VAT) and inflation increased the unit cost of water production. Additional costs included water treatment, provision of meters, increasing pressure to supply densely populated areas and peak periods, provision of large-scale storage facilities to capture water run-off, and operational wages. Full cost recovery, including investments, would require a 90 per cent increase in tariffs (Mbatauwa, 2008; Muhairwe, 2006; WWAP, 2006). However, given the circumstances, the private sector requires an enabling framework, such as energy subsidies and VAT reductions. As a result, water infrastructure improvement and expansion are therefore still left to the government and donors.

Closely related is inadequate sector funding. Over time, the water and sanitation sector suffered from a lack of government funding and low prioritization, leaving development partners as the major players. In financial year 2006/7, the total budget for Uganda's water supply and sanitation sector was UGX 149 billion (USD 90 million), of which USD 73 million was actually spent, an average spend of USD 2.37 per inhabitant (WWAP, 2006). In the

2010/11 financial year, the overall budget for the water and environment sector was UGX 352.2 billion, of which UGX 256.4 billion (73 per cent) was on-budget funding while UGX 95.8 billion (27 per cent) was off-budget support. The on-budget allocation was 3.1 per cent of the total national budget. The government released only UGX 200.3 billion, or 78.1 per cent, of this amount, however. It is noteworthy that this was insufficient to meet National Development Plan sector targets, or the Millennium Development Targets targets for water supply and sanitation (MWE, 2011). Of the on-budget funding, UGX 164.9 billion was allocated to the water supply and sanitation subsector. Of this, UGX 77.7 billion (47.1 per cent) was allocated to the rural water sector and UGX 33.7 billion (20.4 per cent) for urban water (MWE, 2011). For nearly 10 years there has been a sector-wide approach, whereby government and development partners pool funds. However, the government continued to underfund the water sector, and the overall budget for the water and environment sector dropped from UGX 489.3 billion in financial year 2011/12 to UGX 382 billion in 2012/13, which was only 2.8 per cent of the total national budget (UG, 2013).

WWAP shows that although there was increased funding for the rural water subsector over the period 1991–2003, which more than doubled over the period 1997–2001, the increase in coverage was only modest over the same period. Apart from significant investment in capacity building for new districts, this was attributed to the use of more expensive technologies, rehabilitation of non-functioning facilities, and high overhead costs resulting from inadequate technical capacity of both the districts and the private sector (DWD, 2011b; Foster, 2013; Naiga et al., 2015; WWAP, 2006: 66). Deep boreholes were particularly expensive, estimated at USD 9,000 each to construct, with USD 100 maintenance costs per annum.

In addition, the politics of regional imbalances are also apparent in the distribution of water in Uganda. Whereas access to improved water sources had increased from 44 per cent in 1990 to 60 per cent in 2004 and then to 64 per cent in rural areas, average measurements such as these tend to hide sharp regional variation. While the Pader District in northern Uganda had coverage of only 20 per cent, Rukungiri in south-western Uganda had coverage of 95 per cent (MWE, 2010). An estimated 20 per cent of Uganda's urban dwellers did not have access to safe water and around half a million of these people lived in Kampala. There are also significant variations in coverage between different urban centres and within different classes in an urban centre. Whereas Mbarara town in western Uganda had attained water coverage of up to 79 per cent, Soroti in eastern Uganda had an estimated 34 per cent (NWSC, 2004). Such a skewed pattern of distribution for a vital resource like water was likely to reinforce the perception of the NRM government as favouring the western region (Nalugo and Naturinda, 2010; Okuku, 2002). It could be argued that areas which supported the regime had more opportunities and more effective representation by well-placed leaders, who could lobby and influence allocation of service-providing projects. However, the regional distribution pattern cannot be fully explained on the basis of political bias. Non-political factors also influence the distribution pattern of water; these include demographic distribution and hydro-geological factors that determine water sources in an area. With regard to demographic distribution, some data for the equity indicator were not merely based on the percentage of the population with access to water, but also on the number of people per improved water source. Therefore, heavily populated areas will show more access than sparsely populated areas (MWE, 2007). In relation to hydro-geological factors, some areas in the northern region and the cattle corridor were less well endowed with natural water sources. Other areas such as the western districts of Kasese, Kabarole, Bushenyi, and Rukungiri are unsuitable for gravity water flow schemes, while the loose soils of areas such as Jonam County in Nebbi, or the volcanic soils of Kisoro in south-western Uganda, complicate water delivery. Consequently, Kisoro has an urban access of 22 per cent compared to Apac in northern Uganda with an access of 95 per cent. In addition, the deep water table in arid areas complicates the success of drilling deep boreholes.

Closely related are the outstanding rural–urban differences in access and functionality rates. By June 2013 there were 104 gazetted urban water suppliers, of which 58 had management contracts with private operators, 21 were managed by scheme operators, and 24 were managed by water authorities. These partnerships led to improved access to safe water in urban centres, from 66 per cent coverage in financial year 2010/11 to 70 per cent in financial year 2012/13 (MWE, 2013: ii). The overall average functionality of 102 small towns improved from 84 per centin financial year 2011/12 to 87 per cent in financial year 2012/13. Based on the reports of 118 towns, the functionality of management boards also improved from 73 per cent in financial year 2011/12 to 75 per cent in financial year 2012/13 (MWE, 2013).

An estimated 29.7 million (83.7 per cent) of the Ugandan population live in rural areas. According to the Local Governments Act (1997), responsibility for providing basic water supply and sanitation services and their maintenance in rural areas is entrusted to the local governments in conjunction with the MWE. Rural water coverage increased from 18 per cent in 1990 to 59 per cent in 2003 (WWAP, 2006); however, more investment is required in order to meet the national target. The average functionality of rural water supplies improved slightly from 83 per cent in financial year 2011/12 to 84 per cent in 2012/13. However, access to an improved water source in rural areas is much lower than in urban areas and the average functionality is still below the sector target of 90 per cent by 2015. In 2007 the World Bank funded an output-based aid project for six selected small towns and rural growth centres (RGCs) at a cost of USD 3.2 million. This was aimed at connecting about 45,000 poor beneficiaries to household yard taps and public standpoints. The private sector was to participate through management contracts in small towns and design-build-operate contracts in RGCs (World Bank, 2007).

In the financial year 2010/11 the total population served through the District Water and Sanitation Development Conditional Grant was 559,136 people through the construction of water points. Rainwater-harvesting projects and boreholes served 77,964 people. As of June 2014 access to safe water in rural areas remained at 64 per cent (MWE, 2014). There was a decline in people served under the Sector Conditional Grant in rural areas: whereas in financial year 2010/11 up to 559,136 people were served, this decreased to 542,026 in financial year 2011/12 and further to 535,586 in financial year 2012/13. A total of only 716,981 people were served through investments by central and local governments, UNICEF and NUSAF 11 interventions (MWE, 2013: ii). The South Western Towns Water and Sanitation Project was considered successful in developing appropriate mechanisms and standards for the specific requirements and conditions in RGCs and small towns. Through contracts with private-sector operators and umbrella organizations, there was a strategy to implement low-cost technologies for water supply and follow-up support for O&M. The O&M of rural water supplies was largely based on a community-based water management system, which emphasizes community responsibility and authority over the development, operation, and maintenance of their facility.

While water harvesting in rural areas is encouraged as a means of improving safe water access and sustainability, poor households with grass-thatched houses are unable to harvest appreciable volumes of rainwater. In addition, iron sheet-roofed rural households are on average small, with limited iron-sheet coverage, which would be insufficient to harvest enough rainwater for an average household comprising six people.

Absence of wastewater treatment and little knowledge of groundwater potential or how to harness the available water resource are indicative of low investment in appropriate water technology. Maintenance and rehabilitation of non-functioning facilities were also major problems in the provision of sustainable rural water supply. The collapse rate of boreholes was very high, yet dysfunctional boreholes continued to be counted as providing a water supply in an area (Naiga et al., 2015). This and the usual percentage measurement criterion could give a deceptive impression of high levels of water coverage in Uganda. The government hoped to obtain appropriate technologies which were affordable, socially acceptable, potentially sustainable, and technologically suited to local conditions. The Directorate of Water Development therefore recommended that O&M had to be an integral part of the planning process in order to ensure continuous and reliable operation of a facility for at least eight years (WWAP, 2006: 68). The O&M strategy is operationalized at a community level through a five-year locally developed, realistic plan to ensure long-term access to safe water (DWD, 2011a). The cheaper option of rainwater harvesting at household level was being promoted, especially by some NGOs. As noted, this will largely be feasible during the rainy seasons for better-off and middle-class households with bigger iron-sheet roofs.

Further still, a CBWMS is regarded as a means of encouraging community participation and empowerment. However, poor regulatory monitoring mechanisms and lack of capacity by the water user committees (WUCs) remain a great challenge. For instance, national reports point to ineffective supervision and monitoring in water-related activities in all the 112 districts of Uganda. According to the report, only 38.1 per cent of the existing WUCs received training and 9.4 per cent refresher training by 2010 (DWD, 2011a).

Gender and water

Water distribution and access also show gender configurations. In patriarchal systems, roles are assigned according to gender, with daily chores such as fetching water and cooking being the responsibility of women and girls. Financial pressures among the poor, coupled with attitudes to gender roles, militated against prioritization of daily expenditure on the purchase of water for household use. Provision of water is considered to be one of the 'normal' routine tasks of the non-earning housewife and children. Women also determine the use and storage of water, and this decision-making role has a direct impact on the health of the children and other family members (Upadhyay, 2004).

Accordingly, women and children were constrained in other areas, as the bulk of their valuable productive time was wasted through travelling long distances in search of water. Valuable time was also lost through queuing at water sources (Naiga et al., 2015). In most cases, sources such as boreholes and draw-off points were distant and few, owing to the challenge of constructing enough of them in scattered rural settlements. In the absence of protected water sources, rural households depended on unsafe water in unprotected wells, rivers, and lakes. Such sources were an arena for conflict between the women and herders, whose animals competed with people for the water. Women's loss of valuable productive time in search of water undermined their engagement in other activities, some of which would increase their productivity and income-generation potential. Moreover, the children, notably girls, lost valuable school attendance time. Fetching water is also strenuous. Women and children used head portage, further limiting the quantity of water delivered to their homesteads. Consequently, there was often insufficient water for domestic use like drinking, cooking, and maintenance of adequate hygiene. Hygienic maintenance of the utensils for collection and storage of water was also a major problem.

Despite the rhetoric about women's primary role in water provision at a household level and the existence of the regulatory framework to facilitate women's participation within the demand-driven water governance, female participation has remained low and at best tokenism (Naiga *et al*, 2015; Prokopy 2004). For example an analysis of 50 (fifty) water user committees in Isingiro and Kigarama districts, western Uganda reveal that women's participation in water user committees both in terms of quality (positions) and quantity (numbers) is far below the stipulated 50 per cent (Naiga and Penker 2014). Women's low participation is also reported by the Directorate of Water Development (DWD 2011a). Failure to take advantage of women as the key stakeholders in water management may partly explain why several studies attribute the continued water problem to water mismanagement (GWP 2002; Starkl et al., 2013; Foster, 2013, Mugumya, 2013, Naiga and Penker 2014; Naiga *et al*; 2015). Whilst many women are encumbered by challenges such as low literacy levels, lack of confidence and time (see Naiga et al 2015; Singh, 2007), low women's participation in Uganda has also been attributed to the rapid paradigm which did not allow enough time for stakeholder consultation and sensitization but also to limited funds allocated to software activities (Naiga *et al*, 2015).

Conclusion

There appears to be a connection between the water access and O&M-associated problems in Uganda and the public policy changes initiated in the safe water subsector, and a lack of capacity among the different actors to fulfil the requirements of a demand-driven approach (Naiga et al., 2015). The demand-driven approach was reported to have had a negative effect on the mechanisms in place to manage O&M at the community level (Naiga and Penker, 2014), and the policy shift was not accompanied by a consistent regulatory framework, adequate funding, time and staff for training, or monitoring, particularly in the early phases. If the resources to accompany policy reforms are not available, the reforms will remain fragmented and this can actually become a challenge to effective service delivery rather than a remedy, as initially hoped (Naiga and Penker, 2014). Although there is evidence to show some success under the demand-driven approach, it leaves a lot to be desired in terms of awareness creation, funding appropriate technology, community participation, and gender equity and equality in order to achieve the desired levels of sustainable access to safe water in Uganda.

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CHAPTER 6

Water resources in Uganda

Albert I. Rugumayo, Eleanor Jennings, Suzanne Linnane, and Bruce Misstear

Abstract

Uganda lies within the Upper Nile catchment and its climate is generally characterized by two distinct seasons: wet and dry. Of the country's total surface area, 15 per cent is covered by open water and 13 per cent by wetlands. Most freshwater comes from seasonal rains. Long-term variation in rainfall manifests as cyclical droughts and floods. Direct rainfall is the most important water resource. Aquifers occur in the weathered overburden (regolith) for shallow wells and in the fractured bedrock for most deep boreholes. The shallow wells are especially susceptible to contamination from human and animal waste and other sources. In the study area in Lwengo District, water sources comprise traditional unprotected ponds, improved hand-dug wells, boreholes, and protected springs; these supplies are augmented by rainwater harvesting. Maintaining the functionality of the improved water sources is a significant challenge. Other challenges are posed by changes in natural vegetation through deforestation and wetland drainage, and by climate change. To address these challenges, there is an evolving institutional framework for water resources management in Uganda, with a greater focus on a catchment-based approach.

Keywords: groundwater, geology, climate, institutional framework, river catchment

Introduction

The purpose of this chapter is to outline some of the key issues in relation to water resources in Uganda based on recent studies and to describe some of the water resources issues and challenges in a particular study area within Lwengo District, which has been described in Chapter 1 (Fagan et al., 2015). Uganda has abundant surface water resources including lakes, rivers, streams, and wetlands. The entire country lies within the Upper Nile catchment, with numerous rivers flowing into lakes Victoria, Edward, George, Kyoga, and Albert, and also directly into the River Nile. The surface areas of the major lakes and the mean flows of the main rivers in Uganda are shown in Table 6.1.

The Lake Victoria Basin covers 194,000 km^2, while the lake surface encompasses an area measuring approximately 68,457 km^2. Of Uganda's total surface area of 241,500 km^2, 15 per cent (36,280 km^2) is covered by open water and

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Table 6.1 Major lakes and rivers in Uganda

Major lakes (total surface area, km^2)	**Major rivers (mean flow, m^3/s)**
Victoria (68,457)	Victoria Nile (808)
Albert (5,335)	Aswa (38)
Edward (2,203) Kyoga (2,047)	Albert Nile (900)
Bisinia (308)	Kyoga Nile (789)
George (246)	Kagera (183)
	Semliki (135)
	Kafu (32)

Source: NEMA, 2006

13 per cent (30,105 km^2) by wetlands. The latter include both permanent and seasonal wetlands, estimated at 7,296 km^2 and 22,809 km^2, respectively (NEMA, 1999), although more recently, many of these important wetlands have been drained or filled (Kairu, 2001). Lake Victoria (Nalubaale), the largest lake, is also the world's second largest freshwater body, while the Nile is the longest river in the world. Figure 6.1 shows the main physical features of Uganda.

In Uganda, the Victoria Nile (White Nile) drains from Lake Victoria and flows northwards into Lake Kyoga and Lake Albert before entering South Sudan and Sudan, where it is joined by the Blue Nile at Khartoum, creating the main Nile that continues on its long journey northwards to Egypt and the Mediterranean. The Nile Basin has a wealth of natural resources, including freshwater, as well as fish and other biological resources, thus providing a range of ecosystem services and unique opportunities for socio-economic development. An excellent account of the hydrology of the Nile Basin is given by Sutcliffe and Parks (1999). Many of Uganda's major lakes and rivers cross national boundaries. Lake Victoria, for example, is shared between Kenya (6 per cent), Tanzania (49 per cent), and Uganda (45 per cent); the Lake Victoria Basin is shared by Tanzania (44 per cent), Kenya (22 per cent), Uganda (16 per cent), Burundi (7 per cent) and Rwanda (11 per cent).

Uganda lies in the equatorial zone of low pressure and weather patterns are affected by the Inter Tropical Convergence Zone, which is characterized by cloudiness and precipitation; as a result, most of the country experiences two rainy seasons: the heavy rains are from March to May and the light rains are from October to December. Only the north experiences one rainy season from May to October. The reliability also decreases towards the north and increases towards Lake Victoria (MWE, 2013b). Total annual rainfall ranges spatially from 700 mm to 2,000 mm per year (NEMA, 2002). However, the seasonality in rainfall causes considerable variation in the timing of seasons, and in the amounts of rainfall and streamflow. Weather patterns are sensitive to the *El Niño* Southern Oscillation and the Indian Ocean Dipole, which produces precipitation, while a *La Niña* event can be associated with a dry phase (Eltahir,

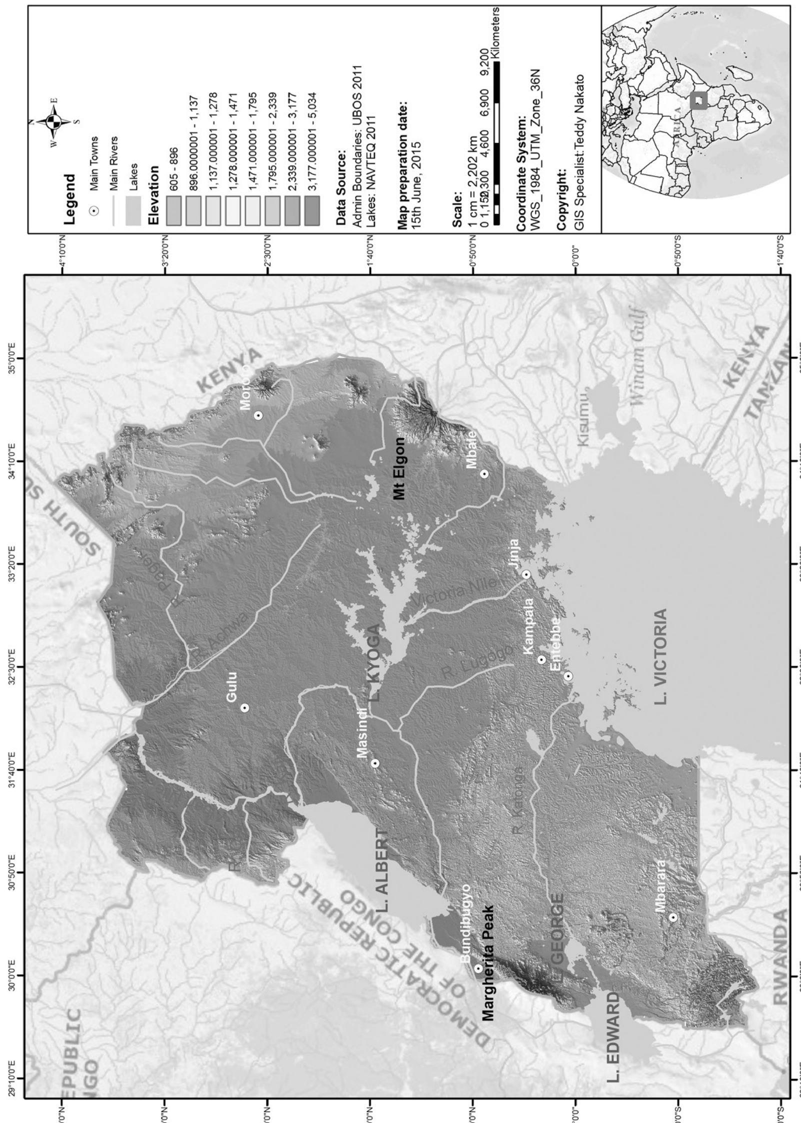

Figure 6.1 Map of Uganda showing the main physical features
Source: Teddy Nakato

1996). The heat storage and moderating effects of lakes Victoria, Albert, and Kyoga and the differential heating of land adjacent to them produce localized winds. Together with the high mountain ranges of Elgon and Rwenzori as well as the western Rift Valley, these are responsible for the spatial variability of the weather patterns (MWE, 2013b). The climate of Uganda, according to the *Thornthwaite Climate Classification*, based on data for 1960–90, ranges from arid to humid (MWE, 2013b), and in the arid areas there is need to emphasize water conservation techniques and the promotion of drought-resistant crops.

Long-term variation in rainfall over most parts of Uganda shows a cyclical behaviour, with a tendency for periods dominated by droughts or floods, which persist for periods of up to six years. Rainfall in the River Kafu catchment, for example, showed cyclical behaviour, with less severe droughts in the 1990s than those experienced in the 1940s, 1950s, and early 1980s (Kahangire and Lubunga, 2001). During the early 1960s, the region also experienced a sequence of very wet years which resulted in water-level rises in most parts of the country, with adverse effects on infrastructure (ports, roads, and homesteads) and flooding of agricultural land. This led to increased flows in the White Nile, and coincided with decreased flows in the Blue Nile. The average contribution of the White Nile during the period 1912–61 was 33 per cent of the combined flow of the two rivers, but was 44 per cent during 1965–86 (Kahangire and Lubunga, 2001).

The Ugandan catchments that drain into the Nile represent a relatively small contribution to the total flow of the river. The Nile flow rate was estimated at 808 m^3/s when leaving Lake Victoria, 789 m^3/s when leaving Lake Kyoga and 900 m^3/s when leaving Lake Albert. However, the yields of these catchments dominate the water resource potential within Uganda. The water balance of Lake Victoria is shown in Table 6.2, where the largest input to the lake is direct rainfall at 82 per cent while inflows from river catchments contribute the remaining 18 per cent. The largest output is evapotranspiration (75 per cent) with outflows from the Victoria Nile accounting for 25 per cent (MWE, 2013b). Kizza (2012) developed monthly and annual water balance models for the Lake Victoria Basin, which indicated a strong link between net basin variability and seasonal rainfall variability. It was noted that the two largest increases in the Lake Victoria Basin level were to a large extent due to the extremely high net basin supply during the short rains of October to December in 1961 and 1997, both *El Niño* periods. The plentiful nature of the rain implies there is a need to promote rainwater harvesting and other water conservation techniques more vigorously, as discussed in Chapters 7 (Asiimwe et al., 2015) and 8 (Nalwanga et al., 2015).

Direct rainfall is an important water resource in Uganda and its patterns largely determine agricultural and land use potential, and subsequently, population distribution. In an agro-based economy like Uganda's, rainfall reliability is an important guide to growth and development potential. The potential for rainwater harvesting is good, but is limited by current housing structures and the investment required for water storage. However, data

Table 6.2 Average annual water balances for Lake Victoria for the period 1953 to 1978

Parameter	Lake Victoria (m^3/s)	(%)
Inflow – Kenyan catchments	291.4	6.6
Inflow – Tanzanian catchments	214.9	4.8
Inflow – Ugandan catchments	281.9	6.4
Total inflow	788.2	17.8
Rainfall on Lake Victoria	3,651.6	82.2
Total input	**4,439.8**	
Outflow through Victoria Nile	1,071.4	24.6
Evaporation from Lake Victoria	3,278.0	75.4
Total output	**4,349.4**	
Balance/storage change	90.4	2.0
Net basin supply	1,161.8	26.2

Source: MWE, 2013b

availability on national rainfall distribution (spatial and temporal) and on evapotranspiration rates is also limited in both duration and extent of coverage.

Groundwater in Uganda

In addition to surface water resources, Uganda has sizeable groundwater resources, which are the mainstay of water supplies in rural areas. Groundwater occurrence is greatly influenced by the varied geological conditions and by local climate. Precambrian rocks underlie over 90 per cent of the country, while Cenozoic rift valley sediments and Tertiary and Pleistocene volcanics cover less than 10 per cent (Tindimugaya, 2008). Hydrogeological conditions are typical of Precambrian basement terrain and aquifers occur in the weathered overburden (regolith) and in the fractured bedrock, forming one discontinuous aquifer system. In most of Uganda, boreholes for water supply are typically drilled into fractured bedrock, while shallow wells are excavated in the overlying regolith. Using a numerical model, Nyende et al. (2013a) showed that the flow to the fractured crystalline rock is controlled by the transmissivity or structure of the regolith, while leakage through the regolith is the major factor of recharge in the Pallisa aquifer in eastern Uganda. Subsequently, weathered and fractured zones represent potential aquifers under a large variety of hydrogeological conditions. In-situ weathering is the primary process in overburden development, and is usually most intense in fractured rocks. A conceptual model of the weathered–fractured basement aquifer system is shown in Figure 6.2.

The hydrogeological characteristics of the deeply weathered crystalline rock derive from long-term tectonically controlled geomorphic processes (Taylor and Howard, 1999, 2000). The bedrock permeability arises from fractures due to decompression resulting from the removal of the overlying

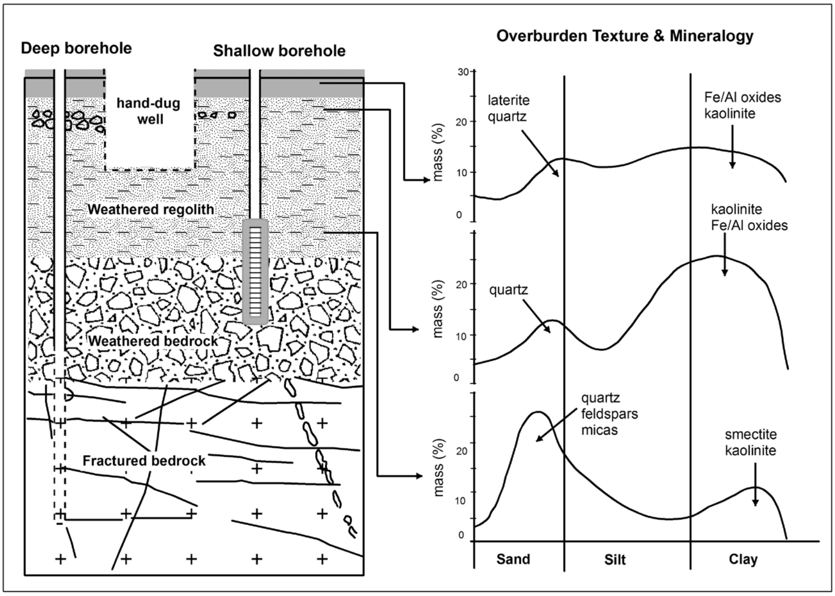

Figure 6.2 Conceptual model of the weathered–fractured basement aquifer system in Uganda
Source: Tindimugaya, 2008

rock both in solution (deep weathering) and by colluvial and fluvial erosion (stripping). The overlying unconsolidated mantle is a product of deep in-situ weathering. Sand-sized clasts predominate at the base of the mantle and form an aquifer that has a transmissivity an order of magnitude (T = 5–20 m^2/d) higher than that in the underlying fractured bedrock (T ~ 1m^2/d). It has also been suggested that corridors of preferential groundwater flow occur in relict river channels like the Katonga River valley in central Uganda, reversed by tectonic activity associated with the development of the East African Rift System (Bradley et al., 2008). In the mid-Pleistocene period, uplift parallel to the escarpment exceeded the rate of river basin incision and led to the reversal of surface flow. On surfaces of low relief east of the upwarp, coarse-grained sediments were overlain by low-energy, fine-grained deposits, which currently support extensive wetlands.

The sustainability of the groundwater source was investigated as part of the Aquitest Programme (Rugumayo and Kibera, 2004) for Bugahya County in the Hoima District in western Uganda and was based on pumping test data from 12 boreholes. The lithological profiles showed the aquifer was overlain by relatively impermeable clay at a depth of approximately 20 m, implying a confined aquifer. Three standard methods were used to determine the aquifer parameters (transmissivity (T), hydraulic conductivity (K), and storativity (S)) from the pumping test data, namely the Theis, the Cooper-Jacob, and the Theis Recovery methods (Kruseman et al., 1990), and the results were comparable. Geostatistical methods were employed by Kigobe and Kizza (2006) to estimate unsampled areas and measure the hydraulic parameters of T and S in the Mpigi and Wakiso districts in central Uganda, where there was limited data availability. The results showed that the underlying aquifer systems are mainly semi-confined and leaky, with low hydraulic conductivity (Figure 6.3). These studies confirmed the availability of groundwater and the nature of aquifers in different parts of Uganda.

Several studies have investigated groundwater flow in the vicinity of Lake Victoria. Mangeni and Katashaya (2006) analysed data from the National Oceanic and Atmospheric Administration and advanced very high-resolution radiometer infrared images as surface temperature maps, and observed distinct warm/cool seasonal patterns, which indicated groundwater inflow into the lake. Furthermore, observations of the lithological interface and hydraulic gradients between groundwater and surface water at Lake Victoria at both Entebbe and Jinja showed that groundwater discharges to surface water via saprolite, which underlies relatively thin (< 5 m) lacustrine sand (Owor et al., 2008).

Some of the challenges experienced in the management of groundwater resources in urban areas have been well documented by Tindumugaya (2008) and include the lack of sewerage systems. This has led to the widespread use of on-site sanitation systems, such as septic tanks and pit latrines, which have caused contamination of groundwater resources in many areas. Substantial efforts are still required to improve groundwater management and governance in Uganda in the form of groundwater regulation and monitoring, and further assessment of groundwater resources is needed.

Groundwater recharge

The sustainability of groundwater development is dependent on the groundwater recharge. Groundwater recharge can be defined as the downward flow of water reaching the water table adding to groundwater storage (Healy, 2010). There are two main types of recharge: direct (diffuse) recharge, which occurs when rainfall infiltrates where it falls on the ground; and indirect (point) recharge, which occurs through infiltration of run-off, lake water, and other surface water (Misstear et al., 2006; Healy, 2010). Recharge will be governed by rates of rainfall and evapotranspiration rates from vegetation, as well as geology and soil type. A study of groundwater recharge estimates by Taylor (1996) in the Aroca catchment in central Uganda (north of Lake Kyoga), which used the soil moisture balance method, supported by stable isotope data and groundwater flow modelling, gave average values of 200 mm/year. Recharge, however, has been shown to be more dependent on the number of intense (more than 10 mm/day) rainfall events than on total annual rainfall (Owor et al., 2008). The study further demonstrated that recharge occurred in most years, but varied according to fluctuations in annual precipitation, and that recharge pulses occurred twice a year in response to the bimodal characteristics

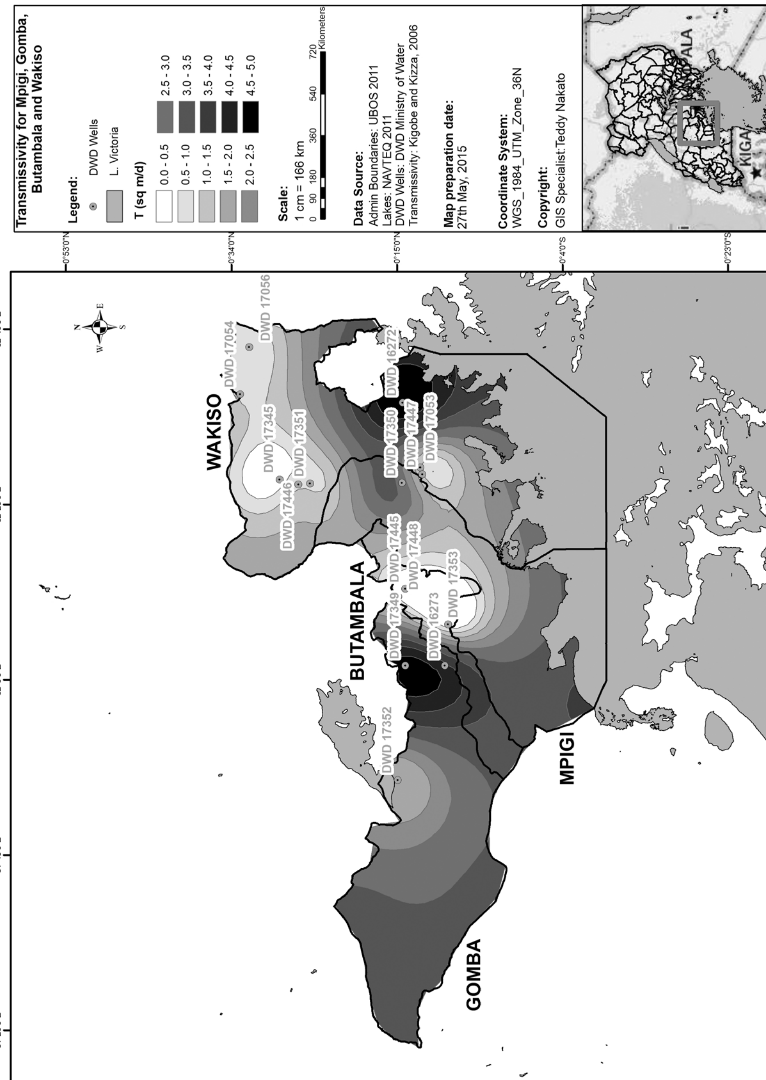

Figure 6.3 Transmissivity for Mpigi and Wakiso districts
Source: Kigobe and Kizza, 2006

of the rainfall distribution (Owor et al., 2008). In addition to the importance of seasonal patterns in rainfall, preferential and/or localized flow mechanisms were shown to dominate recharge behaviour in one long-term (10-year) study of groundwater levels (Cuthbert and Tindimugaya, 2010). Nyende et al. (2013b) used the EARTH model and isotopes in the Pallisa District in eastern Uganda, and showed that groundwater fluctuations were affected by the natural climatic variations and anthropogenic influences in the weathered fractured aquifer, which meant the water table was shallow. Furthermore, replenishment was entirely through precipitation. As well as providing water supplies for people, animals, crops, and industry, groundwater is important for maintaining baseflows to rivers, lakes, and wetlands. Therefore, for sustainability of groundwater resources, abstraction rates should be less than the recharge in order to leave sufficient water for maintaining environmental flows. In Uganda, the National Water Resources Assessment report (MWE, 2013b) recommends that abstractions should not exceed 50 per cent of the estimated recharge.

Groundwater quality

The quality of groundwater reflects both the concentrations of naturally occurring elements and the presence of contaminants from anthropogenic sources, for example, microbial contaminants from pit latrines and other waste systems. In a study carried out in the Pallisa District in eastern Uganda, Nyende et al. (2008) undertook a hydro-chemical evaluation of groundwater from the regolith and basement aquifers, which showed that electrical conductivity values (and thus the degree of mineralization) were significantly lower for springs than for dug wells, which in turn were lower than for boreholes. Further analysis by Nyende et al. (2014) of the groundwater chemistry showed a regime of calcium/magnesium-bicarbonates.

Among the naturally occurring chemical parameters of significance to human health are fluoride and arsenic. While high fluoride levels are often associated with volcanic aquifers in the East African Rift Valley, fluoride concentrations in groundwater in the basement complex and regolith aquifers are likely to be less of a concern (BGS, 2001). Data on arsenic are scarce, but concentrations of 5 to 9 parts per billion have been found in basement aquifers in the Aroca region in north-central Uganda (Taylor and Howard, 1994).

Shallow aquifers in urban and peri-urban areas are particularly susceptible to pollution. For example, in shallow groundwater of the peri-urban waters of the Bwaise suburb of Kampala, seasonal variations in the phosphorus content corresponded to rainfall events, highlighting the link between seasonal rainfall patterns and groundwater quality (Kulabako et al., 2007). The high phosphorus content was linked to waste disposal from animal husbandry.

Water resources in the Lwengo District

The study area for the Water is Life project lies within the Lwengo District in south-west-central Uganda. The largest town in the region is Masaka (Lwengo District was formerly part of the Masaka District). The study area is at a relatively high altitude, with valley floors approximately 1,260 m above mean sea level and hills rising to 1,330 m amsl. The area is characterized by grassland-vegetated hills and valleys, the latter typically occupied by seasonal swamps. It slopes gently south-eastwards to a wide swampy valley, which then drains to the north-east. No large free-draining rivers are visible, although the valley swamps probably constitute a drainage network discharging to the Katonga River system to the north, which then drains eastwards into Lake Victoria.

Most of the area is covered by thick lateritic regolith soils and is underlain by crystalline basement complex rocks of Precambrian age (> 600 million years old). Large outcrops of gneiss form an impressive hill at one locale (Figure 6.4) but, in general, bedrock is rarely observed on the surface. The vegetation is mostly composed of seasonally flooded grassland, with small-scale farmland and occasional small plantations of broadleaved trees. The most popular crops include plantain (*Musa paradisiaca*), maize (*Zea mays L.*), coffee (*Coffea robusta*), and cassava (*Manihot esculenta*), with plantations of eucalyptus (*Eucalyptus grandis*) present in the centre of the valley (Hughes, 2010). As with many of the valleys in the region, the centre of the small catchment studied by Hughes (2010) contained a permanent swamp fringed with papyrus.

Average annual rainfall from Mbarara, a meteorological station in the region, is 1,125 mm/year (UN-Habitat, 2012), while the long-term average for the Masaka station is 1,230 mm/year (Africa Rainfall and Temperature Evaluation System, in Hughes, 2010). Precipitation falls in two seasons: March to May (the main rainfall period) and October to December (a more variable rainfall season). Temperatures are relatively high in all months, with an average annual temperature of 25°C (UN-Habitat, 2012). These relatively high temperatures result in high evapotranspiration rates from vegetation over the full annual cycle in Uganda, although water losses will be lower during drought periods and will also depend on the vegetation type (Hughes, 2010).

The seasonal pattern in rainfall, together with the changes in the loss of water to the atmosphere through evapotranspiration, govern the seasonal changes in the aquifer water table level, and therefore the availability of groundwater as a drinking water source for the local population. Estimates of the rate at which groundwater recharges in such regions in Uganda vary from 7 to 20 per cent of annual rainfall (UNESCO, 2005). These estimates are mainly based on soil water budget approaches. A more recent study of recharge in similar terrain in north-east Uganda using groundwater level fluctuation data gave similar recharge values of between 4 and 18 per cent of annual rainfall for the period considered (Cuthbert and Tindimugaya, 2010). Interestingly, the well hydrographs showed that recharge occurred even in periods when there was a high soil moisture deficit, indicating the importance of preferential flow paths in recharge.

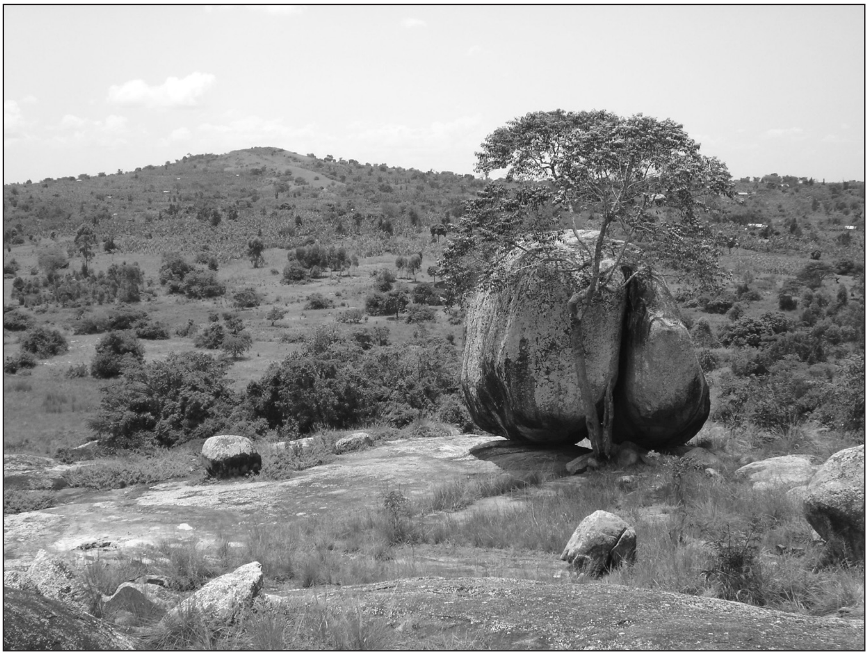

Figure 6.4 Outcrop of gneiss, Lwengo District
Source: Bruce Misstear

Lwengo District has also experienced increasingly intense drought periods over the past decade, as well as changes in land use, such as the removal of the papyrus swamp and deforestation (Aggrey et al., 2010; MWE, 2008a). Of note for the Water is Life project study period is that 2010 and 2011 were designated as drought years by the Ugandan Department of Disaster Management (2012) based on data from Mbarara and also from Gulu in northern Uganda. While annual rainfall rates were slightly above the long-term average values at Mbarara in those two years, 36 per cent of the months between January 2010 and July 2011 were below average (Department of Disaster Management, 2012).

Water sources in the Lwengo District

In rural areas, four main types of water source are generally used (MWE, 2010b), all of which are represented in the study area: traditional water sources; improved water sources, including shallow wells and protected springs; boreholes; and rainwater harvesting. In the former Masaka District (which has now been subdivided into three districts: Lwengo, Bukomansimbi, and Masaka), access to safe water varies from 54 per cent to 95 per cent across the various sub-counties (MWE, 2010b). The traditional water sources in this area are ponds, unimproved shallow wells, and unprotected springs, and they tend to be located at the edge of the valley-bottom seasonal swamps. The waters in these sources are generally turbid, with high levels of suspended solids, and can be expected to be contaminated with faecal bacteria. Figure 6.5 shows examples of an unprotected water source and a protected spring.

In rural areas, improvements in water sources are implemented by the relevant government district water office as well as CBOs and NGOs. There are between 220 CBOs and NGOs involved in the water sector in Uganda, of which 180 (81 per cent) are considered active (UWASNET, 2014). The implementation and maintenance of improved sources, including wells, require the involvement of local communities and the establishment of village water and sanitation committees. The majority of the improved sources in the study area are hand-dug wells, typically only a few metres deep, and equipped with U2 or U3 handpumps. The wells are usually located 5 m to 20 m upslope from the edge of a valley-bottom swamp, where the traditional water sources are located. The top of each improved well is covered by a concrete apron, into which a steel pipe is set for connecting the handpump. After making the concrete slab, the well is left for two to three weeks to allow the concrete to cure, and then the pump is installed. Typically, the concrete apron around the well includes a drainage channel (approximately 3 m long) leading downslope towards the swamp. A couple of wooden poles are sometimes set horizontally above and below the handle of the handpump to prevent excessive movement of the handle (Figure 6.6). The wells are reportedly constructed with circular concrete caissons (1 m in diameter, 0.6 m high, 50 mm thick) made in Masaka. Water flows into the well through the well base (filled with sand and aggregate) and through the gaps between those caissons, which are below the water table (the lower caissons are not made with holes). Although the improved wells are better than traditional water sources, their location in valley bottoms, coupled with their shallow depths and the shallow water tables, mean that they are still vulnerable to contamination.

Unlike the hand-dug wells, which are located in the valley bottoms away from the villages, boreholes tend to be drilled on higher ground close to or within the villages. Verbal reports indicated that many of the boreholes are non-functional, either due to poor siting or broken pumps. Statistical information derived from borehole records for the former Masaka District is summarized in Table 6.3. The large standard deviations probably reflect limitations in the data, as well as variability in geological conditions. Nevertheless, it can be inferred from the table that the mean regolith thickness in the area is approximately 50 m. Hydrochemical data from the borehole database indicate a mean electrical conductivity of 491 microsiemens/cm, with some exceedances of Ugandan mean average for electroconductivity, hardness, sulphate and iron (MWE, 2008b). In view of their greater depth, boreholes are generally less susceptible to microbial pollution than traditional sources and improved hand-dug wells, and therefore the bacteriological water quality would be expected to be better.

Rainwater harvesting provides an alternative water source for some people in the area. The collection of rainwater is facilitated by: 1) the occurrence of

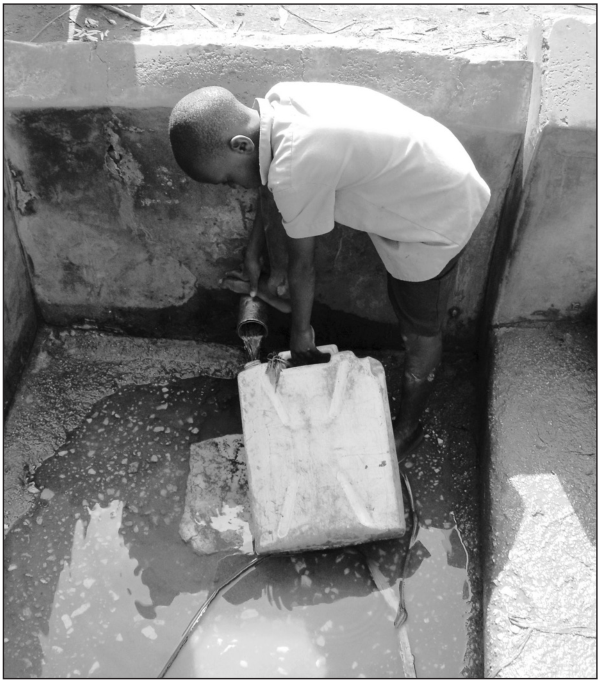

Figure 6.5 An example of an unimproved water source (top) and a protected spring (bottom) water source in the Lwengo District
Source: Bruce Misstear

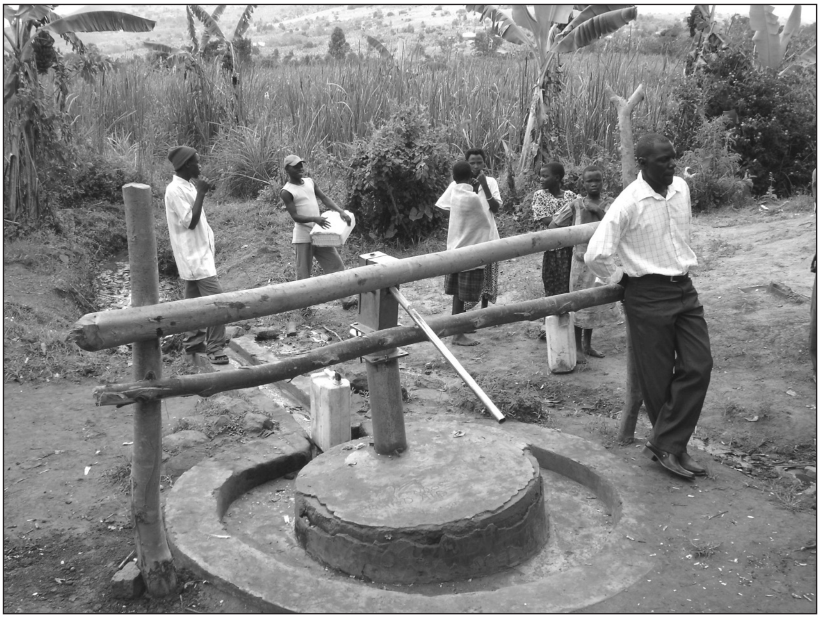

Figure 6.6 A hand-dug well with horizontal wooden poles designed to prevent excessive movement of the handle of the handpump
Source: Bruce Misstear

the two wet seasons a year; and 2) the fact that many houses have galvanized iron roofs (as opposed to traditional thatched roofs). For example, in the case of a house with a 40 m^2 area of roof and 1,000 mm of annual rainfall, a total volume of approximately 32 m^3 could be collected (assuming a capture efficiency of 80 per cent, which is equivalent to a supply of about 90 l per day for a household) if adequate water storage is provided. As with the construction of improved wells, rainwater collection is supported by NGO programmes in the area; in addition, government grants are available. Rainwater-harvesting tanks are usually made of galvanized iron and are manufactured in Masaka, though imported heavy-duty plastic tanks are also used.

Table 6.3 Borehole data from Masaka District

	Static water level (m below gl)	Depth to fresh rock (m)	Estimated yield (m^3/hr)	Total casing length (m)
Maximum	70.1	107.0	17.6	178.0
Minimum	0.7	–	–	6.0
Mean	27.0	47.2	1.5	62.0
Standard deviation	11.9	21.2	2.0	26.4

Source: MWE, 2008b

Water resource management issues and challenges for the future

Water demand

The main water demands in Uganda are domestic use (both rural and urban), agriculture, industrial purposes, and hydropower. Water is also used for transport. Currently, the major factors causing increased water demand are population growth, economic development, and to a lesser extent, the expansion of irrigated agriculture. Water for livestock constitutes a significant water use, especially in semi-arid and arid areas where long dry periods are common. Rangelands, popularly known as the 'cattle corridor', are a drought-prone area that traverses the country from south-west to north-east (NEMA, 2006). There are also inequalities in use, access, and participation in local water governance.

Catchment conditions

Uganda's catchments are experiencing degradation as a result of land use pressures arising from increased human and livestock populations and the combined effects of agricultural encroachment and deforestation. Catchments have experienced wetland loss and river bank erosion, while open field defecation and discharge of untreated sewage are still common. Increased sedimentation of water bodies has resulted from the removal of vegetation cover. Uganda has been divided into 10 erosion zones, based on severity and impact (NEMA, 1999, 2002).

Water quality

For the past two decades, the quality of Uganda's surface water has been deteriorating. One important example of this problem is the pollution of Murchison Bay in Lake Victoria, the main water source for the city of Kampala. In their study, Banadda et al. (2009) showed that for Kampala city, pollution from non-point sources was higher than from point sources. Non-point sources include agriculture and urban stormwater run-off. A number of primary factors that contribute towards increased non-point pollution were identified, including population growth, political appeasement, land use, and ownership. Deforestation, crop and animal production, wetland degradation, development of transportation infrastructure, housing development, industrialization, and lack of adequate waste disposal facilities were all identified as secondary factors. In rural areas, water quality problems arise from the shallow nature of many improved wells and non-functionality of handpumps, leading people to revert to unprotected traditional water sources.

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has stated that it is now certain that global mean surface temperature has increased since the late 19th century (Hartmann et al., 2013). For Africa generally, this IPCC report noted a lack of reliable data or studies in many regions, but cited Christy et al. (2009), who reported no significant trend in maximum daily air temperature using data from Kenya and Tanzania (1905–2004), but a significant and an accelerating trend in minimum daily air temperature and a decline in the diurnal temperature difference between maximum and minimum temperatures. Given that trends in air temperature show regional coherence, a similar trend is likely for East Africa, including Uganda. Additional evidence in Uganda includes the following:

- The ice caps on Mount Rwenzori in western Uganda have receded to about 60 per cent of their 1955 recorded cover and are projected to disappear by 2023 (MWLE, 2006; NEMA 2006). Temperature rise associated with global warming is the primary driver of the retreat (Taylor et al., 2006).
- Temperature rise has resulted in an increase in malaria incidences beginning in the 20th century. A study done by Wandiga (2006) in the region revealed that previous malaria epidemics coincided with high peak flows in rivers and high temperatures.

The effects of climate change on both water supply and ecosystem sustainability may be difficult to separate from other anthropogenic effects. In fact, Carter and Parker (2009) concluded that while climate change impacts are likely to be significant, the direct and indirect impacts of demographic change on both water resources and water demand are not only known with far greater certainty, but are also likely to be much larger. In his study of Lake Victoria, Azza (2006) noted that the deterioration in the lake's ecosystem was a result of both anthropogenic factors and climate change: longer-term changes were a result of climate change, while shorter-term changes were due to human activity. His study also noted that the responses in lakes Tanganyika and Victoria differed from each other. While increasing nutrients produced higher primary productivity in Lake Victoria, they reduced primary productivity in Lake Tanganyika. This was attributed to differences in the frequency and spatial extent of nutrient upwelling and entrainment in surface waters, possibly caused by differences in morphometry.

For the human population, a strong correlation between sanitary risk and bacteriological contamination of groundwater emphasizes the importance of mitigating the increased risk of diarrhoeal diseases posed by climate change (Taylor et al., 2009). In Kampala city, high-frequency sampling of protected springs showed gross but ephemeral contamination by thermotolerant (faecal) bacteria in response to heavy rainfall events (>10 mm/day). Dynamical downscaling of future climates predicted by the HadCM3 general circulation model (SRES A2 scenario) using the regional climate model PRECIS also projected that the frequency of heavy rainfall would increase in the 21st century (Taylor et al., 2009).

Declining water levels in major lakes

Water levels dropped drastically in Lake Victoria between 2002 and 2006; the causes were attributed to regional drought and increased abstraction rates from the hydropower stations at Nalubaale and Kiira (MWLE, 2006). In order to compensate for the resulting reduced hydropower, the government was forced to procure expensive thermal power generation using heavy fuel oil. Consequently, the maintenance of acceptable water levels in Lake Victoria is considered a priority that needs to be vigorously pursued by the Directorate of Water Resources Management and falls within its mandate. Similar drops in water levels were observed in the Rwizi catchment and Lake Wamala, primarily because of deforestation, overgrazing, prolonged droughts, and climate change (MWE, 2011b).

Wetlands management

Wetlands are one of the most valuable ecosystems in Uganda and have the capacity to store, filter, distribute, and gradually release large quantities of Uganda's freshwater. Uganda is a signatory member to the Ramsar Convention and has developed a 10-year Wetlands Sector Strategic Plan. However, anthropogenic activities are threatening Uganda's wetlands, including draining land for agricultural use, excavating wetlands for mining and brickmaking, dumping of waste, deforestation, and deliberate swamp fires. One system that has great potential for improved management of wetlands is the 'fingerponds' concept, which exploits fringe wetlands sustainably for food production, while conserving swamp integrity and biological diversity (Denny et al., 2006).

Water governance and integrated water resources management

Governance issues are covered in Chapter 2, (Asaba et al., 2015); however, some brief discussion of current initiatives is relevant here. The MWE implements a sector-wide approach in the planning and implementation of its annual targets and interventions (MWE, 2014). Whereas the institutional framework was designed to operate at three administrative levels – national, district, and local (MWE, 2011a) – this is gradually being replaced by catchment-based water resources management. Water Management Zones (WMZs) have been created in order to: 1) enhance the collection, storage and transfer of water use planning data; 2) enhance compliance monitoring, including water quality and discharge permits; 3) provide environment impact assessments; and 4) provide technical support to stakeholders. The WMZs are being demarcated into catchments, with a Catchment Management Organization (CMO) being established for each. The CMOs are developing Catchment Management Plans (CMPs), which include costed measures to protect and restore the catchment while improving people's livelihoods (MWE, 2010a). A framework for water source protection has been developed (MWE, 2013a) to improve the water quality and reliability, and to promote better livelihoods. Considerable progress has been made in establishing the CMOs and in developing the CMPs, as well as gradual restoration of the catchments (MWE, 2015). However, there is a need for more awareness creation, stakeholder engagement, and additional funding from both development partners and the private sector in order to realize catchment restoration and improve the livelihoods of the local communities. Nevertheless, the establishment of a catchment-based approach is a step towards integrated water resource management (IWRM).

Inadequate funding, data, awareness, and capacity

Several challenges to IWRM have been identified for Uganda (MWE, 2010a; Rubarenzya, 2007), including:

- inadequate funding for the sector, both public and private;
- inadequate spatial and temporal data for rainfall and for streamflow gauging stations;
- network functionality – the functionality of the hydrometric network for the 137 surface water stations, 33 groundwater stations, and 17 automatic weather stations during the 2013/14 reporting period was only 57 per cent (MWE, 2014);
- lack of awareness at societal, policy, and management levels;
- limitations in human resources capacity (numbers, skills, focus, experience, attitude, and knowledge);
- inadequate decision-making supports, including numerical models of water resources, to facilitate IWRM.

Conclusions

This chapter has provided a brief overview of Uganda's water resources and some of the main challenges being faced. The water resources within a study area in the Lwengo District have also been described. From the above discussion, a number of conclusions can be drawn:

- Uganda's water resources are variable in time and space. Although currently adequate, these water resources are threatened by increased population growth, increased urbanization, and the increased water demands associated with improved economic well-being. These challenges can be mitigated through an integrated approach to water resource management, with increased use of water conservation methods, rainwater harvesting, drought-resistant crops, and reafforestation.
- Local geology, topography, and climate affect the availability of groundwater, factors which cannot be directly managed or changed. Aquifers

are present in both the regolith and in the underlying fractured bedrock, and are especially important as sources of water supply in rural areas. The groundwater resources are also essential for maintaining environmental flows to surface water bodies and wetlands, so it is important that they are not over-exploited.

- Anthropogenic factors affect the quality and quantity of groundwater and include contamination of water supplies by human and animal wastes, changes in natural vegetation through deforestation and wetland drainage, and climate change. Problems of poor functionality of some of the water supplies in the Lwengo District need to be addressed through a combination of improved community management and external support, as discussed further in Chapters 4 (Mugumya et al., 2015) and 5 (Asiimwe and Naiga, 2015).
- Global warming is occurring and the impacts of climate change in Uganda are potentially of most consequence to the poorest members of society. Intense rainfall events, which may become more frequent according to many climate change predictions, can lead to increased risk of microbiological pollution of water sources.
- Surface water quality and wetlands experience severe degradation due to lack of enforcement of regulation. There is a need to enforce regulations through the appropriate structures of a catchment-based water management system.
- There is an evolving institutional framework, especially with the introduction of catchment-based water resources management, which promotes IWRM. However, there is a need to disseminate these messages to different stakeholders in order to create enough synergies to promote the catchment-based water management system. There is also a requirement to provide adequate funding for the WMZs.
- There is a need to improve the hydrometric data collection network and ensure the existing monitoring facilities are functional.

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CHAPTER 7

A school-based approach to community promotion of solar water disinfection

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Abstract

This chapter discusses how primary school children can be effective agents of change in the promotion and dissemination of solar disinfection (SODIS) of drinking water within the community. In this study, pupils were instructed to drink only SODIS-treated water whether at school or at home. The effectiveness of SODIS was monitored using the microbial quality of the water, and incidence of diarrhoea and/or gastro-intestinal complaints severe enough to cause pupil absenteeism. Community use of SODIS was assessed through observation of and in-depth interviews with community members. Results show that SODIS was effective in improving microbial quality of drinking water with over 50 per cent of all treated samples meeting the WHO standard for drinking water for both Escherichia coli *and* Enterococcus faecalis, *compared to only 16 per cent of untreated samples. Absenteeism due to diarrhoea and gastro-intestinal complaints significantly dropped from a baseline average of 1.9 ± 2.2 days to 0.2 ± 0.6 days, and community use of SODIS increased from 4.9 per cent at baseline to over 60 per cent post-intervention.*

Keywords: water treatment, solar disinfection, efficacy, implementation

Introduction

The WHO/UNICEF Joint Monitoring Programme (JMP) monitors progress towards global achievement of the Millennium Development Goals (UN, 2012) and takes the proportion of people using improved or unimproved water sources as proxy indicators to assess the global population's access to safe water. Improved water sources are those that are protected from outside contamination, particularly from faecal matter, and include piped water, public stand taps, tube wells, boreholes, protected springs, protected dug wells, and harvested rainwater. Unimproved water sources, on the other hand, include unprotected dug wells, springs, cart or truck tank-water, and surface water (WHO and UNICEF, 2012). It is important to note that so-called improved water sources may not be adequately protected and therefore may not supply safe water. Consequently, the number of people without access to safe drinking water is likely to be underestimated. This chapter highlights the

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use of solar disinfection (SODIS) as a water treatment technology aimed at improving safe water access in rural Uganda. The study was based in a rural community in southern Uganda.

Safe water supply and access in rural Uganda

The Ministry of Water and Environment (MWE) in Uganda defines safe water as that which is free from disease-causing organisms, toxic chemicals, colour, smell, and unpleasant taste (MWE, 2012). Statistics from the MWE suggest that only 66 per cent of Ugandans have access to safe water (MWE, 2012). The situation is worst in rural areas, which remain underserved relative to urban populations. The MWE's Directorate of Water Development highlights unprotected open water sources as supplying 30.5 per cent of rural water domestic needs (UBOS, 2010). Other studies have found that in some rural parts of Uganda, unprotected water sources account for over 82 per cent of domestic water supply (Mellor, 2009).

Access to safe drinking water in rural Uganda is officially determined by three factors: the walking distance from the household to the water source; time spent travelling to and from the water source; and the volume of water used per person per day in each household (MWE, 2012; Rugumayo, 2008: 15–16.; UBOS, 2007). The combination of a distance of 1 km or less, a time of less than 30 minutes round trip to the water source from home, and use of 20 litres per person per day is considered as access to sufficient water for the rural population (UN, 2014). This compares to the WHO-recommended 100 litres per person per day to meet all consumption and hygiene needs (WHO, 2003a). The MWE reported that safe water access in rural areas declined from 65 per cent in 2010 to 64 per cent in 2012; this was attributed mainly to general cuts in government funding to the water sector, coupled with the creation of new districts, which meant that some resources for water services were diverted to cater for other district infrastructure development (MWE, 2012). With an estimated 30 million Ugandans living in rural areas (Kidimu, 2013), it is likely that some 10 million people in rural areas are still without access to safe drinking water. Sixty per cent of rural households in Uganda reported travelling 1.5 km or more to access safe water (MWE, 2012).

Solar water disinfection

These water quality and access statistics clearly indicate that the situation in rural Uganda requires concerted effort from both central government and private partners to ensure sufficient access to safe drinking water. Point-of-use (POU) household water treatment and safe storage technologies (HWTS) have been promoted by the WHO as a means to provide safe drinking water to people who have no centralized supply. It is estimated that, if used appropriately, such measures can significantly reduce the diarrhoeal disease burden (WHO and UNICEF, 2010). Solar water disinfection is one such technology approved

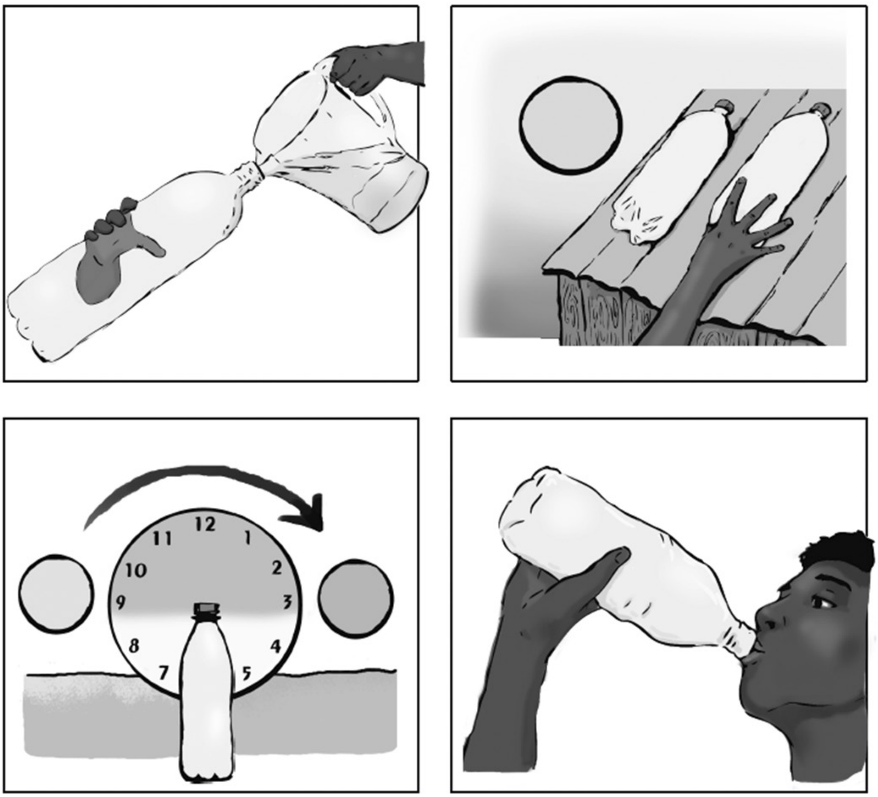

Figure 7.1 Graphical representation of the solar disinfection technique

by the WHO in 2005 for water treatment at household level. The basic SODIS technique (Figure 7.1) entails filling a transparent plastic or glass bottle or plastic bag with contaminated water and exposing it to unobscured sunlight for a minimum of six hours in strong sunny conditions, or longer (usually 48 hours) under cloudy weather (Lantagne et al., 2006).

The exposure to the sun's ultraviolet (UV) rays inactivates the pathogens present in the water, making the water safe to drink (Dejung et al., 2007; Walker et al., 2004). Polyethylene-terephthalate (PET) plastic bottles are preferred for SODIS, since PET is generally considered to be inert and therefore a suitable material for food packaging, in comparison to other plastic materials (EAWAG–SANDEC, 2009). In addition, plastic is more robust than glass bottles and does not break easily, making it more durable for SODIS use (McGuigan et al., 2012). SODIS works best with clear non-turbid water – usually less than 30 nephelometric turbidity units (NTU) – which allows the UV light to penetrate easily. In turbid or cloudy water, the suspended particles can block UV light penetration through the water, slowing the disinfection process. Preliminary treatment of highly turbid water including sedimentation and filtration is therefore recommended, when possible, for effective SODIS treatment (Sommer et al., 1997). Where filtration pre-treatment of turbid water is not possible, SODIS can still be used, although treatment will take longer.

SODIS inactivation mechanisms

All solar UV light (UVA, UVB, and UVC) has the ability to kill or inactivate bacteria and other microorganisms in water. However, UVA and infrared light are the most critical for the SODIS process (Kramer and Ames, 1987). Solar disinfection occurs due to a combination of solar UV light and thermal processes. Solar UV damages the DNA and outer membranes of microbial pathogens in the water, so as to fatally injure the bacteria, viruses, and protozoa present. Under this hostile environment, one by one the various cellular functions within the organisms shut down, leading to complete and irreversible cell death. The high temperatures generated by the infrared part of the spectrum also cause bacterial inactivation through pasteurization. In addition to pasteurization, high water temperatures inhibit DNA repair mechanisms leading to accelerated disinfection (McGuigan et al., 1998). The strong synergistic combination of thermal and optical inactivation is accelerated if the water temperatures rise to above 45˚C. In fact, Wegelin et al. (1994) showed that at temperatures of 50˚C the rate of bacterial inactivation in SODIS-treated water was three times faster than at lower temperatures. The synergistic combination of raised temperatures and UV-induced damage can inactivate bacterial populations in excess of 1 million cells per ml in less than two hours under strong, tropical, sunny conditions. However, since strength of sunlight, cloud cover, and the turbidity of the water can vary, the usual recommendation is to expose the water for a minimum of six hours in strong sunlight.

SODIS promotion via schoolchildren

One of the main objectives of our primary school study was to introduce SODIS as an alternative POU household water treatment technology to the entire community using a school-based trial. The specific objectives were to:

1. assess the effect of SODIS on the microbial quality of water used by pupils while at school, and hence their health in terms of water-related diseases, with particular emphasis on the occurrence of diarrhoea and gastro-intestinal complaints;
2. assess the effect of SODIS on pupils' attendance patterns and the extent to which diarrhoea and gastro-intestinal complaints contributed to absenteeism;
3. assess the effectiveness of pupils in transferring SODIS knowledge back to their caregivers or community through an interview-based survey of community members.

The study was located in a 25 km^2 parish located approximately 40 km south-west of the town of Masaka in southern Uganda. All 15 schools within this area were approached and 14 agreed to participate; these included schools which were state-funded, privately funded, Christian faith based, and Islamic faith based. A total of 700 pupils from 14 primary schools in this area were selected to participate in the study (age range 6–9 years, in lower primary classes P1–P3). The study was conducted in four phases following the school academic calendar, as shown in Table 7.1. First, a baseline study was carried out to assess microbial water quality and the types of water source used by the pupils while at school. In addition, a baseline measure of pupil absenteeism was conducted at selected schools to gauge the various causes of absenteeism, with particular focus on the occurrence of diarrhoea and gastro-intestinal complaints – diseases usually associated with unsafe drinking water.

In the second phase, each pupil was supplied with two 1.5-litre PET plastic bottles to treat their drinking water using the SODIS technology. Here, a randomized cluster, stepped-wedge design was used to introduce SODIS to the schools. The 14 schools were grouped into two clusters of four schools and one cluster of six schools. SODIS was then introduced on a cluster-by-cluster basis at different time periods corresponding to the start of successive school terms (Table 7.1). The first cluster of schools started SODIS in June 2011, the second cluster in September 2011, and the last cluster began using the technology in February 2012. Since SODIS had already been shown to have beneficial health outcomes (Conroy et al., 1996; Graf et al., 2010; Rose et al., 2006), this design was ethically appropriate, since all the participating pupils got a chance to treat their water using SODIS, thus minimizing the time during which cohorts were without intervention.

The clusters that were not yet practising SODIS acted as a control for those that were. In the last phase of the study, all pupils were practising SODIS, with baseline data acting as the control for this phase of the study. Specific data on attendance patterns, absenteeism, and water quality for the schools practising SODIS and those not practising continued to be monitored for the duration of the study period (January 2011 to May 2012).

Table 7.1 Summary of SODIS promotion via schoolchildren study design

Cluster	Term I (2011) (phase 1)	Term II (2011) (phase 2)	Term III (2011) (phase 3)	Term IV (2012) (phase 4)
1	Baseline data, no treatment	Treatment	Treatment	Treatment
2	Baseline data, no treatment	Control	Treatment	Treatment
3	Baseline data, no treatment	Control	Control	Treatment

During the third phase, an in-depth interview and/or questionnaire survey was conducted among selected caregivers of participating pupils to gauge the extent to which SODIS knowledge had been transferred to the general community and if the technology was being practised at household level. In total, caregivers from 175 households were interviewed.

Key findings

The key findings of this study are presented in three sections: first, the discussion of the general water situation and quality of water used by pupils and community in the study area; secondly, the highlights the effect of SODIS on water quality, disease, and hence health outcomes among participant pupils; and finally, the efficacy of pupils as community promoters of SODIS.

Water sources, treatment, and quality

Open water sources such as ponds and unprotected hand-dug open wells were the most frequently used water sources for schools and the community in the study area. Of the 14 primary schools that participated in this study, six used open dug wells or ponds, four used shallow wells, three used harvested rainwater, and one used a borehole. However, in schools that had rainwater-harvesting systems, this water was usually reserved for teachers, especially during dry spells when pupils had to resort to nearby open-dug wells for their water needs.

None of the schools had any drinking water treatment plan for pupils prior to our study, and pupils drank untreated water from whatever source the school used.

All of the 138 untreated water samples tested during this study were unfit for human consumption. All were contaminated with coliform bacteria, *Escherichia coli* and *Enterococcus faecalis*, the two indicator bacterial species used to gauge the microbial quality of water in this study; this included water from 'improved' sources, which are expected to provide clean and safe water. Open water sources showed the highest contamination levels for both indicator species, while borehole water had the least contamination, with harvested rain and shallow-well water falling in between (see Table 7.2). The microbial water quality from the various sources in this study was similar to that reported for other studies on rural water quality in northern Uganda (Opio, 2010, 2012; Parker et al., 2010). Generally, as water sources are increasingly separated from the human environment, contamination pathways are reduced and the microbial water quality improves (Parker et al., 2010). This would explain why sources which had some form of protection from human or animal activity had relatively low microbial contamination, while open sources had the highest microbial load and hence the poorest quality. Such open water sources are prone to contamination not only by human and animal faeces, but also by surrounding vegetation and debris in storm-water run-off, which can also be a source of bacterial contamination.

Table 7.2 Efficacy of SODIS: Mean bacterial contamination (CFU/100 ml) of samples from the various water sources

Water source	Raw water			SODIS-treated water		
	No. of samples	*E. coli* (SD)	*E. faecalis* (SD)	No. of samples	*E. coli* (SD)	*E. faecalis* (SD)
ODW	60	227.2 (104.3)	233.5 (101.6)	30	26.9 (32.8)	12.1 (13.5)
SW	34	112.3 (120.4)	24.9 (55.9)	17	7.8 (16.8)	0.1 (0.2)
BH	10	5.4 (8.3)	1.6 (2.2)	3	0.0	0.0
HRW	34	115.0 (71.5)	166.5 (131.7)	27	0.0	0.0

Note: ODW (open-dug well); SW (shallow well); BH (borehole); HRW (harvested rainwater) ; CFU (colony-forming units); SD (standard deviation)

Effect of SODIS on water quality

SODIS was effective in improving the microbial quality of drinking water, and during the course of this study, 77 water samples from a range of source types were treated using SODIS. The technology was associated with significant (95 per cent CI, $p < 0.001$) improvement in microbial quality of water with respect to the indicator organisms *E. coli* and *E. faecalis* (Table 7.2). The treatment was most effective for water collected from boreholes and harvested rainwater in tanks, where there was complete inactivation of indicator bacteria; the treatment was least effective in samples from open-dug wells. In open-dug wells, initial microbial load declined for both *E. coli* and *E. Faecalis*. While there was not complete bacterial inactivation in water samples from open wells, the mean microbial contamination was nevertheless significantly reduced to levels considered 'low risk' according to the WHO public health risk categories for drinking water (Parker et al., 2010; WHO, 2003b). The three different WHO categories used for comparison were conformity/low risk (0–10 CFU/100 ml), intermediate risk (11–100 CFU/100 ml), and high risk (101–1000 CFU/100 ml). In addition, it has been previously demonstrated that viable cells of *Salmonella typhimiurium* and *Cryptosporidium parvum* that have survived SODIS treatment are much less capable of inducing subsequent illness (McGuigan et al., 2012). This loss of infectivity in SODIS-treated pathogens may be one reason why SODIS is associated with significant reductions in waterborne disease even when only partial inactivation has occurred.

Effect of SODIS on pupils' school attendance patterns

Diarrhoea and gastro-intestinal complaints severe enough to prevent pupils attending school were the main outcomes used to assess the impact of SODIS on the health of the pupils and hence their school attendance patterns. These illnesses were chosen because they are commonly related to water quality. We hypothesized that improving the microbial quality of water using the SODIS treatment would have a positive effect on reducing the prevalence of these diseases among subject pupils and thus improve school attendance patterns.

To avoid bias from respondents (pupils), we also recorded other common causes of absenteeism such as malaria, lack of scholastic materials or fees, and work at home. The results revealed that general pupil absenteeism gradually reduced from the baseline through the subsequent SODIS treatment follow-ups. On average, general absenteeism fell from 4.2 days pre-intervention to 2.0 days post-intervention. Absenteeism due to diarrhoea and gastro-intestinal complaints dropped significantly from a baseline mean of 1.9 ± 2.2 days to 0.2 ± 0.6 days by the end of the study. Overall, absenteeism due to diarrhoea and gastro-intestinal complaints was also significantly lower (IRR 0.51, p = 0.012) in schools with a protected water supply. The significant drop in general absenteeism could not be solely attributed to the SODIS treatment, as other causes of absenteeism which were not expected to be affected by water quality – such as lack of scholastic materials and work at home – also declined. This study complements the evidence already available that solar disinfection can be used as a public health measure to improve microbial quality of water and therefore population health outcomes, most especially with respect to diarrhoeal diseases (McGuigan et al., 2012).

Community dissemination and general effect of SODIS

To assess pupils' effectiveness in transferring knowledge about SODIS to their homes and communities, we interviewed 175 primary caregivers (159 female and 16 male) of pupils who were participating in the school SODIS trial project. These were the key findings:

Open-dug wells were the main source of water for both drinking and other domestic purposes in the study area, with the majority (74 per cent) of respondents stating that they used such wells for their daily water needs. In addition, over 90 per cent of respondents reported taking more than a 30-minute round trip to the water source and home, with the majority fetching water at least two to three times a day.

Over 94 per cent of respondents stated that they heard about SODIS for the first time from their school-going children. When asked about their knowledge of SODIS, 54 per cent of the respondents were knowledgeable and could describe the SODIS process very well to the interviewer, 42 per cent had scanty knowledge, and 3 per cent could not describe the SODIS process, although they assured the interviewer that they had heard about it.

When asked about the workload involved in treating water using SODIS compared to other water treatment means, 65 per cent of respondents felt that their workload had reduced, 3 per cent felt that the time taken to look for bottles, clean them, and fill them with water for the SODIS treatment increased their workload, whereas the remainder (32 per cent) reported no noticeable difference in workload.

The majority of respondents (92 per cent) stated that they had noticed a general reduction in illness at home, especially among children who were drinking SODIS-treated water. In addition, 97 per cent of respondents reported reduced absenteeism for their school-going children. However, as with all self-reported responses, the effect of 'courtesy bias' should not be ignored.

Key recommendations

It is of concern to note that the most common water source for schools and households in the study area is the open-dug well. Therefore, better quality sources, in particular rain-harvesting systems, should be encouraged and promoted. Although shallow wells and deep boreholes would be an appropriate technology, they are expensive to construct and maintain and have low functionality rates, meaning they may not be sustainable systems in the long run. Rainwater-harvesting systems of about 10,000 m^3 are, however, relatively cheaper to construct, and since they are individually owned, repair can be quicker in the event of any breakdown. In addition, the water is less likely to become contaminated during transportation and storage, as the harvested water is usually stored close to the school or home, and consumers can use just the volume of water they need.

SODIS was effective in disinfecting water to make it safe for drinking, especially water from boreholes and rain tanks where the water has a low turbidity (less than 5 NTU). SODIS technology should therefore be promoted both at community and household level to improve access to safe water, and thus improve people's health.

Household water treatment technologies including SODIS can lower health costs and increase productivity, and may also reduce school absenteeism (Hutton et al., 2007), thus improving pupils' academic performance. This is especially true for girls, who more often than not must assume the responsibility of caring for ill family members (UNICEF, 2008). This survey found that SODIS was viewed as having a positive impact on the community in terms of fewer episodes of family illness, reduced workload, and reduced pupil absenteeism from schools.

In comparison to boiling water, which was the most popular household water treatment in the community prior to this study, SODIS has many advantages: there is no cost or time needed to procure fuel for boiling water, and no indoor air pollution from smoke, with the associated respiratory infections. The technology should therefore be promoted as an alternative water treatment to boiling water.

Conclusions

Previous SODIS studies, such as those described by McGuigan et al. (2012), have introduced the treatment at household level. In this study we chose instead to use primary schools and the students themselves as the instruments of change. Several factors limited the success of the study; in particular, we underestimated the level of mobility of teachers within Uganda's primary education system. As a result, some data were lost when teachers transferred to other schools, taking their data and training with them. In addition, we paid small stipends to the teachers at the start of each term, but if we were to repeat the study elsewhere, these payments would be scheduled differently to guarantee maximum compliance for the duration of the project. Nevertheless, our experience with this school-based intervention model has been profoundly positive and sufficiently encouraging to lead us to believe that only minor adjustments to the study method will yield even more significant results than those reported here.

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CHAPTER 8

Solar water disinfection (SODIS) as a suitable treatment technology for harvested rainwater in rural Uganda

Rosemary Nalwanga, Charles Muyanja, Kevin G. McGuigan, and Bríd Quilty

Abstract

Harvested rainwater (HRW) is an effective method for dealing with water scarcity. Water is collected from roofs and provided close to the household, thus reducing the need for people to walk long distances to collect it. The practice of HRW is promoted and encouraged throughout Uganda, especially in rural areas where centralized distributed water systems are rare. However, despite government efforts to promote the technology, little attention has been given to the quality of HRW. This chapter describes a study carried out in a rural community near Masaka in southern Uganda. Households using HRW were identified and the quality of HRW was investigated. In the majority of cases the water was found to be unsafe for human consumption. Solar disinfection (SODIS) is a water treatment technique whereby available water is stored in transparent containers that are exposed to strong sunlight for at least six hours. SODIS was shown to be an effective and sustainable method for treating HRW. The community responded enthusiastically to training provided in aspects of sanitation, hygiene, and the use of SODIS.

Keywords: solar disinfection, harvested rainwater, water quality

Introduction

Uganda, which lies on the equator, has a moderately humid, equatorial climate characterized by prolonged periods of dry, sunny conditions throughout the year. The country has a bimodal rainfall pattern, with two rainy seasons and two dry seasons each year. The two rainy seasons are March to May and October to December. The wettest areas of Uganda are along the western shores of Lake Victoria and the most arid areas are in the northern regions of the country (NEMA, 2010). Two-thirds of Uganda receives rainfall in excess of 1,200 mm per year (UBOS, 2010). However, during the rainy seasons, 70–85 per cent of rainfall is reported to be lost due to soil evaporation, deep percolation, and surface run-off into streams, rivers, and lakes (Falkenmark

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et al., 2001). In such situations, rainwater harvesting is a viable option to ensure water supply during long spells of drought (Helmreich and Horn, 2009). In this chapter, a study on the use of harvested rainwater (HRW) in a rural area near Masaka in southern Uganda is described. The quality of the HRW in this area had never previously been investigated and the findings are reported together with findings on the use of solar disinfection (SODIS) as a suitable treatment technology for the water.

Harvesting rainwater in rural Uganda

A number of studies have highlighted the significant economic, social, and environmental benefits of HRW as an alternative water source in rural areas (Hatibu et al., 2006; Sturm et al., 2009). Many rural areas lack traditional centralized water supply systems because they have sparsely distributed populations and because installing such systems in these areas is very expensive (Amin and Han, 2009; Helmreich and Horn, 2009; Lee et al., 2010). HRW is collected from roofs and provides water directly to the household, thus reducing the need to walk long distances to collect water (Mwenge-Kahinda et al., 2008). Finding solutions to water-related problems is an accelerator to economic growth and poverty reduction in developing countries (McGarvey et al., 2008). Thus, practising HRW has the potential to provide a solution to the issue of water scarcity in the developing world (Amin and Han, 2009; Hatibu et al., 2006; Helmreich and Horn, 2009).

Lye (2009) described rainwater collection systems as those using surface/ground catchment areas and those using above-ground rooftop catchment areas. In Uganda, rainwater is harvested from a number of surfaces, including house roofs made from galvanized iron sheets, asbestos sheets, tiles, thatching (grass), and tree fronds; it is also harvested from courtyards, threshing areas, paved walking areas, plastic sheeting, and large rock surfaces.

The total storage volume (size) of a tank for a household is recommended as the volume of water required by a household per day multiplied by the number of days in the longest dry season (Parker et al., 2013). In Uganda, this recommendation is rarely followed due to lack of sufficient funds to buy a tank of the required volume. Many people in Uganda use tanks of different volumes, ranging from 20 l jerrycans to tanks with capacities of up to several thousand litres. The size of tank used is determined either by custom (what is being used by other households in the area) or by the relative costs of different sizes of tanks and what a particular household can afford to spend (Parker et al., 2013). The collection/storage vessels may include 5 l or 20 l jerrycans; 50 l and 100 l injection moulded or plastic drums; 200 l steel drums; 420 l to 1,500 l cement jars; 220 l to 15,000 l plastic tanks (Aquatank and Polytank); 3,000 l above-ground plastic-lined tanks; below-ground plastic-lined tanks (10,000 l and over); ferrocement concrete tanks (4,000–10,000 l); partially below-ground cement concrete-lined cisterns (6,000–10,000 l); and brick tanks (10,000 l) (Danert and Motts, 2009) (see Figure 8.1).

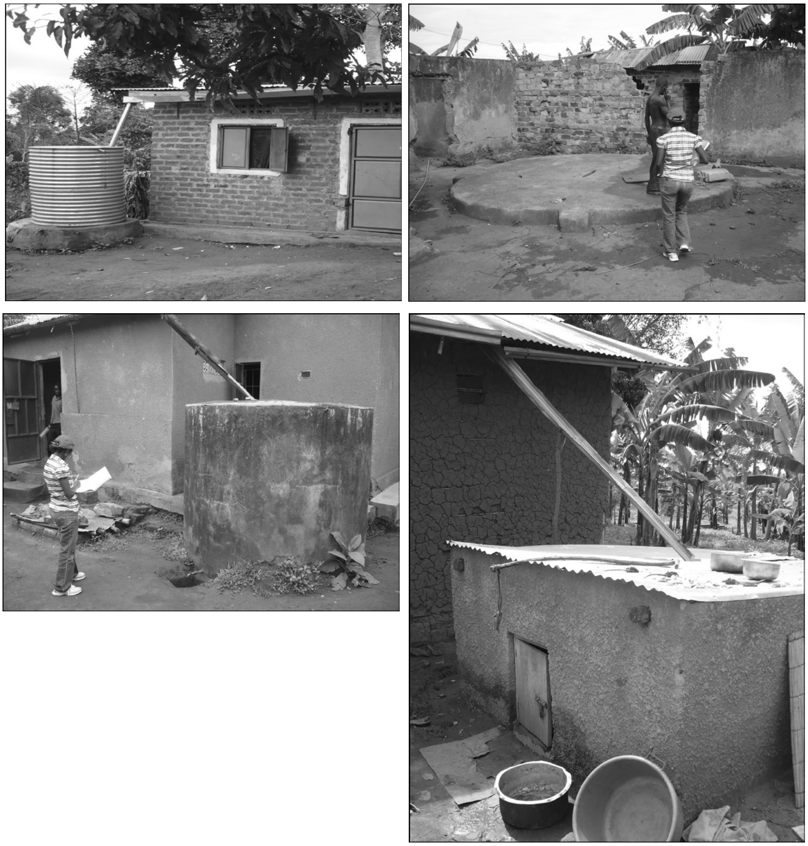

Figure 8.1 A selection of HRW systems from the study area. Clockwise from top left: a 3,000 l galvanized metal tank; a subterranean ferroconcrete cistern (capacity unknown); a home-constructed catchment tank (capacity unknown); a 5,000 l ferroconcrete tank

Treatment of HRW

Several studies have recommended treatment of HRW before consumption (Amin and Han, 2009; Helmreich and Horn, 2009; Levesque et al., 2008). Such treatment should be affordable and applicable to local communities in order to be sustainable (Helmreich and Horn, 2009). These studies also recommended that the treatment technologies should be sustainable (in terms of energy required), inexpensive, and appropriate for removing microbial hazards and parasites.

In Uganda, many household water treatment methods are used, such as sand filtration, boiling, and chlorination. However, some of these treatment methods – chlorination, for example – are expensive and therefore not readily available to rural communities in Uganda. Despite the fact that a single chlorine tablet capable of treating 20 litres of water costs just UGX 500 Ugandan shillings (US$ 0.2), many rural households cannot afford them.

In addition, chlorine use is often rejected by rural communities due to the smell and taste of treated water. Chlorine efficacy is also limited by its reaction with suspended organic matter that settles to the bottom of the tanks and forms undesired by-products (Gordon et al., 1995). Some parasitic species have also shown resistance to low doses of chlorine and this further limits its use as a disinfection treatment for HRW (Helmreich and Horn, 2009). Slow sand filtration is another inexpensive method of improving the bacterial quality of water used by households (Jenkins et al., 2011; Palmateer et al., 1999; Thomas et al., 2004). The use of sand filters is still limited because they require frequent maintenance (Helmreich and Horn, 2009). Researchers have developed ceramic filtration technologies for treating HRW with the ability to filter out viruses and bacteria (Mohr, 2006; Sobsey et al., 2008), but this is expensive; it is therefore unsuitable for household treatment and is more suitable for central treatment of collected rainwater (Sobsey et al., 2008).

Many households boil water to treat it. Boiling requires an investment of time in order to collect firewood, or money to purchase fuel, usually in the form of charcoal (in the case of sub-Saharan Africa). While boiling is an effective method of water treatment, it has significant impact on the environment, including deforestation and CO_2 emissions associated with charcoal production and use.

For all of these reasons, therefore, people continue to consume untreated water, which exposes them to a wide variety of waterborne diseases, such as cholera, dysentery, and typhoid (Baguma et al., 2010). In Uganda, the consumption of microbiologically contaminated drinking water is still among the major causes of diarrhoeal diseases, which are particularly dangerous to children under 5 years of age.

SODIS is known as an inexpensive and accessible treatment technology (McGuigan et al., 2012) that uses solar energy to disinfect disease-causing pathogens. The technology is not new. Baker (1981) reported descriptions of communities in the Indian subcontinent that placed drinking water outdoor in open trays to be 'blessed' by the sun hundreds of years ago. Rigorous investigations were first completed on the bactericidal effect of sunlight in 1877 by Downes and Blunt; however, the first reports of using sunlight to disinfect contaminated water for use in oral rehydration solutions were published by Acra and co-workers in the University of Beirut (Acra et al., 1980, 1989). The treatment was termed SODIS almost three decades ago (Acra et al., 1984) and since then extensive research has been carried out to investigate its potential to inactivate a wide range of waterborne pathogens (Conroy et al., 1996; Joyce et al., 1992; McGuigan et al., 1998; Reed, 1997; Sommer et al., 1997; Wegelin et al., 1994).

The use of HRW by the community in the rural study area

The 25 km^2 study area consisted of 15 rural villages located approximately 40 km south-west of the town of Masaka in southern Uganda. Thirty households in the study area participated in the investigation of their HRW systems. Households were selected following visits to the community and discussions with local leaders and facilitators. All the households had HRW tanks (Figure 8.2). The cost involved in installing the HRW tanks varied widely. In the case of 23 per cent of the households, the tanks had been donated by the local NGO, the Medical Missionaries of Mary. The cost of 47 per cent of the tanks varied from UGX 300,000 ($110) to UGX 700,000 ($250) and the cost of the remaining tanks was reported to have exceeded this figure.

In all the households surveyed, the primary use of HRW was drinking; other activities that involved the use of HRW were washing clothes (70 per cent), while the remainder (30 per cent) was utilized for watering animals. It was pointed out that HRW was used for watering animals only

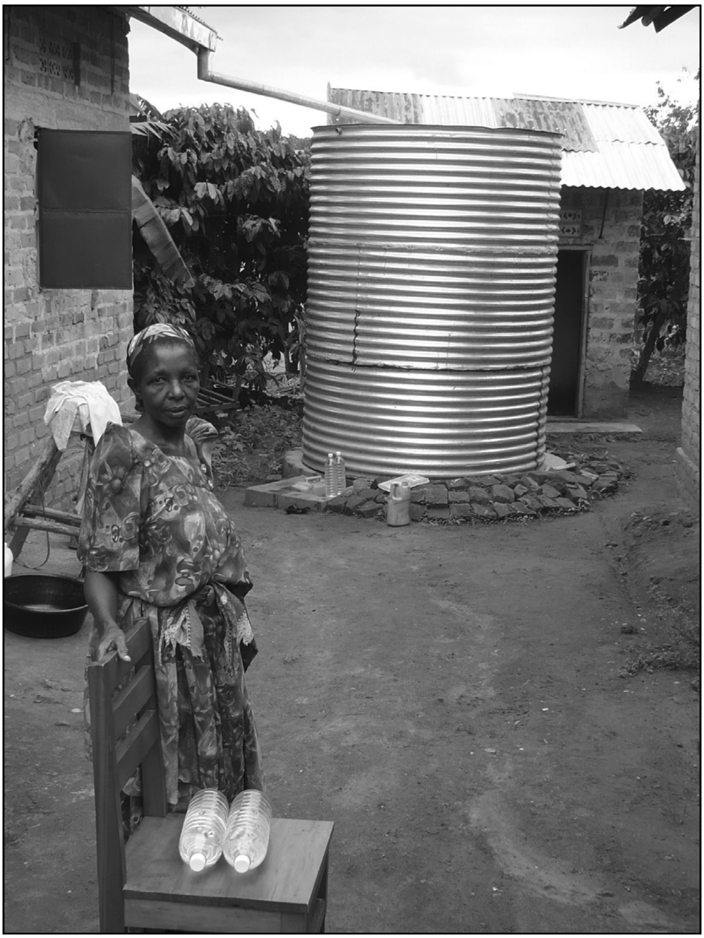

Figure 8.2 A participant in the study uses solar disinfection to treat HRW collected from her 5,000 l metal tank

during periods when households had excess water, such as in the middle of the rainy season.

The majority (63 per cent) of household members experienced illness once a month, and the most common diseases reported were gastro-intestinal disturbances (60 per cent), followed by fever (40 per cent). Other illnesses that are waterborne, for example, cholera, dysentery, or diarrhoea, were not reported by any of the survey respondents. Out of the 30 households, 16 (53 per cent) felt that the water they were using was not safe to drink. Only five households (17 per cent) felt they were using safe drinking water, and nine (30 per cent) reported that they did not know whether or not the water they were using was safe.

Only 10 of the surveyed households treated HRW before drinking it; eight of these reported boiling the water and two reported using chlorine tablets. While one household had heard of SODIS, no household reported ever using SODIS prior to the start of the study. When invited, the community readily engaged in training and information sessions on SODIS. Meetings were scheduled at convenient times for the community and took place in locations that were within walking distance for the majority of households. The training sessions involved discussions on sanitation and hygiene, together with a demonstration of the SODIS method involving the use of a PET bottle to expose the water to the sun. While PET bottles were distributed for the study, the majority (53 per cent) of participants indicated the availability of PET bottles and 30 per cent were willing to buy PET bottles.

Case study

The types of HRW system used by each household varied, and included metallic, plastic, and concrete tanks as well as some catchment ponds. The case study area comprised a single parish and the HRW systems were dispersed throughout this area. The study was designed to cover both wet and dry months in order to get an overview of seasonal changes. It was carried out in 2011 during April and May, which were wet months, and June and July, which were dry months. The amount of rainfall recorded during these four months is detailed in Table 8.1.

The daily amount of rainfall ranged between 0 mm and 26 mm during April and May 2011; the total monthly rainfall was 143.1 mm and 83.9 mm for April 2011 and May 2011, respectively. April marked the beginning of the first rainy season of the year following the dry season (January to March). The daily amount of rainfall ranged between 0 mm and 0.2 mm during June 2011, and 0 mm and 17.8 mm during July 2011. Despite the fact that June and July 2011 were generally dry months, the total monthly rainfall was 0.7 mm and 27.8 mm for June and July, respectively. June marked the beginning of the second dry season of the year.

Table 8.1 Rainfall data for the study area, April to July 2011

Month	Average daily rainfall (mm)	Monthly total rainfall (mm)	Daily range (mm)
April	5.01 ± 32.1	143.1	0–23
May	2.72 ± 6.2	83.9	0–26.4
June	0.02 ± 0.1	0.7	0–0.2
July	0.9 ± 3.3	27.8	0–17.8

± denotes plus or minus standard deviation
Source: Kagwisagye (personal communication, 2013)

Quality of HRW during the wet season

The physico-chemical parameters of the tested HRW were dissolved oxygen level, temperature, pH, and total dissolved solids (TDS), as shown in Table 8.2. Water quality analysis was carried out on whatever water was used in the households in addition to HRW. Analysis was also carried out on boreholes and wells and other sources of water used after all HRW was exhausted in the dry season. During the first two months (April and May), all samples were HRW samples because April and May were rainy season months. In June and July, samples of boreholes and wells were also analysed.

Based on the findings of the physico-chemical analyses (pH and TDS), the majority of the HRW systems contained safe drinking water as recommended by the WHO (2011). These findings are similar to those reported by Uba and Aghogho (2000) and Adeniyi and Olabanji (2005), where the majority of HRW systems in south-west Nigeria met the recommended physico-chemical standards of potable water according to WHO drinking water guidelines.

Although the pH of the HRW systems in the current study ranged from 5.3 to 8.5, for the majority of the systems it was generally close to neutral, with an average of 7.3 ± 0.8 and 6.9 ± 1.3 in April and May, respectively. The pH values recorded were in line with Lee et al.'s (2012) study, which investigated the quality of HRW collected from roofs of different roofing materials and had pH values of neutral or near-neutral, ranging from 6.0 to 7.9. Their study recorded pH variations in HRW as a result of different roofing (collection catchment) types; however, this was not a significant factor in our study, since 92 per cent of the collecting roofs surveyed were constructed from galvanized iron sheets.

All samples tested were safe for drinking water, which meant the TDS levels were all below 600 mg/l, the levels recommended by the WHO (2011) and the Uganda National Bureau of Standards (UNBS, 2009) for safe drinking water. These findings are in agreement with those of Lee et al. (2010), where the TDS values of HRW from rooftops ranged from 40 to 230 mg/l and were again within the recommended WHO safe drinking water guidelines. However, Lee et al. (2010) reported that the rainwater collected in reservoirs had 280 to 1,200 mg/l TDS, which was far above the recommended safe drinking water guidelines for TDS of ≤600 mg/l.

Table 8.2 Physico-chemical parameters of HRW for April and May 2011

Parameter	Minimum		Maximum		Mean		Median	
	April	May	April	May	April	May	April	May
Temp (°C)	20.9	19.5	27.8	28.2	23.5 ± 2.1	22.5 ± 18	22.6	21.9
DO (mg/l)	2.4	2.4	6.1	7.6	3.9 ± 0.9	4.6 ± 1.1	3.9	4.5
pH	5.3	3.6	7.9	8.5	7.3 ± 0.8	6.9 ± 1.3	7.3	7.1
TDS (ppm)	5	6	43	46	12.5 ± 9.3	12.9 ± 8.8	9	10.0

Note: Temp (temperature); DO (dissolved oxygen); TDS (total dissolved solids). ± denotes plus or minus standard deviation

Table 8.3 Microbial parameters of the HRW during April and May 2011

Parameter	Minimum		Maximum		No. of non-potable systems	
	April	May	April	May	April	May
HPC (CFU/ml)	160	160	>10^4	>10^4	–	–
TTC (CFU/100ml)	0	1	>400	>400	–	–
E. coli (CFU/100ml)	0	0	>400	>400	22 (73%)	23 (71.9%)
Faecal enterococci (CFU/100ml)	0	1	>400	>400	27 (90%)	32 (100%)

Note: HPC (heterotrophic plate count); TTC (thermotolerant coliforms); CFU (colony-forming units). In May, 32 HRW systems were sampled because two of the households studied had two HRW systems of different designs, and the users wanted to know the microbial quality of both.

Microbial quality

The microbiological examination of the collected HRW included investigations of heterotrophic plate count (HPC), thermotolerant coliforms (TTC) *Escherichia coli* (*E. coli*) and faecal enterococci.

The minimum number of organisms detected was 160 colony-forming units per ml for the total bacterial count. In the case of TTCs none was detected in some systems, indicating that these had potable water. However, in the majority of systems a high number of organisms, >400 CFU/ml, was detected across all categories tested. The presence of *E. coli* and faecal enterococci indicated that the water was non-potable and, depending on the indicator organism used, this ranged from 72 per cent to 100 per cent of the HRW systems (see Table 8.3).

Quality of HRW during the dry season and the use of SODIS

During the dry season, some of the households did not have HRW and therefore used alternative water sources such as boreholes and open-dug wells. In such cases this water was analysed. The values for temperature, dissolved oxygen, pH, and TDS for all the systems are tabulated in Table 8.4. The values for the HRW were similar to those for April and May.

Table 8.4 Physico-chemical parameters of the HRW and water from other sources during June and July 2011

	Temp. (°C)		pH		TDS (mg/l)	
	June	July	June	July	June	July
Harvested rainwater						
Min	20	23	4.8	4.2	0	8
Max	28.9	29	7.3	7.4	85	129
Mean	24.9 ± 2.4	26.2 ± 1.6	6.0 ± 0.1	6.6 ± 0.7	26.2 ± 26.1	25.5 ± 25.1
Median	25.4	26.7	5.8	6.7	13	17.5
Other sources (boreholes and wells)						
Min	27.8	27	5.3	4.4	42	48
Max	29.3	29.3	6.4	7.5	193	87
Mean	28.7 ± 0.7	27.9 ± 0.9	5.7 ± 0.5	5.9 ± 1.3	99.3 ± 65.4	65.6 ± 16.6
Median	28.75	27.7	5.55	6.3	81	68

Note: Temp (temperature); TDS (total dissolved solids). ± denotes plus or minus standard deviation

The temperature ranged from 20°C to 29°C. The temperature of other sources of water (boreholes and wells) ranged from 27.8°C to 29.3°C, which did not significantly differ from that of HRW ($p = 0.08$). This could be explained by the fact that the samples of water from the boreholes and wells examined were taken from the containers of the respective households rather than the actual sources. The majority of these containers were 20-litre jerrycans (plastic containers), which had been exposed to sunshine after collection.

Microbial quality of untreated and treated HRW during the dry season

The pH of HRW measured in June and July ranged from 4.2 to 7.4, which is within the WHO guidelines (WHO, 2011). The pH of the majority of other sources of water was comparable to that of HRW, with an average value of 5.9 ± 1.3. TDS values of other water sources and HRW were also generally in the same ranges, although the minimum TDS (48 mg/l) in other sources was generally higher than that of HRW (8 mg/l). It is worth noting that the results of HRW and those of other sources cannot be compared properly, since the sample size of other sources ($n = 9$) was very small compared to 47 samples of HRW.

Of the 47 systems sampled in June and July 2011, 32 (68 per cent) consistently had contaminated water that was unsafe for drinking (Tables 8.5 and 8.6). Given the levels of microbiological contamination detected in the HRW during April and May, the use of SODIS to treat the water was investigated. The water's response was monitored by determining the presence of *E. coli* and faecal enterococci before and after treatment. The absence of these indicator bacteria from 100 ml of water would indicate that the water was potable.

As in the first two (rainy) months of sampling, the majority of the samples in the following two (dry) months were contaminated, with levels of microbial indicators above those recommended by WHO (2011) and UNBS (2009). However, the levels of indicator organisms were slightly lower than in the first two (rainy) months, which showed a slight indication of the possible variations in the microbial quality of HRW.

Since the majority of the HRW samples in the first two months of the study were unsafe for drinking, SODIS was introduced into the case study area as a technologically appropriate and sustainable low-cost treatment. Following SODIS treatment, the water samples showed significantly ($p < 0.05$) lower levels of contamination for both *E. coli* and faecal enterococci (Tables 8.5 and 8.6). Moreover, the HRW and the water from other sources responded well to SODIS treatment, with treatment efficiencies of 65–81 per cent recorded. During the first month of SODIS trials, samples of HRW from the study area were also treated on the roof of the School of Food Sciences in Makerere University in Kampala, in order to compare them with the samples treated by the local households. The samples of HRW treated on the Makerere University roof showed higher treatment efficiency than the samples treated by households.

The findings demonstrated that if SODIS is carried out following the correct procedures, treatment efficiencies of up to 100 per cent can be achieved.

The other sources of water sampled also showed generally high treatment efficiencies. Both the samples treated by local households and the samples treated on the university roof were comparable to the HRW samples. The SODIS treatment efficiencies for HRW and other sources of water (boreholes and wells) were not compared, due to the small sample size of water sources from boreholes and wells. In carrying out microbiological examination of the water, a number of tests were used. Initially, the water was tested using the HPC, TTCs, *Escherichia coli* (*E. coli*), and faecal enterococci. The majority of the HRW samples were not safe to drink and required treatment. During the dry season, HPC and TTC were omitted to reduce costs; testing for *E. coli* and faecal enterococci was thought to be more than adequate. *E. coli* has been shown to account for 70–80 per cent of all TTCs (Garcia-Armisen et al., 2007; Hachich et al., 2012; Rasmussen and Ziegler, 2003). Furthermore, many studies have recommended *E. coli* as a better indicator organism for faecal contamination in fresh waters than TTCs (APHA, 2005; US EPA, 2004; WHO, 2008). In addition, organisms such as those detected using the HPC are mainly environmental (WHO, 2008) and are less sensitive for detecting faecal contamination as opposed to detecting *E. coli* and faecal enterococci. Therefore, the presence of HPC would have fewer implications for the microbial safety of HRW.

As faecal enterococci survive longer in the environment (Ahmed et al., 2013; WHO, 2008, 2011) than *E. coli*, it was considered suitable for detecting less recent contamination. However, as *E. coli* is more resistant to solar radiation (Ahmed et al., 2013; Wegelin et al., 1994), it was considered most suitable for testing the safety of HRW for drinking after SODIS treatment. For these reasons, all water samples, both raw and treated, were tested for both *E. coli* and faecal enterococci.

Table 8.5 Microbial parameters of HRW and water from other sources before and after SODIS treatment by local households and at Makerere University during June 2011 (dry month)

Microbial parameter	n	Range CFU/100 ml	No. potable (%)	n	Range CFU/100ml	No. potable (%)	n	Range CFU/100ml	No. potable (%)
	Untreated			Treated in situ (field conditions)			Treated at Makerere University (laboratory conditions)		
Harvested rainwater: n=21									
E. coli	21	0–75	8 (38%)	21	0–29	16 (76%)	20	0–1	19 (95%)
Faecal enterococci	21	0–154	5 (25%)	21	0–14	17 (81%)	20	0–0	20 (100%)
Other sources of water (boreholes and open-dug wells): n=4									
E. coli	4	0–35	1 (25%)	4	0–6	3 (75%)	4	0–0	4 (100%)
Faecal enterococci	4	0–2	2 (50%)	4	0–1	3 (75%)	4	0–0	4 (100%)

Table 8.6 Microbial parameters of HRW and water from other sources before and after SODIS treatment by local households during July 2011 (dry month)

Microbial parameter	Range CFU/100 ml	No. non-potable (%)	No. potable (%)	Range CFU/100 ml	No. non-potable (%)	No. potable (%)
	Untreated			Treated		
Harvested rainwater: n = 26						
E. coli	0–>400	16 (61%)	10 (39%)	0–>400	9 (34.6%)	17 (65%)
Faecal enterococci	0–>400	18 (69.2%)	8 (31%)	0–36	5 (19.2%)	21 (81%)
Other sources of water (boreholes and open-dugwells): n=5						
E. coli	2–>400	5 (100%)	0 (0%)	1–>400	5 (100%)	0 (0%)
Faecal enterococci	0–69	4 (80%)	1 (20%)	0–53	2 (40%)	3 (60%)

Key findings and recommendations

The community valued being able to harvest rainwater. Of the 30 households studied, 30 per cent reported saving rainwater for between two and three hours a day, while others reported doing so for more than three hours a day during periods when they needed HRW for domestic activities. The majority (77 per cent) used the time they did not have to invest in collecting water from alternative sources in the locality for farming, while others reported using the time saved for engaging in leisure activities. All households agreed that harvesting rainwater was a good mitigation practice against water scarcity in an era of climate change.

While the physico-chemical characteristics of the HRW complied with Ugandan government and WHO guidelines for safe drinking water, more than 70 per cent of the water samples tested showed bacterial contamination, indicating that untreated water from these tanks was not safe for human consumption.

The rainwater-harvesting community within the study area engaged enthusiastically with the study. They were anxious to know about the quality of their drinking water and were eager to learn about and use SODIS, which was shown to be an effective treatment method for HRW. When used properly, SODIS is an effective method for treating HRW. The following are recommendations for carrying out solar disinfection and further training on water sanitation:

- When using SODIS, 2-litre bottles should be exposed for a minimum of seven hours. However, when conditions are cloudy, bottles should be exposed for two complete days to ensure total disinfection.
- The use of SODIS at household level was not as successful as when SODIS was carried out at the laboratory, suggesting the need for further training on the effective use of SODIS.
- To minimize cost as well as ensure optimal treatment of water, PET bottles should be provided to households in order to encourage the use of SODIS.
- Up to one-third of the community had never been consulted about the safety of their drinking water. Greater efforts should be made to increase awareness of the dangers of contaminated water and how to avoid contaminated water through training in sanitation and hygiene.

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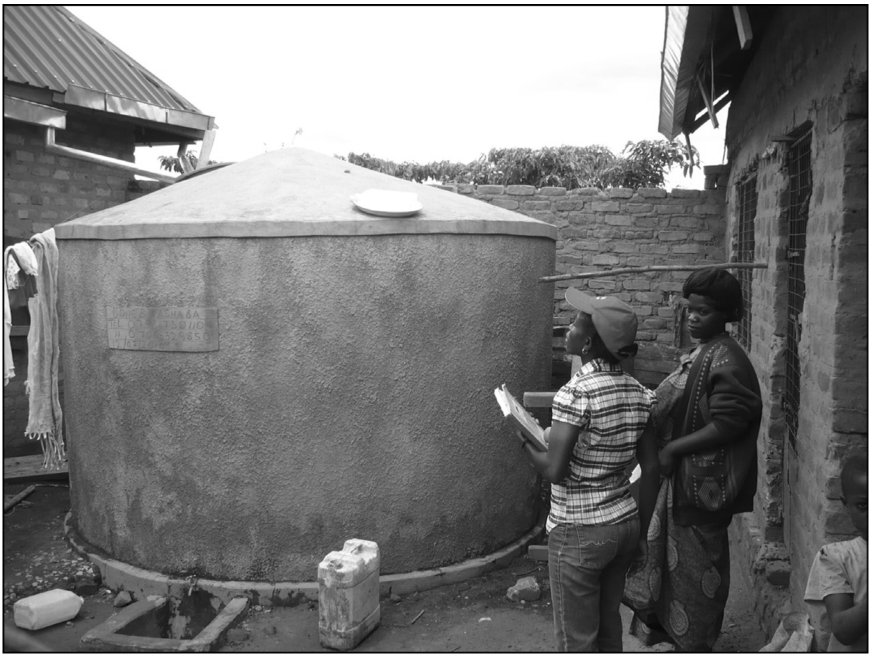

Figure 8.3 A project researcher and householder examine bottles of HRW being treated by solar disinfection. The bottles are exposed on top of a ferroconcrete HRW tank

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CHAPTER 9

Improving reliability and functional sustainability of groundwater handpumps by coating the rubber piston seals with diamond-like carbon

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Abstract

In many rural communities, handpumps are essential in order to provide access to safe drinking water from groundwater sources. The functional sustainability of handpumps is poor, however, and most maintenance issues in handpumps are caused by wear of the nitrile rubber piston seals. This study identified handpump problems faced by a rural community in southern Uganda, specifically related to wear of piston seals. We investigated a novel surface-engineering approach to improve the wear resistance of piston seals by depositing diamond-like carbon (DLC), and silicon (Si) doped DLC onto the seals. Wear mechanisms for the coated seals were determined using a piston seal wear test rig. Tests were undertaken with clean normal water, and water seeded with sand particles. Wear mechanisms identified included adhesion, abrasion, and fatigue. For the DLC and Si-DLC coated piston seals the dominant wear mechanism was abrasion, with minimal fatigue wear. Adhesive wear on the coated piston seals is explained by the generation and transfer of a tribo-layer, which increases wear resistance and functional sustainability of the piston seal. Wear-resistant seals could significantly reduce the maintenance costs of existing handpump designs, and improve their functional sustainability.

Keywords: functional sustainability, handpumps, nitrile rubber, piston seals, wear mechanisms

Introduction

According to the WHO standards, improved water supplies from groundwater and protected springs are safe drinking water sources. Safely managed drinking water services reliably deliver water that is sufficient to meet domestic needs and does not represent a sufficient risk to health (WHO and UNICEF 2014). Quantitative maps of groundwater resources in Africa indicate that groundwater is the largest and most widely distributed store of fresh water on

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the continent (Vorosmarty et al., 2010). The most common and cost-effective means of accessing and delivering groundwater for rural water supply is by using handpumps (Arlosoroff et al., 1987). In India alone, 1.3 million India Mark II handpumps were serving 360 million people by 1989.

The India Mark II design was developed in the 1970s, predating the concept of village-level operation and maintenance (VLOM). It relied heavily on centralized maintenance. The India Mark III is a VLOM derivative of the Mark II. Repairs to Mark III pumps took a third of the time needed to carry out similar repairs on below-ground components in Mark II pumps. As a result, VLOM principles became an increasing priority for handpump design, manufacture, and selection (Arlosoroff et al., 1987; Reynolds, 1992; UNDP and World Bank, 1984). While VLOM was successfully applied in India, its transfer to sub-Saharan Africa was less successful, due to social, cultural, and hydrogeological differences (Esposto, 2009). Establishing supply chains for standardized spare parts was problematic in sub-Saharan Africa, as various handpump designs were introduced haphazardly by different NGOs (Harvey, 2003). Furthermore, by the end of the International Decade of Water Supply and Sanitation (IDWSSD) in 1990 there was a shift towards 'software' issues, which eclipsed handpump hardware or design issues, irrespective of the fact that pertinent design issues regarding handpumps remained (Black, 1998). These reasons explain, in part, why handpumps frequently performed inadequately and/or broke down shortly after installation.

A rethink of handpumps in Africa is required in order to ensure their functional sustainability. Sustainability refers to long-term duration without external support for the project, implemented with a clear understanding that support for development should bring with it autonomy for the beneficiaries (Esposto, 2009). In Uganda, rural water services continue to face challenges in sustainability of supply. The increasing failure rate of rural water services led to the inception of the Triple-S (Sustainable rural water Services at Scale) project from 2009 to 2014, which mainly focused on service delivery rather than on the functionality of the rural water supply technologies (IRC, 2014).

The functional sustainability of handpump technology can be defined as the availability and reliable operation of a handpump over a long period without any maintenance interventions. Previous definitions of sustainability with regard to handpumps in developing countries have focused more on the VLOM concept. This approach failed, however, because handpump technology still has pertinent design issues with piston seals, rising mains, foot valves, and bearings (Reynolds, 1992). Few attempts have been made to improve the problematic components of reciprocating handpumps, to understand common failure modes, or to systematically refine common designs to improve their performance.

Efforts continue to focus on rigidly attempting to satisfy the VLOM principle. This has encouraged the design and production of new handpumps, with each new design claiming to satisfy VLOM principles more precisely than previous designs. This has resulted in a saturated handpump market with numerous handpump designs and little standardization. This leads to supply chain issues when maintenance, either preventive or breakdown, is required. Therefore, without timely maintenance, handpump functional sustainability is low in the medium term (Harvey, 2003; Reynolds, 1992). The unreliability of handpumps is a common reason given by users in rural African communities for not paying access fees to use handpumps, along with the fact that most people view water as a free natural resource (Gleitsmann et al., 2007). Thus, any endeavour that seeks to maximize the availability of handpumps must promote handpump reliability.

By the end of the IDWSSD it was reported that 75 per cent of repair and maintenance interventions on handpumps were caused by below-ground components. Failure of piston seals was the biggest cause of handpump breakdowns, at about 24 per cent (UNDP and World Bank, 1984). Following the modification of the India Mark II to a more VLOM-compatible India Mark III design, and after extensive testing during IDWSSD, acrylonitrile butadiene or nitrile rubber has been the material of choice for piston seals (Arlosoroff et al., 1987; Aspegren et al., 1987; Reynolds, 1992). The main reason for choosing nitrile rubber is its low cost; this is important because the piston seal is a high-wearing component responsible for most handpump failures (Yau, 1985).

The piston seals endure frequent reciprocating motion during operation, and constant adhesion and abrasion with the metal cylinder wall that encloses it result in high rates of wear. Entrapment of solid particles within the pumping element enhances the abrasive wear. In order to maintain normal handpump performance, it is recommended that nitrile rubber piston seals be replaced at least every two and a half years, and more frequently if the water flow reduces from the handpump (Reynolds, 1992). For a multitude of reasons, many of which are non-technical, these replacements usually do not take place.

Piston seals are responsible for maintaining pressure levels during both the upstroke and downstroke operation of the piston assembly in the handpump. They directly affect the water output at the spout. A worn piston seal presents real problems for handpump users, and leads to increased leakage rates and lower water flow rates at the spout. This may mean users perceive handpumps as unreliable (Gleitsmann et al., 2007). The time it takes to acquire replacements and personnel to carry out the replacements (Harvey, 2003) means that people in rural communities are often unable to access the groundwater that is their only source of safe water. As a result, handpump users in these rural communities seek alternative water sources. Frequently, women and children must walk several kilometres to working handpumps in other villages, increasing the demand and use on these handpumps and thus accelerating the wear on their seals. Moreover, longer queues at handpumps mean many users resort to unsafe water sources such as open wells, where health implications including diarrhoea and worm infestation are well documented (WHO and UNICEF, 2014).

Piston seals fail due to wear of the seal (Arlosoroff et al., 1987; Reynolds, 1992; Yau, 1985). To achieve functional sustainability of handpumps we took a novel, surface-engineering approach to solving the wear problem of nitrile rubber piston seals, which is responsible for most maintenance interventions.

Our approach seeks to enhance the wear resistance of the seals without re-engineering the basic handpump structure. In our approach, diamond-like carbon (DLC), and silicon (Si) doped DLC films were deposited onto nitrile rubber piston seals; the piston seal is expected to perform under both dry and wet sliding conditions. Our approach has two main advantages: first, it would not affect the established front-end processes involved in handpump manufacturing; and second, it would use the same supply chain, maintenance system, and personnel that are in place for ordinary seals.

Methodology

A mixed-methods approach was used in this study, with both qualitative and quantitative methods. The methodology used in the field had to be flexible and ethically driven, with minimal intrusion to the daily schedule of the participants. Field visits were made to the study area to survey handpump users and mechanics. A first-level surface analysis was used to determine wear mechanisms of nitrile rubber piston seals. DLC and Si-DLC films were deposited onto nitrile rubber piston seals, and the coated piston seals were tested in a wear piston test rig.

Field visit to the study area

The 25 km^2 study area consisted of 15 rural villages located approximately 40 km south-west of the town of Masaka in southern Uganda. A 40-day field visit to the study area was undertaken to quantify both field and user-operating conditions relating directly and indirectly to piston seal failure. This field visit grounded the handpump as a developmental technology into a specific rural community. The objectives were to determine the availability of handpumps in the study area, as measured by the number of functional and non-functional handpumps there at a given time; identify the handpump component that is most often replaced; and conduct structured interviews and group discussions with women and children, who are acknowledged in the literature as the main bearers of the water-collecting burden. Other target groups included men involved in fetching water as an economic activity, and handpump mechanics in the study area.

Field observation

This was used to physically locate the handpumps that were functional and those that were non-functional. Data points for each pump were entered, as well as the pump's functionality at that time. We also observed users operating the handpumps. The number of strokes needed to fill a 20-litre water container (jerrycan) was recorded in a non-intrusive manner. Before beginning any observational activity at a handpump, users were informed of the purpose of the field visit to foster an atmosphere of camaraderie.

First level of surface analysis

First-level surface examination was used to identify possible wear mechanisms and modes (Ludema, 1996); the handpump was then dismantled and the worn piston seal surfaces cleaned. Sensory judgement (using visual inspection, touch, and smell) was used to make a first assessment of the seal-operating environment. Seal wear patterns were inspected using a 10x eyepiece magnifying glass for pits, ploughed ridges, and surface cracks in order to identify possible wear mechanisms.

Structured and semi-structured interviews

Semi-structured interviews were carried out with primary school children, women, and men. Participants were chosen randomly and informed of the purpose of the study. Participatory approaches were used, with respondents being given a set of cards to help them identify handpumps in their areas and to locate problems. To facilitate the identification process, respondents were given A4 photographs of various handpump types and were also shown the internal components of a handpump, enabling them to understand the internal construction of the handpump chain, rising main, cylinder, valves, and piston seals.

The primary school children ranged in age from 9 to 14 years; in addition, 50 secondary school children ranging from 15 to 18 years volunteered to complete questionnaires. Group discussions were held with at least two women representatives from each of the 15 villages that constitute the study area. The respondents were encouraged to ask questions and cite examples related to their particular village. These interviews lasted for 30–45 minutes. As a condition of participation, all participants were required to be regular handpump users.

Structured interviews were used with the study area's two resident handpump mechanics, who were informed of the purpose and structure of the interview. An appointment was made and a venue selected for these interviews, each lasting approximately an hour.

Deposition of DLC and Si-DLC films

Typical nitrile rubber piston seals were used as substrates for this study. The DLC and Si-DLC films were deposited using closed field unbalanced magnetron sputtering ion plating (CFUBMSIP) in argon/butane plasma. The CFUBMSIP system consisted of four magnetrons evenly distributed around the chamber. Two opposing magnetrons were used as carbon targets and one magnetron as the silicon target. We used a special mounting to hold the piston seals during film deposition; this sample holder was rotated at a speed of 5 rotations per minute. Detailed description of the deposition process has been presented elsewhere (Lubwama et al., 2012a; Lubwama et al., 2012b; Lubwama et al., 2013; Lubwama et al., 2014).

Piston seal wear testing

The DLC and Si-DLC coated piston seals were tested in a piston seal wear test rig. This rig consisted of: an India Mark II cast iron cylinder with brass lining of diameter 63 mm; a brass piston assembly that included the upper and lower piston seal housing and the piston valve; a unidirectional foot valve made of brass located at the bottom cap of the cylinder assembly; nitrile rubber piston seals placed in the upper and lower housing; and a steel pump rod of diameter 12 mm and length 41 cm that connected the piston assembly to the pneumatic system, which provided power for the reciprocating motion.

Two seals each were tested for DLC, Si-DLC, and DLC with Si-C interlayer. One seal acted as the top seal and the other as the bottom seal, corresponding to their respective locations in the upper and lower housings in the piston assembly. Two operational conditions were tested: in normal clean water, and in water seeded with solid particles – the solid particles used were sand particles of diameter 0.05 mm. The test rig was set up to produce 115 strokes to fill a 20 litre container of the kind typically used to collect and store water in sub-Saharan communities. This rate was an average determined from over 40 observations of the number of strokes needed by two handpumps at two locations in the study area. Each seal was tested to 100,000 strokes, equivalent to filling about 890 20-litre capacity containers. The tests were carried out at room temperature.

After testing, the coated piston seals were analysed using mass difference and digital microscopy techniques. A digital weighing scale (Mettler analytical balance with reproducibility 0.1 mg and linearity of ±0.2 mg) was used to measure the mass of the piston seals before and after testing, and a digital microscope was used to evaluate the surface changes in the piston seals before and after testing. This surface evaluation was undertaken at the piston seal base and side.

Results and discussion

Handpump functionality and problems handpump users face

Out of a total of 34 handpumps in the study area, only 10 were functional. The India Mark II, India Mark III, and U3M pumps were the main handpump types available in the parish. With less than 30 per cent of handpumps operational, this directly affected the availability of safe water for these communities, as handpump users can only use functioning handpumps.

A total of 328 respondents participated in the handpump user survey. This included 154 primary school children, 50 secondary school children, 78 women, and 46 men. More primary school children were included in the survey, as they were the most frequent users of handpumps in the parish. Figure 9.1 shows the problems that handpump users identified, as a percentage of each user category. The key problems varied by category. For example, for primary school children, the main problems were long queues at the handpump and blockages, while distance from home was less of a problem.

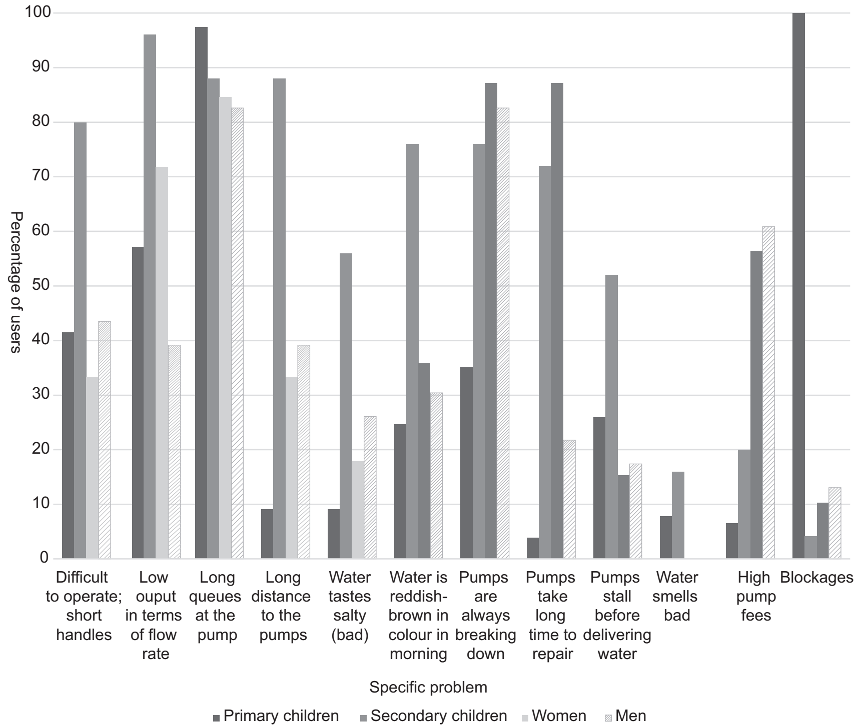

Figure 9.1 Problems faced by handpump users

However, for secondary school children, the major concerns were low output in terms of flow rate, and the water having a reddish-brown colour early in the morning. For women, pumps breaking and the long time taken to repair them were of major concern. These responses reveal that handpump technology has a social dynamic particular to each category of handpump user.

Wear of nitrile rubber piston seals

According to the resident handpump mechanics in the study area, the piston seal is the component most often replaced during breakdown maintenance interventions. The nitrile rubber piston seals wear significantly before the expected two and a half years, with replacements at about one year being commonplace. Many of the problems highlighted by users (see Figure 9.1) relate directly or indirectly to the functionality of the piston seal. For example, long queues at a pump can be due to low output, in terms of a slow flow rate, or frequent breakdown of neighbouring pumps, resulting in more people converging at a functional pump. The overarching problem is usually a worn piston seal, which results in inadequate sealing. As a seal becomes increasingly worn, leakages during the delivery stroke will increase both along the cylinder wall and at the piston seal.

Figure 9.2 Wear mechanisms of a worn piston seal

The first level of surface analysis method was used to identify the possible wear mechanisms occurring in a piston seal, as shown in Figure 9.2. Schallamach (1968) wave patterns typical of rubber abrasion were observed. The direction of the wave formations parallel to the sliding direction of the piston seals is evidence of roll formation stemming from adhesive frictional behaviour (Mofidi, 2009; Myshkin et al., 2005). Significant differences in surface roughness and hardness between the nitrile rubber piston seal and the brass cylinder contribute to adhesive and abrasive wear, respectively. A deep plough was also observed in Figure 9.2, which indicates either third-body interaction between the piston seal and the cylinder wall, or fatigue crack propagation, or both occurring at the same time, as the presence of a third body can contribute to surface cracks on a nitrile rubber piston seal. Possible sources of this third body are rust particles that break off from the galvanized iron rising mains and soil particle ingression. Third-body particles exacerbate both micro-cutting and third-body abrasion between the piston seal and the cylinder wall. Embedded particles in the piston seal present a point of stress concentration that can lead to points for crack initiation, propagation, and fracture, and ultimately fatigue wear of the piston seal. Therefore, we concluded that the wear mechanisms involved in the wear of nitrile rubber piston seals include adhesion, abrasion, and fatigue.

Wear of coated piston seals

Figure 9.3 shows the altered surface morphology of the coated piston seals at the base, after over 100,000 strokes in the test rig for water with sand particles, for both the top and bottom seal in the piston assembly of a reciprocating handpump. Micro-cracks typical for DLC films deposited on rubber substrates were observed. Such micro-cracks allow the coated piston seals to deform and continue to perform their sealing function by being able

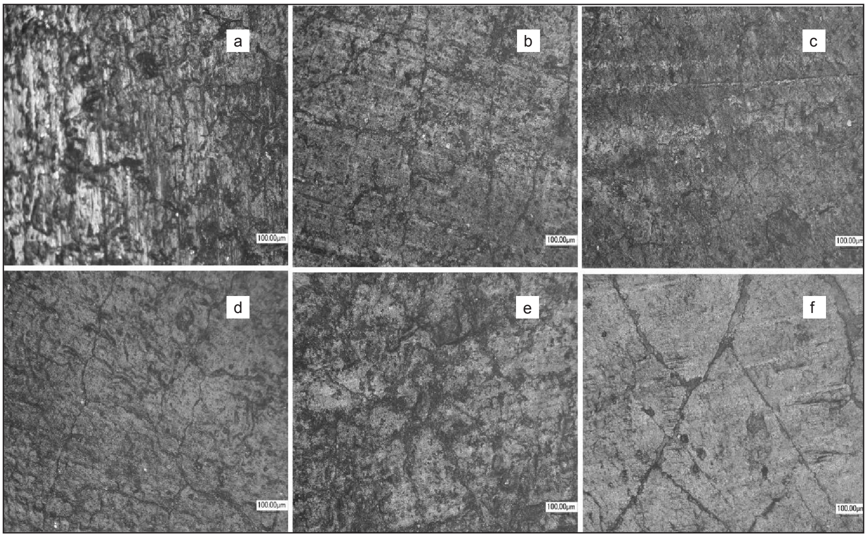

Figure 9.3 Coated piston seal base comparisons for wet sliding with solid particles: a) DLC; b) Si-DLC; c) DLC with Si-C interlayer for top seal; d) DLC; e) Si-DLC; and f) DLC with Si-C interlayer for bottom seal

to accommodate higher stress intensities without interfacial delamination occurring (Tsubone et al., 2007). The wear mechanisms were characterized by the presence of scuff marks. More scuff marks were observed for the top seals of coated DLC, and DLC with Si-C interlayer, compared to the bottom seals. For the Si-DLC coating more scuff marks were identified in the bottom seal compared to the top seal; however, the wear mechanisms in the top and bottom coated Si-DLC piston seals did not appear to differ significantly. The scuff marks are attributed to abrasive wear between the base of the coated piston seal and the brass piston seal housing (Hutchings, 2002). Interfacial delamination and de-bonding was observed for the bottom seal coated with DLC with Si-C interlayer.

Table 9.1 shows a comparison of the masses of the coated piston seals before and after 100,000 strokes of operation in the wear testing rig. For the top seal tested in water seeded with solid particles, the DLC-coated piston seal lost less mass compared to both the Si-DLC, and the DLC with Si-C interlayer coated seals. This result is possibly due to the formation of a tribo-layer. For the bottom seal tested in water seeded with solid particles, the seal coated with Si-DLC lost the least mass after testing. The very low mass differences were attributed to the presence of the coating, which protected the seal against the onset of wear. The piston seal coated with DLC with Si-C interlayer had the least mass loss for both the top and bottom seals for piston seal wear testing in clean water (without solid particles). This low mass difference is due to the presence of the Si-C interlayer, which enhanced the adhesion to the piston seal substrate (Lubwama et al., 2012a). The mass difference of DLC and Si-DLC coated top seals was much higher than expected.

Table 9.1 Comparison of the masses of the coated seals before and after 100,000 strokes of operation

Testing condition	Coating	Mass of top seals (g)			Mass of bottom seals		
		Initial	Final	Difference	Initial	Final	Difference
Water and solid particles	DLC	18.8752	18.8720	0.0032	17.6020	17.5991	0.0029
	Si-DLC	18.8618	18.8582	0.0036	17.5762	17.5749	0.0013
	DLC with Si-C interlayer	18.7995	18.7945	0.0050	17.1003	17.0968	0.0035
Water	DLC	17.4696	17.4561	0.0135	17.0816	17.0769	0.0047
	Si-DLC	16.9763	16.9625	0.0138	17.4953	17.4784	0.0169
	DLC with Si-C interlayer	17.3635	17.3623	0.0012	18.3161	18.3132	0.0029

The wear mechanisms associated with a nitrile rubber piston seal include adhesion, abrasion, and fatigue. For the DLC and Si-DLC piston seals it was determined that the dominant wear mechanism was abrasion, with minimal fatigue wear. The absence of roll formation related to adhesive wear was noted. The adhesive wear mechanism on the coated piston seals is attributed to the generation and transfer of a tribo-layer, which reduces the frictional coefficients and hence reduces wear.

Cost analysis

The investment cost for a magnetron sputtering rig to deposit protective coatings on seals ranges from US$80,000 to $200,000. Handpumps cost from $1,000 to $2,500. If 30 handpumps are installed at a unit cost of $1,000, and a magnetron sputtering rig costing $80,000 is installed, the total investment comes to $110,000. The average maintenance cost for handpumps is $300 per pump per year (Pezon and Bassono, 2013), giving an annual expected maintenance bill of $9,000 for 30 handpumps. These figures mean that the cumulative maintenance cost will overtake the total investment cost after 12.2 years.

As piston seals are responsible for 24 per cent of all maintenance interventions, the possible extension of piston seal life using the protective coatings described in this chapter may significantly increase the time taken for maintenance costs to overtake the investment costs. We observed a reduction of over 50 per cent in the coefficient of friction for the DLC and the Si-DLC films compared to uncoated nitrile rubber, with an expected increase in wear resistance. If a corresponding 50 per cent increase in wear resistance is achieved, an additional one and a half years would be required for the maintenance costs to overtake the initial investment costs (assuming that coating the seals eliminates all seal-related maintenance). This is significant considering that the life of a typical handpump ranges from 7 to 15 years.

The cost analysis presented here is simplistic and assumes that, since the wear resistance of coated piston seals is increased compared to uncoated piston seals, we can expect a corresponding reduction in maintenance costs. The number of maintenance interventions should also be reduced and the availability of the handpump increased, thus increasing handpump functional sustainability. Increasing the availability of handpumps is important because the human cost of unavailability, as a result of worn piston seals, has a direct impact on health, health spending, and time lost walking to functioning handpumps located more than 1 km from people's homes.

Conclusion

This study combined a mixed-methods approach to investigate the functional sustainability of piston seals for handpumps. At the time of the field study, only 30 per cent of handpumps in the study area were functional. The problems that handpump users highlighted related to wear of the piston seal, which was also the component responsible for most maintenance interventions as reported by the handpump mechanics. Using the first level of surface analysis, the wear of the piston seals revealed a cumulative mixed-wear model involving adhesion, abrasion, and fatigue. A novel solution to the wear of piston seals was investigated, involving the deposition of DLC and Si-DLC films onto the nitrile rubber piston seals. A piston seal wear test rig and digital microscopy were used to determine the wear mechanisms involved for the coated piston seals, which included adhesion, abrasion, and fatigue. For the DLC and Si-DLC piston seals the dominant wear mechanism was abrasion, with minimal fatigue wear. The absence of roll formation related to adhesive wear was noted. The adhesive wear mechanism on the coated piston seals is described in terms of generation and transfer of a tribo-layer, which increases wear resistance and thus reliability and functional sustainability.

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CHAPTER 10

How a participatory geographic information system provides voice to demand services from government: A village case study

Mavuto D. Tembo, Alistair Fraser, and Hannington Sengendo

Abstract

People in rural Uganda who rely on surface water will endure additional hardship as a result of climate change. This chapter investigates the adaptive capacity of a rural community in the face of seasonal water variations and demonstrates how participatory geographical information systems (PGIS) assist communities to access services from local government. We found that adaptive capacity exists at the local level in complex social connections between specific places and informal networks which need to be managed effectively through communication. When individuals and communities communicate their adaptive capacity to decision-makers, this can create new knowledge and lead to changing attitudes and the release of new resources such as funding, thus enhancing the overall adaptive capacity. Sharing knowledge about coping mechanisms between communities and service providers can also enhance adaptive capacity. If there is no opportunity to integrate knowledge, then individual local practices such as rainwater harvesting will be needed to help affected people cope with water challenges and construct new, better, and safer practices. This study also demonstrates that PGIS provides communities voice to demand services from service providers and government, and can act as a tool for accurate and sensitive data collection.

Keywords: climate change, participatory geographic information systems, adaptive capacity

Introduction

Against a backdrop of ongoing climate change, seasonal rains could become more erratic, less frequent, or fail to arrive at all (IPCC, 2007). When that happens, the majority of people in this case study area who rely on surface water, like many rural areas across sub-Saharan Africa, will endure additional hardship (Tembo, 2013). We need to understand how people and communities,

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such as those encountered in this study, might adapt to cope with climate change. To study the household and village practices that influence adaptive capacities requires context-sensitive and grounded observations which allow residents to participate in and shape research outcomes. However, the dominant methodological approach in the literature on adaptive capacity in the region relies on surveys, and is what we might refer to as 'static', as opposed to long-term, ethnographic, and participatory approaches (Eriksen and Silva, 2009; Vincent, 2007). Instead of adopting such a static approach, our study was based on a more dynamic assessment of adaptive capacity, drawing on grounded, rigorous, and participatory methodologies. This allows us to record the small-scale, modest, and gradual adaptive practices that people depend on, and include these in final assessments of adaptive capacity (e.g. see Nielsen and Reenberg, 2010; West et al., 2008). The dynamic approach discussed here combined in-depth ethnographic research with a participatory geographic information system (PGIS). The ethnographic research entailed living in the community and, whenever opportunities arose, holding both informal discussions (with notes taken) and formal interviews with community members, and making numerous wide-ranging observations. The PGIS involved using GIS in a qualitative way, rather than the traditional quantitative way, with community members helping to generate the data about their village, specifically regarding water resources and their use (e.g. see Rambaldi et al., 2006). We worked with the people of one specific village. Combining both methodologies, and paying critical attention to the nature of relationships between villagers and service providers (including NGOs), made for a more dynamic approach than previously seen in the literature.

Our research approach is important because, as scholars have noted recently, understanding adaptive capacity not only entails asking villagers what they do, but also paying attention to how they interact with external actors (Adger et al., 2009: 5). Studies have shown that what individuals and communities know and do has to be viewed as the 'platform' on which external adaptive strategies can be built (Kansiime, 2012). At the same time, adaptive capacity in any one place is affected both by what happens inside and outside the village, for example as external adaptive strategies or practices build on that of the community scale (e.g. see Adger et al., 2005; Pelling, 1999).

In this chapter, we focus on the challenge of using PGIS to assess adaptive capacity, as this was the unique aspect of this research for the Water is Life project. We discuss the benefits and pitfalls as well as the broader issues regarding PGIS use in developing countries. First, however, some comments are needed on research design.

Research design

Data collection occurred in three stages. The first, a formative and exploratory stage, lasted six weeks. The lead researcher travelled to all 15 villages in the case study parish with a view to identifying the specific places where the remainder of the work would occur. While collecting data from interviews and from direct observations, the researcher learned about local understanding of domestic water management and aspects of how the communities deal with water-related challenges. This allowed him to begin building a GIS database of the parish. The specific village where the more detailed work was carried out was selected because, unlike most of the other villages, it had been bypassed by NGOs since at least 2001.

In the second stage of the research, we began the work of eliciting information regarding adaptive capacity in this single village. Using hand-held GPS units, digital cameras, and a digital audio recorder, the lead researcher worked with three community members to map water and other resources in the village. He also held regular meetings with the community members to discuss emerging findings, conducted 70 interviews with community members in the village, and used these diverse interactions to collaboratively construct a comprehensive GIS database about the village. This stage constituted the bulk of the fieldwork.

In the third and final stage, a forum was created where villagers could communicate their knowledge about their adaptive capacity to decision-makers from local government and other actors, particularly NGOs. The key event was a one-day workshop when community members, including those with poor literacy skills, could speak as well as listen to councillors, planners, and other officials with decision-making powers. After this workshop, open-ended and semi-structured interviews were conducted with workshop participants, with a view to understanding the project's potential continuing benefit to the participants.

Using PGIS to assess adaptive capacity to climate change

PGIS is a collaborative process for collecting and developing spatial data, and generating the crucial dataset that will be used to construct maps to represent the spatial information. Rather than mining official data and statistics, a PGIS database relies on research respondents generating data about their place. This collaborative data collection process – focused on social and material situations – allowed the lead author to develop a deep knowledge of a wide range of empirical issues in the field study site. This is a complex, under-researched process, yet one with significant potential to shape how qualitative research occurs (Chambers, 2006; Rambaldi et al., 2006). However, the respondents' limited knowledge of GIS software means that PGIS is participatory only up to a point. Despite this limitation, there were several important benefits in using PGIS. In the rest of this section we discuss some of the ways in which the approach that was adopted helped to shape our conclusions about adaptive capacity to climate change in the case study area.

Uncovering water sources and connections

The fieldwork in the village was largely organized around asking villagers one key question: 'Where are your water resources?' In addition to recording respondents' answers, we wanted to combine the PGIS and ethnographic methodologies to develop a detailed and accurate answer. One component of the fieldwork entailed working with some villagers to conduct an exercise we called 'GPS-assisted mental mapping'. After some training, respondents from the village could use hand-held GPS units to walk around and map aspects of their village. This gave respondents valuable opportunities to openly discuss water-related issues such as how a water source was looked after, or how quickly it dried up after the rains ended.

This GPS-assisted mental mapping delivered several benefits. One was that it ameliorated the challenges of spatial data management, particularly the risk of data loss after fieldwork (e.g. Cannon et al., 2003) that could have occurred if the same data had been collected using participatory rural appraisal (PRA) mapping (e.g. Mbile et al., 2003). Another benefit was that the lead researcher and the villagers could accurately trace village and household boundaries, and identify fixed data points, particularly water resources. The exercise also allowed the researcher to collect additional data about the village, for example via informal but recorded discussions with respondents. These discussions generated rich information in relation to village life, which subsequently shaped how the rest of the research progressed. A key advantage of using the GPS units was that they put the respondents at ease, as people did not need to draw, or use pen and paper, thus eliminating the literacy and communication challenges that are frequently encountered when using PRA methodologies. Villagers might not have understood fully the process or the technology, but when the lead researcher used the GIS software to show respondents maps of their village and the boundaries that they had helped to draw, there was considerable satisfaction and interest in the outcome.

The map of village water resources which the respondents constructed identified three types of water source: dependable water points that are available to all villagers; seasonal sources accessible only to some; and other sources that are assigned to specific groups, such as agro-pastoralists. The exercise revealed a wide range of water sources, and more than the lead author had discovered in his initial investigations. Whereas villagers revealed only three water sources in their initial meetings, 17 further sources were revealed after the GPS-assisted mental mapping. In total, 20 water sources were identified, revealing a different picture from the initial one of life in the village.

Discussing these maps with the respondents provided further ethnographic insight and enabled us to interpret the significance of each location and resource to life in the village. The name assigned to each water source had meaning, and in asking about the names, the lead researcher was able to identify questions for further research. One such line of enquiry led to insights regarding the diverse sources of funding and support for development initiatives in the village, including those initiatives that had worked well and those that had failed to realize their initial aims and objectives. Discoveries of this sort helped to shape the rest of the fieldwork in this village, as well as the work throughout the rest of the parish (Tembo, 2013).

Revealing the use of rainwater harvesting technologies

A major consideration in understanding adaptive capacity regarding water is whether community members can harvest and store rainwater. Part of the fieldwork was therefore aimed at assessing the use of rainwater harvesting (RWH) technologies in the community, and so villagers were asked to collect data on RWH using PGIS. They first identified three houses with large installations of 1,000-litre tanks. But, as with the research into the number and distribution of water sources, this proved to be only an initial picture. In further discussions with community members, we discovered that another, more traditional and widely used form of RWH was practised by almost all households in the village; specifically, people in houses with a sheet-iron roof would collect rainwater during every wet period. Therefore, GPS-assisted mental mapping of households in the village was conducted with the villagers to identify houses with a sheet-iron roof (Figure 10.1), which revealed that RWH was far more widely used in the village than the initial research suggested.

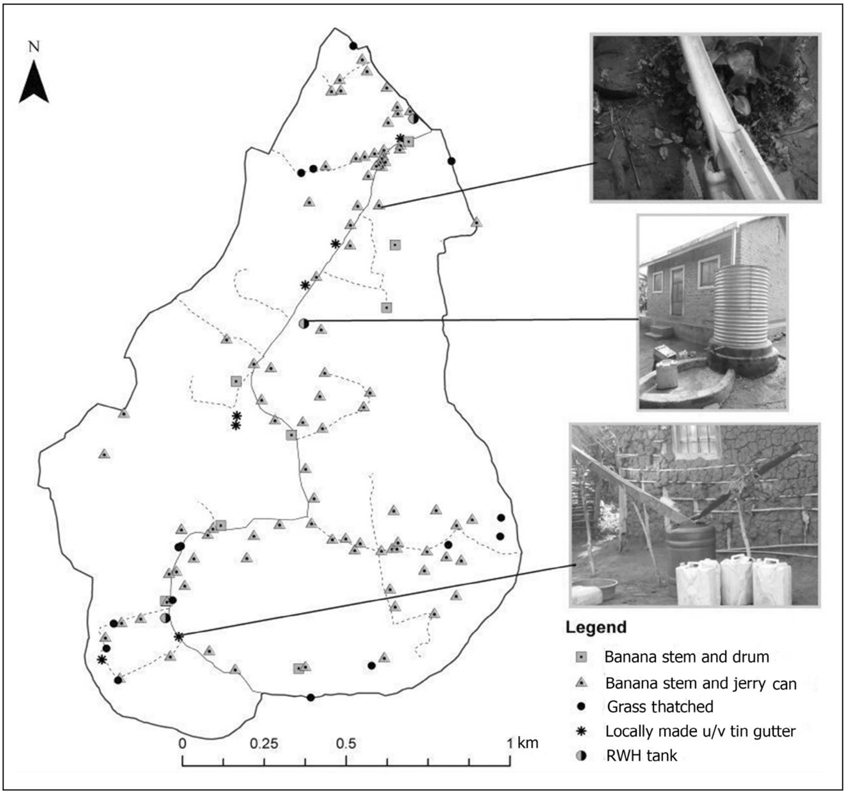

Figure 10.1 Spatial distribution and types of rainwater harvesting practices in the village

Crucially, during one such 'walk and talk' around the village, an elderly couple revealed that RWH had been an integral part of their water management since they moved to the village in the early 1950s, and explained how they would use fresh banana stems to harvest water falling from rooftops. As it turned out, many others did likewise: 105 of the village's 125 households practised RWH, and 91 of those used fresh banana stems to trap water falling from the roof, while seven used gutters made locally from old iron sheets. This finding enriched what the lead author was able to conclude about adaptive capacity. Clearly, traditional RWH practices strengthen the ability of individuals and households to deal with drier periods, albeit with severe limitations still in place.

The crucial point about traditional forms of RWH is that they give a major boost to village productivity during periods of insufficient rainfall. If women and children, who most often fetch water, are given some relief from that task in wetter periods, they are freer to perform other tasks. Furthermore, if the harvested water can be stored in containers for use in dry periods, it can boost dry season productivity. Finally, there are health benefits from the widespread use of RWH insofar as additional and more accessible stores of water facilitate more frequent washing of clothes and more water for bathing (from 3 litres in dry periods to 10 litres in wet periods). Of course, a better scenario for a village such as this would be for more households to have new, expensive yet more efficient RWH tanks. Put simply, having an RWH tank creates the possibility for a household to retain access to water during the dry season, increasing their capacity to cope and to develop other ways of adapting.

Having a tank is one thing; using it effectively is another. For example, at the end of the rainy season in May, a 1,000-litre tank could be full after two days of reasonable rainfall (Tembo, 2013), and this could potentially provide water for at least three weeks if used with minimum control, or last three months if used sparingly, such as only for drinking. Some households risk losing water from their tank, however: for example, if the inhabitants of a household are elderly, or the household is headed by children, then some neighbours might try to take advantage and draw water from their tank. By contrast, in households headed by middle-aged and/or educated residents, the harvested water will probably be managed carefully. For example, one 40-year-old woman with secondary school education offered water to neighbours in 5-litre containers once a day, but pleaded with them to use it sparingly and only to use the water in the tank for drinking. Having an asset does not necessarily mean it will increase adaptive capacity; rather, the resource must be coupled with the capacity to manage and to contend with multiple pressures at household level. Moreover, as these scenarios indicate, the capacity to use RWH is always going to be highly differentiated.

As noted, RWH shapes adaptive capacity to deal with climate change in places similar to this village. The value of our PGIS approach was that it allowed us to generate a rich dataset about RWH practices in the village and, combined with ethnographic methodologies, created opportunities for a fuller understanding of a broader range of processes shaping life in the village. In the approach to mapping both water sources and RWH practices, PGIS interacted with ethnographic techniques in productive ways, demonstrating its potential as a research tool for use in rural sub-Saharan Africa.

The use of PGIS in a community-oriented workshop

In addition to using PGIS to explore adaptive capacity to climate change, PGIS was employed to assist people to communicate their situation to service providers and decision-makers. An attempt was also made to fuse what local people know and do with the sorts of skills and resources that local decision-makers can deliver.

With these issues in mind, we investigated how PGIS could be used to help community members communicate their situation more compellingly to decision-makers. Towards the end of the fieldwork, we organized a one-day community workshop and, with the villagers' assistance, invited district and sub-county officials and planners, politicians at sub-county and village level, officials from NGOs, and members of nearby communities. The event, which lasted six hours, had 61 participants; all agreed to use Luganda as the main language for communication and to use a traditional workshop arrangement that promoted face-to-face discussion. In the morning session, villagers made presentations about their use of water and their concerns about climate change. Each presenter distributed printed maps that they had helped to produce, which showed village settlement development and boundaries, the functionality of various water sources, and RWH initiatives and potential. In the afternoon, the workshop turned to group discussions of the issues raised during the morning session.

One major issue that emerged in the morning session was non-functioning boreholes and shallow wells. Using the map in Figure 10.2, community representatives explained why their borehole and shallow well were not functioning. Some of the men suggested that the factors included political interference, service provider inefficiencies, and communities' lack of knowledge about what was needed to access services from providers such as local government. Later, some of the women described how they continued to fetch water mainly from open wells which were shared with livestock. The district water and public health officials were visibly alarmed by this information, as open wells are considered 'unimproved and unsafe water sources'. In 2006 the Ugandan government clearly stated that it wanted to end their use, but in places such as this village there is obviously a long way to go, not least in terms of policymakers' understanding of the situation on the ground. Indeed, in introductory remarks at the beginning of the workshop one official suggested that 59 per cent of all water sources in the district were functioning and, to the villagers' surprise, their borehole was included in this figure.

The workshop also shed light on the complex connections between community members and service providers. It revealed that individuals, households,

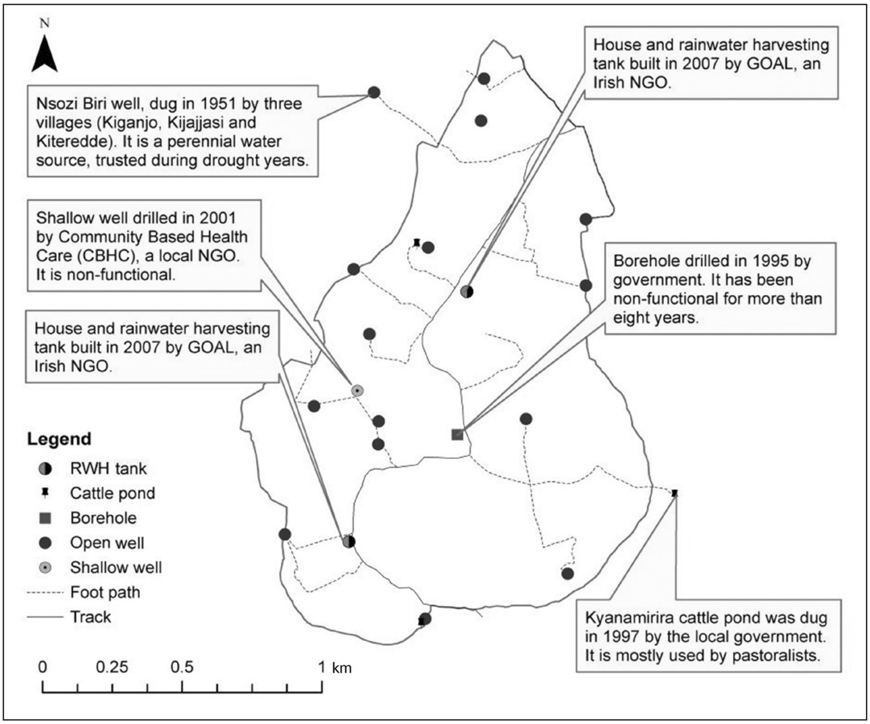

Figure 10.2 An example of a map used in the workshop

occupational groups, local leaders, and service providers all shared responsibility for shaping the acquisition and distribution of resources and interventions in diverse ways, thereby affecting the degree to which coping mechanisms in this village can succeed. The PGIS helped to visualize this complex connection, because the villagers used a map similar to Figure 10.2 to report on the range of connections that exist between villagers and other actors and stakeholders, as well as the historical development of water supply initiatives since 1951. During the workshop, participants explained how the village depended for many years on open wells, but that in 1995 a borehole was drilled and then a shallow well was dug in 2001. Crucially, however, the villagers also used the map to report that neither water source was constructed satisfactorily, and hence did not supply any water to the village. In using the map, villagers spoke to the various service providers and decision-makers about the range and condition of water supply technologies in their village. The discussions were often emotionally charged. The maps evidently helped them to communicate how their adaptive capacity to deal with climate change had been shaped by the history of connections regarding water supply technologies.

Regarding some of the many challenges facing the people in this village, the workshop also shed light on how assets and knowledge are exchanged, integrated, and shaped through connections with service providers. This is evident in questions posed by Shakul and Jude (names have been changed) to the district water officer. Shakul: 'How can you help us who live on hilly places to access water easily?' Jude: 'Why is our borehole not functioning when you have told us you have expertise and funds?'

Shakul's question triggered the service providers to list technologies that are made available to communities, such as boreholes, shallow wells, RWH tanks, valley dams, and handpump spares, as well as non-material assets, mainly expertise and training for water user committees (WUCs). Participants were shocked to hear about this wide range of technologies and services available to them. This new awareness raised their expectations and immediately they started requesting RWH technologies to be delivered to their village, and repairs to be carried out on their borehole. One official emphasized that access to technologies and services was not automatic, that communities must follow procedures, and that funds were always limited. He then suggested that other actions were necessary: 'Don't just wait for technology to come to you. Do something. Put in some effort to solicit support …'.

In emphasizing the need to do something, this official then explained that community members needed to elect a WUC and then pay for any water drawn from any new improved facilities. He highlighted they had to go beyond in-kind contributions such as attending meetings. The importance of WUCs was stressed because they provide the government with a formal entry and contact point in the community. In addition, it is through a WUC that a community channels any requests for water services to the district water officer, NGO officials, and handpump mechanics. On a related note, one NGO official responded to Jude's question regarding the borehole, saying: 'the mistake you make is that instead of soliciting for help to repair the boreholes or shallow wells, you keep waiting and looking forward to a person who constructed the water source to come and repair it, yet you don't inform this person …'.

The water source that Jude referred to was a shallow well installed by a former NGO employee. As a result, community leaders thought no one else could help them to repair the borehole. Jude's problem, then, was a reflection of poor communication between the community and service providers. This incident demonstrated that information about practices which might assist adaptive capacity, including borehole repair or management, is not equally accessible to all, either because of the manner in which it is communicated, the channel used, or the service providers involved. It follows that, given these worrying findings about the nature of knowledge exchange and communication between people living under vulnerable circumstances in villages such as this and decision-makers in local government or in NGOs, perhaps the greatest benefit from using a PGIS is its capacity to assist marginalized and vulnerable communities to communicate. Indeed, what the PGIS component of the research seemed to help in most was giving the community members a greater sense of authority to represent their issues and concerns to an audience of senior decision-makers with access to funds and resources. Hearing and seeing where villagers sourced their water also left an impression on the service providers. The spatial information the villagers had compiled made a difference because they could refer to the map and use the map's authority, official appearance, and political and scientific nature to communicate their situation. In turn, the authority of their knowledge compelled the officials attending the workshop to respond. Some resolved to meet their obligations to provide services and to begin networking regarding water governance in this village and more broadly across the case study parish. Others shared their mobile phone numbers in order to improve networking. But perhaps the most important outcome of the workshop was that some service providers agreed to release funds – funds that might not otherwise have been directed to this village – to pay a private pump mechanic to repair the borehole. Such an intervention is not the solution to the challenges villagers will face if climate change gets worse, but it is part of a package of changes that will need to take place if the people living there are to stand any chance of adapting to climate change.

Summary

This chapter discusses fieldwork conducted in one village to demonstrate that PGIS can assist in revealing critical data about people and their place that might not otherwise emerge. PGIS can help to locate, characterize, and explain the meaning of various water resources, and can also assist in identifying RWH technologies. Using PGIS, a new map of the village has emerged and this spatial information has subsequently allowed villagers to inform decision-makers about how they use water and what their future needs will be. Going a step further, and combining PGIS as part of ethnographic enquiry, offers a methodology that redresses the perceived gaps in using any single approach. Ethnographic enquiry, in the research outlined here, has also improved the rigour of PGIS, revealing complex realities about adaptive capacity in relation to social connections between specific places and formal and informal social networks. Furthermore, this work suggests that using PGIS in a community-oriented workshop can help to integrate knowledge about coping mechanisms between communities and service providers. PGIS if combined with opportunities for water users (or communities) can carry the information and communicate it to influential stakeholders.

In addition, our study suggests that criticisms of PGIS can be greatly reduced if its practice is combined appropriately with ethnography. In particular, it can offset Elwood's (2006: 700) concerns that PGIS can disempower respondent communities via a process of data mining. In contrast, our research highlights how PGIS can empower communities, helping them to negotiate with influential decision-makers and even to unlock resources.

Finally, this study demonstrates the scope that exists to use PGIS in other developing country contexts. PGIS – especially combined with ethnographic methodologies – has the potential to be a tool for accurate and sensitive data collection, and for capacity enhancement of communities. While some dilemmas remain regarding the use of this sort of technology, the work discussed here suggests that PGIS can be a valuable aid to communities. Helping them to communicate their situation to decision-makers can in turn lead to a shift in attitudes, the creation of new knowledge, and, as we saw in this village, ultimately to the release of new resources from local government.

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CHAPTER 11

Water is Life: Reflections on effective research capacity building

Suzanne Linnane, Arleen Folan, and Edel Healy

Abstract

The crucial role of water in accomplishing Uganda's development goals and in tackling widespread rural poverty is clear from the evidence presented in this book. Challenges highlighted include environmental, human, and educational capacities to effectively progress and manage water resources sustainably. Uganda, like many sub-Saharan countries, still faces huge challenges in attempting to achieve the water-related Millennium Development Goals. The Water is Life: Amazzi Bulamu *project has demonstrated that Higher Education Institutes (HEIs) have a significant role to play in achieving these MDGs and contributing to research capacity building in developing nations like Uganda. It has served to highlight the interface between activities that conventionally belong to the sphere of development, and those activities that are fundamentally academic in their nature but act as enablers towards better progress for development through their presence.*

Keywords: research capacity building, higher education, partnership, multi-disciplinary, cross-cutting

Introduction

The evidence provided in this book demonstrates that research can have powerful influences on development objectives and ultimately in reducing the burden of poverty. It is clear from the outcomes of the Water is Life: *Amazzi Bulamu* project that research has a crucial role to play in helping to develop evidence-based, innovative approaches to water and development. In recent years, the emergence of new models of research funding, such as the Irish Aid and Higher Education Authority Programme of Strategic Cooperation between Irish Aid and Higher Education and Research Institutes 2007–2011 (PSC) and equivalent programmes including the Royal Society–DFID Africa Capacity Building Initiative funded by the UK's Department for International Development, and the South African Netherlands Platform for Alternatives in Development programmes, have gradually allowed the higher education sector to contribute in a more meaningful way to policy and development. Policymakers and practitioners in development fields have

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always depended on the availability of reliable and trustworthy evidence for planning and practical purposes, but for many the research required to support the generation of such evidence has often been unavailable to them when they require it. Added to this, the agencies charged with overall development of water infrastructure and policy formation and planning are fragmented. This fragmentation impedes coordination and renders the task of academic researchers somewhat more difficult, particularly in terms of grassroots impact. Therefore, it has become increasingly recognized that a well-functioning higher education system is a key component in strengthening governance, in research generation and dissemination, and in knowledge development. In addition, strengthening the capacity of the higher education sector in developing nations and the creation of strategic partnerships and networks are crucial to the overall development of higher education systems.

Ireland's relationship with Africa is an important priority in Irish foreign policy and is considered positive and constructive. Ireland's engagement with Africa goes back over 100 years to the work and legacy of missionaries and aid workers as early educators to the strong government-to-government links that exist today. Currently, 80 per cent of Irish Aid's budget is focused on sub-Saharan Africa (DFAT, 2011) where the enormous challenges of reducing poverty and promoting equitable and sustainable development, human rights, and good governance remain the top priorities. Irish Aid has, in recent years through the PSC, acknowledged that greater recognition should be given to the potential of higher education and research sectors in developing countries to contribute to achieving their own goals of poverty reduction and economic development. The intended outcomes of the PSC were 'strengthened institutional capacity for development research and teaching in both Northern and Southern Higher Education Institutes and sustained and flexible collaborative partnerships by 2015'. This chapter deals primarily with the process undertaken by Water is Life to fulfil the PSC objectives. In addition, it examines the added value of participating in a multidisciplinary and international network comprising academics, policymakers, NGOs, and community, which is far beyond the more traditional individual research student and supervisor model, and which was seen as a real strength of the programme by all participants, in both North and South. For the network to engage at multiple levels of civil society, the active involvement of NGOs with a track record of service provision on the ground is essential. In addition, it is vital that all the participants have a realistic vision for their involvement and ultimate outcomes. While primarily an academic research programme with conventional academic outputs, Water is Life also attempted to balance the expectations of all its stakeholders through delivery of a wide-ranging suite of outputs, including policy information, public dissemination, community engagement, and sustainable capacity development within the community.

Research capacity building and the partnership approach

In many developing countries, particularly those in sub-Saharan Africa, the contribution of higher education to social and economic development has not mirrored that of developed countries. The missing link seems to be developing countries' ability to develop sufficient capacity within higher education and ultimately benefit from a well-functioning higher education system. In order to be truly effective, the higher education sector must contain appropriately qualified leaders in their fields. Doctorate holders, in particular, are considered key actors in the creation of knowledge-based economic growth and innovation. The Careers and Productivity of Doctorate Holders in Uganda report estimated the total population of PhD holders in Uganda in 2010 to be approximately 1,000 individuals, equating to approximately one PhD for every 34,000 people (UNCST, 2012). In addition, the time taken to complete these doctorates can often be double the average outside of sub-Saharan Africa. By comparison, the European Union has approximately 31 PhDs per 1,000 of the population. Presently, Uganda produces less than 100 doctorates per year on average, giving an annual production rate of one doctorate for every 300,000 people, well below the number of doctoral graduates required to support a competitive knowledge-based economy (UNCST, 2012). While not conclusive, this metric is an indicator that academic contribution at the policy and practical levels of water service provision can be much improved.

In an attempt to address these issues, the PSC and other similar programme approaches encourage strategic, collaborative partnerships with which to build research capacities at North-North, North-South and South-South levels. Water Is Life specifically aimed to build capacity in water and development research within and across all its partner organizations, both academic and non-academic. In particular, the strategic partnerships formed from the outset with water practitioners on the ground, including Uganda Water and Sanitation NGO Network, Medical Missionaries of Mary, government, and community, proved invaluable in planning and designing the overall project. The multidisciplinary nature of the research, comprising academics and practitioners from the natural sciences, engineering, and social sciences, coupled with the cross-cutting and collaborative approach of Water is Life, were key to much of the academic success of the project, in particular the training of eight African doctoral students and the joint development of a Master in Development Studies, led by Makerere University. Water is Life was fully aware that the reality of achieving the overall goal of poverty reduction requires that any research conducted must have impact and address policy. This meant that its research was designed to address the issue of water resource management across a range of disciplines involving higher education institutes, government, and the wider civil society. This approach has produced robust and evidence-based results which can now contribute in a meaningful way to poverty reduction and ultimately an improvement in the lives of the local community. In addition, as 'community engagement' was considered to be a key success factor for effective research outcomes from Water is Life, the PhD students were encouraged to live and work within the local community to really experience the daily lives of the people in managing their water resources, which benefited the outputs of their research enormously. From the outset, Water is Life drove all its constituent parts (including PhD research) towards cross-cutting and engaging practice. Doctoral students underwent initial collaborative induction training so that the establishment of lateral communications at the student level were facilitated from the outset. All participants worked collaboratively towards a Certificate in Sustainable Water Management so that a common basis of understanding was developed. Technically cognate students acquired the language of development and vice versa. As the programme progressed, cross-institution communication between academic supervisors and students was accelerated as a consequence.

Water is Life's approach to doctoral training and management

Water is Life's approach to doctoral training was four-fold. Firstly, as it is well known that many students fail to complete PhD programmes due to a lack of structured training in basic skills in research methodologies and critical thinking, Water is Life designed a structured training programme for researchers of different disciplines. This Certificate in Sustainable Water Management, accredited by the Dundalk Institute of Technology (DkIT), was jointly developed and delivered by all the academic partners, and was undertaken together by the eight Water is Life PhD students at the start of their programme of study. This approach clearly defined for the students their roles and responsibilities in the overall Water is Life programme. It also allowed them time to become an integrated network of researchers with a common goal from the outset.

'I look at the members of staff and I see a gritty determination to steer these students in the right direction. I really like this college! Really! It was in DkIT that seven other PhD students and I spent considerable time. We were engaged in different modules, incorporating a wide spectrum of ethos. Think about it for a second. You have someone with a Masters in Mechanical Engineering being taught Sustainable Community Development, Water Management and Health, and Research Methodology mainly geared towards the social sciences. This was an amazing experience! I hope other PhD programmes could borrow a leaf from the Water is Life project. This approach was holistic. I now know exactly what my colleagues are doing and through this close interaction we have been able to see the linkages in our topics … I look forward expectantly at a bright future …' (Water is Life PhD student following completion of the Certificate in Sustainable Water Management).

Secondly, Water is Life was designed to ensure completion of its doctoral candidates' degrees in the shortest possible timeframe. Joint supervisory arrangements were put in place to ensure that each student had support and mentoring both in Ireland and in Uganda, and to enhance the student experience and increase the prospects for a successful outcome of each individual project. In addition, this approach fostered collaboration, mutual learning, and the development of strategic and long-lasting networks between North-North, South-South, and North-South higher education institutes. All eight Water is Life PhD students completed their doctoral degrees in three or four years.

Thirdly, the achievements of the Water is Life project can also be attributed to its innovative, community-focused approach. The chapters in this book describe the evidence-based research carried out by Water is Life at community level in response to community needs. The research topics reflected the real issues of the community as identified by the community, thus ensuring societal relevance.

Finally, the role of the day-to-day project management was fundamental to Water is Life's success. From the outset, partner and stakeholder buy-in was considered crucial to the realization of goals and was achieved through a number of measures, including setting the agenda together, defining roles and responsibilities, communicating regularly, and agreeing on a shared vision and a strategic plan. The basis of the partnership was outlined in a clearly defined Memorandum of Understanding signed by all partners. The project lead, DkIT, through effective and efficient project management, ensured that there was ongoing dialogue across all levels – academic, government, and community – at all stages of the project. As a result of this open communication, transparency and mutual trust were strong features of the project. As primary knowledge carriers for this programme, the research students' input to the full range of Water is Life initiatives was essential. The Water is Life team recognized this and instituted regular meetings of the student group across the full duration of the programme to obtain their views on overall programme aims and management. This forum functioned alongside conventional research colloquia. The value of this structure meant that beneficial suggestions for the operation of the overall programme could be clearly voiced separately to the normal process of academic dialogue. Academic supervisors in particular found this forum of assistance, as it allowed them to decouple programme-specific issues from individual project issues. In addition, common issues of logistics and resourcing were raised in an effective and efficient fashion.

The way forward

The story of the Water is Life: *Amazzi Bulamu* project reflects the gravity of the situation in relation to water and sanitation for a community in rural Uganda, and points out key issues in relation to safe water, accessibility, affordability, management, climate change, and gender. In addition, the importance of stakeholder engagement at all levels and the need to strengthen capacity within the Ugandan higher education sector has been both examined and reflected upon. However, all participating partners will acknowledge that although great progress has been made by the Water is Life project in addressing many of the requirements of the PSC programme, there is a long way to go in addressing the capacity requirements of the higher education sector in Uganda. Uganda simply does not have enough doctoral capacity and needs more PhD holders per capita. Water is Life's training of eight African PhD students in Africa has contributed in a small but successful way towards a reduction in the often-cited 'brain drain' of Africa.

The novel Water is Life programme offers some meaningful lessons for how capacity can be built using international research partnerships. A global partnership like the Water is Life model fosters the creation of new networks, which are central to the creation of shared knowledge systems. However, in order to be sustainable and effective, these networks must have a clear vision and must be nurtured and supported in order to achieve tangible development outcomes.

Finally, the importance of ensuring that the focus of research is not on individual disciplines, but rather addresses 'problems' that require complementary and cross-cutting skill-sets to work together, cannot be underestimated. Although expertise in individual disciplines is essential for the production of quality research, the ability and the will to bring disciplines together in new and innovative ways is essential if we are to continue to improve the relevance and effectiveness of research and the achievement of our overall outcome in sub-Saharan Africa, the ultimate goal of poverty reduction.

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